PROCEEDING CONTRIBUTIONS IN EXTENSO

16º Congreso Internacional
Organizacion de Conservacion de Suelos

ISCO
Chile 2010

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16º Congreso de la Organizacion Internacional de Conservacion de Suelos

08 al 12 de noviembre de 2010

Sociedad Chilena de la Ciencia del Suelos
Servicio Agricola y Ganadero (SAG)
Universidad Mayor
Universidad de Concepción

Santiago of Chile

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Sociedad Chilena de la Ciencia del Suelo
Chilean Society of Soil Science
Erick Zagal
Claudio Pérez
Ministerio de Agricultura de Chile
Agriculture Ministery of Chile
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Germán Ruiz
Mario Lagos
Mario Ahumada
Corporación Nacional Forestal
National Forest Corporation
Samuel Francke
Celso Carnieletto
Universidad Mayor
Norma Sepúlveda
Jorge Wicha

Universidad de Chile
Manuel Casanova

SCIENTIFIC COMITEE / COMITÉ CIENTÍFICO

Erick Zagal
Universidad de Concepción
ezagal@udec.cl

Germán Ruiz
Servicio Agrícola y Ganadero
german.ruiz@sag.gob.cl

Cristian Prat
Institut de recherche
pour le developpment
christian.prat@ird.fr

Ildefonso Pla Sentis
ISCO Board of Director,
ipla@macs.udl.cat

José Luis Rubio
ISCO Board of Director,
President of ESSC
jose.l.rubio@uv.es

Samir A. El-Swaify
ISCO Board of Director,
University of Hawai, USA,
elswaify@hawaii.edu

Verónica Acosta
Agr. Research Service
veronica.acosta.martinez@ars.usda.gob

Jorge Etchevers
Colegio Post Graduados
Chapingo/Montecillo
jetchev@colpos.mx

Miodrag Zlatic
World Association of Soil and
Water Conservation
miodrag.zla@sbb.rs

Neal Stolpe
Universidad de Concepción
nstolpe@udec.cl

Cristina Muñoz
Universidad de Concepción
cristinamunoz@udec.cl

Leandro Paulino
Universidad de Concepción
lpaulino@udec.cl

Analí Rosas
Universidad de Concepción
arosas@udec.cl

Celerino Quezada
Universidad de Concepción
cequezad@udec.cl

Marcos Sandoval
Universidad de Concepción
masandov@udec.cl

Iván Vidal
Universidad de Concepción
ividal@udec.cl

Juan A. Barrera
Universidad de Concepción
jbarrera@udec.cl

Mario Ahumada
Servicio Agrícola y Ganadero
Universidad Mayor
mario.ahumada@sag.gob.cl

Mario Lagos
Servicio Agrícola y Ganadero
mario.lagos@sag.gob.cl

Manuel Casanova
Universidad de Chile
mcasanov@uchile.cl

Samuel Francke
Corporación Nacional Forestal,
Universidad Mayor
samuel.francke@conaf.cl

Celso Carnieletto
Corporación Nacional Forestal
celso.carnieletto@conaf.cl

Carlos Ovalle
Instituto de Investigaciones
Agropecuarias
covalle@inia.cl

EDITORS / EDITORES

Manuel Casanova
Universidad de Chile

Germán Ruiz
Ministerio de Agricultura de Chile
Servicio Agrícola y Ganadero

Erick Zagal
Universidad de Concepción

The contents of the papers presented in this Proceeding are the sole responsibility of the respective authors and co-authors.

DESIGN
PRINTER

PROLOGUE

The Sixteenth International Soil Conservation Organization Congress is one of a series of meetings. The previous Congresses that have been held are:

Number	Country	Year	Number	Country	Year
1	Belgium	1978	9	Germany	1996
2	UK	1980	10	USA	1999
3	USA-Hawaii	1983	11	Argentina	2000
4	Venezuela	1985	12	China	2002
5	Thailand	1988	13	Australia	2004
6	Ethiopia & Kenya	1989	14	Marrakech	2006
7	Australia	1992	15	Hungary	2008
8	India	1994	16	Chile	2010

These congresses provide a medium for soil scientists from all over the world to discuss about soil conservation and protection, soil degradation, desertification and other topics, with an orientation to transfer knowledge and many advances in this vital resource, the soil, and other natural resources as well.

Soil and Water Conservation, are at present in the frame of the Global Climate Change and therefore are issues of concern in this Congress. Therefore, the presence of national authorities and professionals/ scientifics from different countries in the Congress will give us also the opportunity to share diverse national strategies designed to confront all changes related (e.g. scarcity of water, regional changes in precipitation and temperature).

The 16th ISCO is organized as a joint endeavour of the Chilean Society of Soil Science and Agriculture Ministry of Chile, both acting in behalf of academic (Universidad de Concepcion and Universidad Mayor) and public national institutions. Within these public institutions, Agriculture and Livestock Service is a national and international linked organization, consolidated in protection of all natural resources of Chile, with permanent concern on the degradation of soils with agriculture vocation. As a fundamental complement, National Forest Corporation, in addition to manage Chile's forest policy and to promote sector development, shows an important trajectory working in protection of Chile's soils with forest vocation. With this spirit, both institutions are realizing a big effort for the success of this Congress.

On behalf of the Steering Committee and the Chilean Society of Soil Science, we would like to acknowledge the generous support received from the ISCO General Board. This cooperation and collaborative effort has been the prime reason for the success of previous congresses. The present congress also promises to be so successful, despite of all difficulties we experimented this year and known by you.

To make an international meeting like this successful, many Chilean colleagues and organizations have contributed untold hours of extra work beyond their normal duties. We acknowledge their assistance and support.
On other hand, we want to report that all your contributions have been organized in six Commissions named:

- **Erosive soil degradation**
- **Biological soil degradation and biological soil constraints**
- **Chemical soil degradation and chemical soil constraints**
- **Physical soil degradation and physical soil constraints**
- **Desertification and dry-lands**
- **Institutional and socio-economic issues**

In this context, we hope a beneficial and productive discussion at this congress to advance and improve Soil Protection and to exchange knowledge among scientists that visit us with the same objective.

The land we want for the future must be built today

Be all welcome to Chile and enjoy your stay in our country.

The Organizing Committee.

PRÓLOGO

El Decimosexto Congreso de la Organización Internacional de Conservación de Suelos es uno de una serie de reuniones realizadas. Los Congresos anteriores que se han realizado son:

Número	País	Año	Número	País	Año
1	Bélgica	1978	9	Alemania	1996
2	Inglaterra	1980	10	EUA	1999
3	EUA-Hawai	1983	11	Argentina	2000
4	Venezuela	1985	12	China	2002
5	Tailandia	1988	13	Australia	2004
6	Etiopia & Kenia	1989	14	Marruecos	2006
7	Australia	1992	15	Hungría	2008
8	India	1994	16	Chile	2010

Estos congresos proporcionan un medio para que los científicos de suelo de todo el mundo discutan sobre la conservación y protección del suelo, su degradación, la desertificación y otros temas, con una orientación a la transferencia de conocimientos y de muchos avances en este recurso vital, el suelo, pero también en otros recursos naturales.

La Conservación de Suelos y Agua se encuentran en la actualidad dentro del marco del Cambio Climático Global y por lo tanto constituye el tema de preocupación en este Congreso. Así, La presencia de las autoridades nacionales y profesionales/científicos de diferentes países en el Congreso nos dará la oportunidad de compartir además las distintas estrategias nacionales destinadas a afrontar todos los cambios asociados (por ejemplo, la escasez de agua, los cambios regionales en la precipitación y temperatura).

El 16º Congreso ISCO es organizado, en conjunto, por la Sociedad Chilena de la Ciencia del Suelo y el Ministerio de Agricultura de Chile, ambos actuando a nombre de instituciones académicas (Universidad de Concepción y Universidad Mayor). Dentro de estas instituciones públicas, el Servicio Agrícola y Ganadero constituye una organización vinculada nacional e internacionalmente, consolidada en la protección de todos los recursos naturales de Chile, con una preocupación permanente en la degradación de los suelos con vocación agrícola del país. Como un complemento fundamental, la Corporación Nacional Forestal, adicionalmente al manejo de la política forestal de Chile y la promoción del desarrollo del sector, muestra una importante trayectoria trabajando en la protección de los suelos con vocación forestal del país. Con este espíritu, ambas instituciones están realizando un enorme esfuerzo para que este congreso internacional sea exitoso.

A nombre de Comité Organizador y La Sociedad Chilena de la Ciencia del Suelo, se desea agradecer el generoso apoyo recibido de parte de

la Directiva General de ISCO. Este esfuerzo de cooperación y de colaboración ha sido la razón principal para el éxito de los congresos anteriores. El presente congreso también promete ser tan exitoso, a pesar de todas las dificultades que hemos experimentado este año, ya conocida por ustedes.

Para hacer exitosa una reunión internacional como ésta muchos colegas chilenos y muchas organizaciones han contribuido con incontables horas de trabajo extras, más allá de sus deberes normales. Agradecemos su asistencia y apoyo.

Este Congreso, al igual que los anteriores, es un modelo de cooperación internacional y de logros. En este mismo espíritu, esperamos una discusión beneficiosa y productiva para avanzar y mejorar la protección del suelo, pero además para el intercambio de conocimientos entre los científicos que nos visitan.

Por otra parte, queremos informar a ustedes que todas sus contribuciones han sido organizadas en seis Comisiones que hemos denominado:

- **Degradación erosiva de suelos.**
- **Degradación biológica de suelo y limitaciones biológicas de suelo.**
- **Degradación química de suelo y limitaciones químicas de suelo.**
- **Degradación física de suelo y limitaciones físicas de suelo.**
- **Desertificación y tierras secas.**
- **Asuntos institucionales y socio-económicos**.

En este contexto, esperamos una discusión beneficiosa y productiva, para avanzar y mejorar la protección del suelo y el intercambio de conocimientos entre los científicos que nos visitan con el mismo objetivo.

La tierra que queremos para el futuro debe ser construida desde hoy.

Sean todos bienvenidos a Chile y disfruten de su estancia en nuestro país.

Comité Organizador.

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RELACIÓN ENTRE CAPACIDAD DE CARGA Y DETERIORO AGROECOLÓGICO. CASO DE ESTUDIO: SUBCUENCA ALTO MOTATÁN, VENEZUELA

Edgar Jaimes [(1)]; Zaida Martos [(2)]; Neida Pineda [(1)]; José Mendoza [(1)]

[(1)] Grupo de Investigación de Suelos y Aguas (GISA. Núcleo Universitario «Rafael Rangel (NURR). Universidad de Los Andes (ULA), Venezuela. Email: jaimes@ula.ve, pineida@ula.ve, jgmendoz@ula.ve
[(2)] Ministerio Popular para el Ambiente (MPPA), Región Trujillo, Venezuela.

Resumen
El objetivo general es comparar los valores de capacidad de carga y de deterioro agroecológico determinados en parcelas de 4 comités de riego localizados en la subcuenca Alto Motatán, Estado Mérida, Venezuela. El sistema productivo predominante es la horticultura de piso alto bajo riego, caracterizado por la utilización de prácticas de manejo del suelo que causan un fuerte impacto ambiental en el medio ecológico. El área de estudio es una de las de mayor producción de hortalizas de Venezuela. La metodología es de tipo no experimental, descriptiva y cuantitativa basada en la aplicación de un cuestionario. La capacidad de carga se determinó con base a un modelo previamente definido, que considera como variables: el área efectiva bajo uso agrícola, la demanda percápita de tierra y un factor de cultivo que está definido por los períodos (años) bajo los cuales las parcelas están con y sin uso agrícola. Los resultados permitieron comprobar que existe una relación inversa entre los valores de capacidad de carga y los de deterioro agroecológico, estos últimos determinados de forma independiente mediante una investigación preliminar, concluyéndose que a un mayor valor de la capacidad de carga se corresponde un menor porcentaje de deterioro agroecológico.
Palabras clave: sostenibilidad ambiental, tipos de uso de la tierra, comité de riego.

Introducción
Los usos inadecuados de la tierra a consecuencia de la expansión de la frontera agrícola es una de las principales causas del deterioro agroecológico en la región andina venezolana (López y Contreras, 2007). En efecto, la creciente ocupación y utilización de la subcuenca Alto Motatán por la actividad humana, ha ocasionado erosión y arrastre de sedimentos, disminución de la cobertura vegetal y modificación del régimen hídrico en una gran cantidad de ríos y quebradas (Jaimes *et al* 2007). Esta degradación de las tierras agrícolas se manifiesta tanto en el lugar donde se produce como fuera de él. Los

efectos *in situ* son particularmente importantes en tierras de uso agrícola, donde la redistribución y pérdida del suelo, la degradación de la estructura y el arrastre de materia orgánica y nutrientes, llevan a la pérdida de espesor de la capa arable y al descenso de la fertilidad natural de los suelos desarrollados en condiciones de altas pendientes (Delgado**,** 2003)**.** La resultante global es una pérdida de productividad de estas tierras que, en principio, limita las especies que pueden cultivarse y obliga a un aumento en el uso de los fertilizantes para mantener los rendimientos de las cosechas y la producción de alimentos (Morgan, 1997)**.**

Materiales y métodos

Caracterización pedogeomorfológica del área de estudio*:* El área de estudio está ubicada en la subcuenca Alto Motatán, con una altitud variable entre los 2900 y 3416 msnm; con un promedio anual de pluviosidad de 703,9 mm (1988-2007) y una temperatura media anual de 15,43 ºC. Dos unidades caracterizan la geomorfología del área: laderas con mantos de alteración superficiales y depósitos cuaternarios. La primera presenta un relieve contrastante en donde alternan pendientes onduladas a muy escarpadas que terminan en fondos de valles. Los comités de riego Cruz Chiquita y Alisal-El Pedregal están localizados en esta unidad. La segunda exhibe relieves aplanados o ligeramente ondulados, con pendientes inferiores al 16%, de origen coluvio-aluvial, caracterizada por paisajes con formas de terrazas, cono terrazas, abanicos y conos de deyección. En ella se ubican los comités de riego Rincón de La Venta y el Rincón del Picacho. En general, los suelos son de colores oscuros, con presencia de fragmentos gruesos, espesores e» 30 cm, con predominio de texturas gruesas, variables entre arenosas (a) y franco arenosas (Fa), influyendo en el drenaje externo rápido que tienen estos suelos. El tipo de uso de la tierra predominante es la horticultura de piso alto con riego suplementario (Jaimes *et al*, 2009).

Métodos de campo*:* El método utilizado es no experimental, descriptivo, con enfoque de tipo cuantitativo, basado en un diseño trans-sectorial, cuyo objetivo es estudiar las variables en un momento determinado, abarcando varios grupos o subgrupos de personas, así como diferentes comunidades, situaciones o eventos (Hernández, Fernández y Baptista, 2004).

Los comités de riego, objeto de este estudio, fueron: Cruz Chiquita, Alisal-El Pedregal, Rincón de La Venta y Rincón del Picacho. En el primero se seleccionaron ocho unidades de producción de un total de veinte; en el segundo se visitaron catorce parcelas de un total de quince; en el terce-

ro fueron diecinueve predios los visitados de un total de veintiocho y en el último las parcelas visitadas fueron quince de un total de dieciséis.
Se aplicó un modelo de encuesta, diseñado por Becerra, Arellano y Pineda (2006), para recopilar información agro-socioeconómica de las unidades de producción seleccionadas. La información recabada fue la siguiente: datos del productor y su grupo familiar; tamaño y área cultivada de las parcelas, periodos con y sin usos agrícolas, densidad de mano de obra, prácticas agronómicas, rendimientos y costos de producción.

Método de gabinete*:* Iskandar, (1990) definió la Capacidad de Carga (***W***) como la máxima densidad de usos agrícolas que puede ser soportada por una superficie dada. El modelo utilizado para determinar el valor de ***W*** fue propuesto por la misma autora pero modificado en este trabajo. Su fórmula quedó expresada de la siguiente forma:

$$W = (a / C*L)*100 \quad \text{(Ecuación 1);}$$

donde: **a** es el área efectiva bajo cultivo por productor-parcela, expresada en ha / productor; ***C*** es un factor de cultivo y ***L*** es la demanda de tierra potencial por productor-parcela expresada en ha / productor. El valor del factor ***C*** se calcula con base en la fórmula siguiente:

$$C = (Tb + Tc) / Tc \quad \text{(Ecuación 2);}$$

donde: ***Tb*** es el **t**iempo promedio sin uso agrícola de las parcelas y ***Tc*** es el tiempo promedio en uso agrícola de las parcelas. Los valores de ***W*** se expresan en porcentaje (***%*).**
El deterioro agroecológico (***DA***) fue definido por Jaimes *et al* (2006) como el conjunto de factores y procesos naturales, antrópicos o antrópico-naturales que afectan en forma negativa la estructura, organización, dinámica y desarrollo de un ecosistema dado, incidiendo en la calidad de vida y estabilidad del entorno ambiental. Tres índices son necesarios para determinar dicho deterioro en términos porcentuales, a saber: 1.) Índice de deterioro asociado a sus causas; 2) Índice de deterioro asociado a sus efectos y 3) Índice de deterioro global.
Con la información cuantitativa obtenida mediante las encuestas se elaboró una base de datos, a partir de la cual se obtuvo el valor de ***W*** para cada comité de riego, los cuales fueron comparados con los ***DA*** determinados por Jaimes *et al* (2007). Un análisis de regresión entre los valores de ***W*** y ***DA*** fue realizado con el fin de conocer su grado de vinculación. La hipótesis nula a comprobar fue la siguiente: *Existe una relación inversa entre los valores porcentuales de **W** y **DA** de tal forma que es fácil apreciar una disminución de los valores de **DA** en la medida que se incrementan los de **W**.*

Resultados

Los valores indicados en las columnas dos hasta la seis de la Cuadro 1 corresponden a las variables que definen los componentes de ***W***, de acuerdo con las ecuaciones 1 y 2. En las dos últimas columnas se presentan los valores porcentuales de ***W*** y ***DA*** cuya comparación es objeto de este estudio.

Cuadro 1. Comparación entre los valores de W y de DA de los cuatro comités de riego evaluados.

Comités de Riego	a (ha/prod.)	L (ha/prod.)	Tb (años)	Tc (años)	C	W (%)	DA (%)
Rincón de La Venta	2.43	7.73	6.13	19.88	1.33	0.24	67.32
Alisal-El Pedregal	11.10	20.90	4.50	16.00	1.30	0.41	65.61
Cruz Chiquita	7.16	11.72	1.38	13.63	1.12	0.55	61.55
Rincón del Picacho	9.95	10.05	2.63	11.73	1.22	0.81	57.32

En la Figura 1 se muestra la comparación gráfica entre los valores de ***W*** y ***DA***, observándose que ambos siguen una relación inversa ya que cuando aumentan los valores de ***W*** tienden a disminuir los de ***DA***. La explicación de estos resultados está sustentada en el hecho de que los sistemas de producción hortícolas que se localizan en los comités de riego Rincón de la Venta y Alisal-El Pedregal tienen un mayor tiempo de explotación que fluctúa entre los cincuenta y treinta años, respectivamente. Por el contrario, en el comité Rincón del Picacho el tiempo de uso agrícola de las tierras varía entre los diez y quince años; mientras que en el comité Cruz Chiquita dicho tiempo es intermedio, es decir entre los quince y los treinta años.

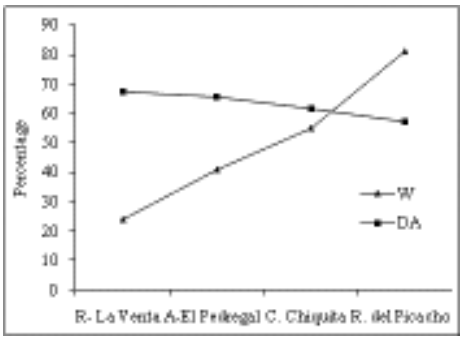

Figura 1. Relación entre los valores porcentuales de la Capacidad de Carga (W) y de Deterioro Agroecológico en los comités de riego bajo estudio.

El modelo de regresión que mejor explica la relación existente entre W y DA es el siguiente: ***DA*** = ***a*** – ***bW*** (Ecuación 3); con un R^2 = 0.90 y un r = 0.95; donde ***a*** es el intercepto y ***b*** es la pendiente negativa de la curva obtenida de la Ec. 3 (Figura 2)

Conclusiones

Se comprobó que existe una relación inversa entre los valores porcentuales de Capacidad de Carga (***W***) y los de Deterioro Agroecológico (***DA***) obtenidos en forma independiente en los comités de riego Rincón de La Venta, Alisal-El Pedregal, Cruz Chiquita y Rincón del Picacho.

Este comportamiento inverso entre las variables ***W*** y ***DA*** está determinado por el tiempo diferencial de explotación en la horticultura al cual han sido sometidas estas tierras de piso alto. En efecto, los comités con mayor tiempo de uso hortícola (Rincón de La Venta y Alisal-El Pedregal) son los que exhiben mayor deterioro y, en consecuencia, menor capacidad de cargo en comparación con los de Cruz Chiquita y Rincón del Picacho, éste último con el menor tiempo de uso hortícola.

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INFLUENCE OF CONSERVATION TILLAGE AND CROP ROTATION ON SUGARCANE YIELD

Denizart Bolonhezi[(1)], Marcelo C. Montezuma[(2)], Everton Finoto[(1)], Lauro M.A. Ivan[(3)], Gustavo V. Gomes[(3)], Rogério Palhares[(3)], Osvaldo Gentilin Jr.[(1)], Antonio Cesar Bolonhezi[(4)]

[(1)]APTA - Agência Paulista de Tecnologia dos Agronegócios / IAC, *dbolonhezi@gmail.com*
[(2)]Monsanto do Brasil, marcelo.c.montezuma@monsanto.com
[(3)]Usina Açúcareira Guaíra, gerenteagric@uag.com.br
[(5)] UNESP – Campus de Ilha Solteira, bolonha@agr.feis.unesp.br

Abstract
The aim of this research was to study the interaction between tillage and crop rotation under sugarcane straw on the yield, technological characteristics of sugarcane SP86-155 and changes in the soil properties. Field experiment was carried out in Guaíra, Brazil. In split-plot design, in which the tillage (conventional, minimum and no-tillage) was the main treatment and crop rotation (peanut, soybean, sunflower, *Crotalaria juncea*, *Mucuna aterrima* and fallow) was the second treatment. Results showed no significant interaction to stalk yield and technological characteristics. No-tillage and soybean it seems to be the best option to renew green harvested sugarcane area.
Key words: No-tillage, Sugarcane Straw, Leguminous

Introduction
The recent expansion of ethanol production from sugarcane in Brazil has raised the cultivated area, specially in São Paulo State where more than 60% of plantations are located in almost 5.4 million ha (Canasat, 2010). According to Lal (2009), the projected global energy demand will increase at a rate of 2.23% per year by 2025, therefore it is extremely important there is the adoption of sustainable production systems, such as the no-tillage, which is practiced only on 6.4% of the world's cropland. Brazil is one good example, because it has a long tradition in the use of renewable energy and has the second largest area under no-till farming (more than 40% of cropland). Recently, the green harvested sugarcane is increasing fast and this system represents around 1,92 million hectares in Brazil. After harvesting a great amount of straw (average 15 Mg of dry matter per hectare each year) is deposited over soil surface, consequently the control of weeds is enhanced (Cristoffoleti *et al*., 2007), the emission of greenhouse gases is reduced and the organic matter of soil may be improved (La Scala *et al*., 2006). On the

other hand, the costs with conventional tillage can increase up to 30%, thus conservation tillage becomes a desirable system to renew sugarcane crop that happens normally after 5 or 6 harvesting. The association of no-tillage and harvesting system without burning reduces the soil erosion to less than 15 Mg $ha^{-1}year^{-1}$ (Prove *et al*., 1995). Between the last cut and the new cane field, it's possible to grow different crops in rotation, mainly leguminous plants. This crop system has a great potential (it's estimated 1 million ha available every year) and the widespread adoption of no-tillage on sugarcane stubble has achieved tremendous success in preventing soil erosion and in improve the net profit (Bolonhezi *et al*., 2009). The benefits of no-tillage into sugarcane straw were study for several crops, such as; soybean (Bolonhezi et al., 2006), peanut (Bolonhezi *et al*., 2007) and green manures. However, there are few scientific results about the effects of conservation tillage after crop rotation on sugarcane yield. Furthermore, it is important to emphasize that the mechanical harvesting has been linked serious problems with soil compaction, specially under wet conditions. In these conditions, the planter machines of crops and the root system of leguminous plant may help to reduce the effects of soil compaction. In this context, the aim of this research was to evaluate the interaction between tillage and crop rotation under sugarcane straw on the agronomic and technological characteristics of sugarcane as well as the changes in the soil properties.

Materials and methods

This research was carried out in a commercial sugarcane area situated at Guaíra city, São Paulo State, Brazil. Chemical attributes of Dark Red Latosol acric (clayey Oxisol) are presented in Table 1. The experiment was set up in a green harvested sugarcane field on 5th ratoon. The amount of dry biomass on the soil surface was estimated at 13,4 Mg ha^{-1}. It was used the experimental design split-plot with four replications, in which the main plots were the conventional tillage (moldboard plowing followed by a two applications of offset disk harrow), minimum tillage (chisel plowing after spray the area with 3.6 kg a.i. ha^{-1} of glyphosate), and no-tillage (crop residues on its surface after spray the area with glyphosate). The six sub-plots were three cash crops (peanut cv.IAC-886, soybean cv. Monsoy 7908rr, sunflower cv. IAC-Iarama), two green manures (*Crotalaria juncea* and *Mucuna aterrima*) and the fallow (weeds grown spontaneously). It was applied lime before planting the cash crops and green manure. All cash crops were fertilized with N, P_2O_2 and K_2O, respectively 12, 60 and 60 kg ha^{-1}, but just sunflower received side dressing of 40 kg ha^{-1} of N plus boron. The sowing date for all crop rotations was 12/12/2006. The

cash crops were harvested from 02/15/2007 (sunflower) to 03/15/2007 (soybean and peanut) and the green manure and fallow were killed with glyphosate at the begin of April. Along with several growth stages of crop rotations it was taken samples of aboveground biomass. Soil samples were taken in all plots in different depth (0-05; 05-0.10; 0.10-0.20; 0.20-40; 0.40-0.60 m) in order to evaluate the fertility. Moreover, undisturbed cores (50 mm x 50 mm, high x diameter) were taken in two points per plot to the following depth; 0-0.10; 0.10-0.20; 0.20-0.30; 0.30-0.40 m, in order to evaluated the bulk density and porosity. These data are not presented in this paper.

Immediately before planting the sugarcane (genotype SP 86-155), the stubble over the soil surface in the plot of conventional tillage were incorporated. A mechanized planter of sugarcane stem (Sermag SMI 10000®) it was used to install the experiment in 04/26/2007. This machine can do all the operations in the same time (opening the furrow, applying the fertilizer, spraying fungicides and insecticides). The distance between furrows was 1.50 m and it was planted 18 buds per meter. Evaluations were done from 45 to 120 days after planting, which showed 12.5% of damaged buds. It was applied 60, 120 and 120 kg ha^{-1} of N, P_2O_5, and K_2O, respectively. The cane plant (first harvest) was done in 05/07/2008 and the first ratoon (second harvest) was done in 09/04/2009. In both of them, it was harvested manually and without burning two furrows with 20 m each. Therefore it was considered 60 m^2 as plot to evaluate the stalk yield. It was used a digital scale to evaluate the stalk yield (kg ha^{-1}). Samples of 15 stalks come from each plot were taken in order to determine the technological characteristics; ^{o}Brix juice, Pol%, Cane Fiber, Juice Purity, AR (reducing sugar in the juice) and ATR (recoverable total Sugar).Data were subjected to ANOVA and the means were compared by Tukey test.

Table 1. Chemical properties of surface soil (0.0-0.20 and 0.20-0.40 m). Usina Guaíra,Guaíra city, Sao Paulo State, Brazil. 2007

Depth (m)	pH	O.M.	P (resin.)	K	Ca	Mg	S	CTC	V
	$CaCl_2$	g dm^{-3}	mg dm^{-3}	----------mmol$_c$ dm^{-3}-------					%
0-0.20	4.6	32	35	2.1	10	3	15.1	75.1	20.1
0.20-0.40	4.7	30	29	1.3	9	3	13.3	67.1	19.8

Results and discussion

No significant interactions between tillage and crop rotations were observed to stalk yield in both of year. It is possible to verify (Figure 1) that in the average of crop rotations, the yield in no-tillage was lower than in conventional (> 5 Mg ha^{-1}), but not statistically different ($p>0,05$). However, the results from second harvest (first ratoon) the mean of stalk yield in no-tillage was almost 7,1 Mg ha^{-1} higher than in

conventional tillage, but no statistic difference was observed. Researches carried out in Australia concluded that no-tillage associated with soybean, as crop rotation, increased significantly (more than 40 Mg ha^{-1}) the stalk yield (Garside *et al*., 2007) and could contribute to solve the problem of «yield decline» in sugarcane. In Brazil, Bolonhezi *et al*. (2006) have studied the interaction of liming and tillage and have observed that no-tillage showed the highest stalk yield in the cane plant (first harvest) for two genotypes. There are results which disagree and showed the highest yield in conventional tillage, but those researches were carried out without crop rotation and in burned harvest.

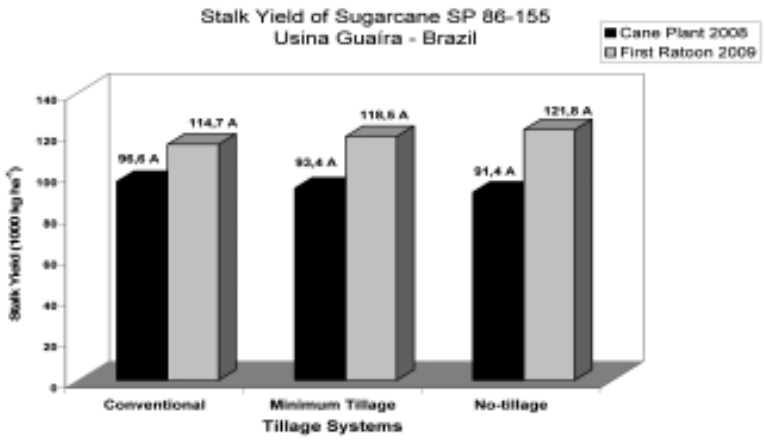

Figure 1. Stalk yield of sugarcane (genotype SP86-155) in different tillage. Means come from the average of six crops and four replications. Guaíra, São Paulo State, Brazil, 2008 and 2009

There are results which disagree and showed the highest yield in conventional tillage, but those researches were carried out without crop rotation and in burned harvest. The Figure 2 showed no significant difference between crops, regarding the average of tillage systems. Nevertheless, it is important to emphasize the yield after soybean. Since 1980s is known the great contribution of leguminous to sugarcane in terms of nitrogen and nematodes control, but the great new in the present research is to prove the same trend in no-tillage.

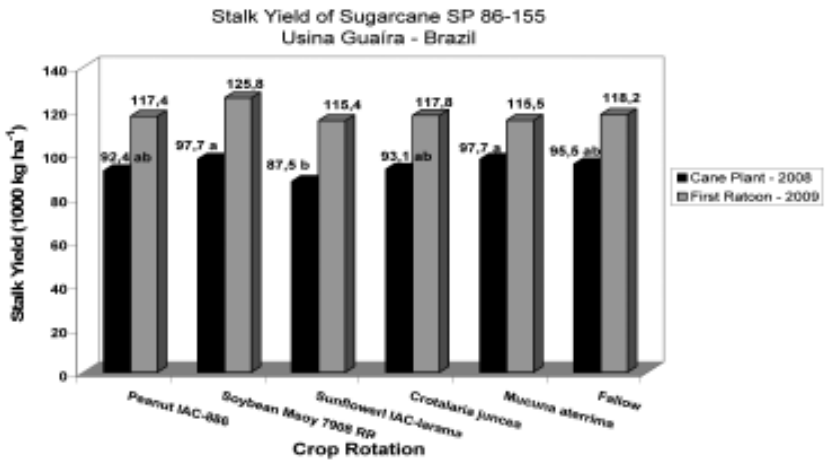

Figure 2. Stalk yield of sugarcane (genotype SP86-155) in crop rotation. Means come from the average of three tillage and four replications. Guaíra, Sao Paulo State, Brazil, 2008 and 2009

Table 2. Technological characteristics of sugarcane SP 86-155 in different tillage and crop rotations, in the first harvest. Usina Guaíra,Guaíra city, Sao Paulo State, Brazil. 2008

Tillage	Brix juice	Pol %	Cane Fibe	Juice Purity	AR	ATR
Conventional	16,9	14,4	11,8	84,7	0,62	122,3
Minimum Tillage	16,9	14,3	11,8	84,9	0,63	121,9
No-tillage	17,2	14,6	11,9	84,8	0,62	123,3
F test	0,91 ns	0,34 ns	0,61 ns	0,11 ns	0,11 ns	0,35 ns
LSD (Tukey 5%)	0,52	0,75	0,28	1,4	0,07	5,2
Peanut	16,8	14,1 b	11,9	84,2	0,65	119,5 b
Soybean	17,3	14,6 ab	11,9	84,7	0,63	123,6 ab
Sunflower	17,0	14,5 ab	11,7	84,9	0,61	123,1 ab
Crotalaria juncea	16,9	14,2 ab	11,8	84,7	0,63	121 ab
Mucuna aterrima	17,3	14,6 a	12	85,9	0,59	125,2 a
Fallow	17,0	14,5 ab	11,9	84,6	0,62	122,5 ab
F test	2 ns	2,31 *	0,69 ns	0,89 ns	1,6 ns	2,41 *
LSD	0,61	0,77	0,43	2,5	0,07	5,4
Interaction	1,62 ns	1,63 ns	0,73 ns	0,86 ns	1,09 ns	1,67 ns
C.V. plot	3,4	5,9	2,7	1,89	12,3	4,8
C.V. split-plot	2,9	4,4	3	2,43	9,4	3,6

When it comes to technological characteristics (Table 2), there were significant differences for sucrose content (Pol %) and ATR (recoverable total Sugar) just in the cane plant, with the highest values in the treatment of *Mucuna aterrima.* Others researches showed significant effect of green manure on Pol%, mainly at the first harvest.

Conclusions

There were no significant interaction between tillage and crop rotations to stalk yield and technological characteristics of sugarcane SP 86-155. There was no significant difference on the stalk yield among crop rotations as well as among tillage. In conclusion, independently of cash crop or green manure, the yield of sugarcane was not decreased when the field was planted without tillage. No-tillage and soybean it seems to be the best option to renew green harvested sugarcane area.

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ASOCIACIÓN DE MAÍZ DE INVIERNO CON ESPECIES FORRAJERAS EN SABANA BRASILEÑO

(INTERCROPPING CORN-FORAGE SPECIES IN THE BRAZILIAN SAVANNAH)

Gessi Ceccon[1], Antonio Luiz Neto Neto[2], Islaine Caren Fonseca[2], Rodrigo César Sereia[2], Aline de Oliveria Matoso[3]

[(1)]Embrapa Agropecuária Oeste, Dourados, Mato Grosso do Sul, Brasil. gessi@cpao.embrapa.br;
[(2)]Universidade Federal da Grande Dourados, Dourados, Mato Grosso do Sul, Brasil. Becario, PET-Agronomía SESu/MEC, aln_neto@hotmail.com
[(3)]UNESP, Faculdade de Ciências Agronômicas, Botucatu, São Paulo, Brasil. Becario, FAPESP

Resumen

La Asociación del maíz con forrajes tropicales es una importante alternativa para mantener el rendimiento de grano, y una aportación de residuos y nutrientes en suelo, con sostenida rentabilidad económica de la soja y maíz siembrados en la rotación. El objetivo del estudio fue evaluar el rendimiento de forraje y maíz (*Zea mays* L.) sembrado solo y asociado con cinco especies de *Brachiaria* spp. e cuatro espécies de *Panicum* spp. Los experimentos se llevaron a cabo en Dourados, Naviraí y São Gabriel do Oeste, estado del Mato Grosso do Sul, en Brasil. El diseño experimental fue de bloques al azar en un factorial 3x10, tres localidad y diez tratamientos. La unidad experimental consistió en cuatro surcos de maíz y tres hileras de forraje, de cinco metros de longitud, se utilizaron cuatro repeticiones. El rendimiento del maíz no fue afectado significativamente por la presencia de la especie en asociación. La asociación del maíz con especies forrajeras ofrece mayor rendimiento total de paja, sobre todo con marandu (*Brachiaria brizantha* Stapf cv. Marandu), xaraés (*Brachiaria brizantha* Stapf cv. Xaraés) y tanzânia (*Panicum maximum* cv. Tanzania).

Palabras clave: Labranza, forrajes, paja.

Abstract

The intercropping corn-forage is an important alternative to maintain grain yield, and a provide aboveground crop residue and nutrients in soil, with profitability for soybean and corn crops in rotation. The aim of this study was to evaluate the performance of forage and corn (*Zea mays* L.) sowed alone, and intercropped with five *Brachiaria* spp. species and four *Panicum* spp. species. The experiments were conducted in Dourados, Naviraí and São Gabriel do Oeste, state Mato Grosso do Sul, Brazil. The experimental design was randomized block

in a 3x10 factorial, three local and ten treatments. The plot was four rows of corn and three rows of forage, five meters long, and four replicates. Corn yield was not affected by species intercropped. The intercrop corn-forage provides higher total yield of aboveground crop residue, especially by Marandu (*Brachiaria brizantha* cv. Marandu), xaraés (*B. brizantha* Stapf cv. Xaraés) and Tanzania (*Panicum maximum c*v. Tanzania).
Key words: tillage, forrage, straw.

Introducción

La producción de granos en el período del segundo cultivo se ha convertido en una realidad en la sabana brasileña, mientras que el maíz es una importante opción para esta región debido la produción de cultivos y su contribución como una rotación en la siembra directa.

En cuanto al sistema de siembra directa, la principal preocupación es la falta de rotación de cultivos, así como la protección del suelo, ya que el modelo de producción sigue la sucesión de soja / maíz y no tiene en cuenta la disponibilidad otros cultivos para la rotación. Con eso, el maíz y otras especies forrajeras se convirtió en una important opción de cultivo, destacando las especies forrajeras que permiten la producción de rastrojos y forrajes. Así permite la entrada de animales, y incrementar los ingresos de paja en la temporada baja. La *B. ruziziensis* se destaca, que pueda manejarse con herbicidas, tiene bajo nivel de competencia con el maíz, y la producción de masa hasta la siembra del cultivo siguiente (Ceccon, 2007).

El consorcio de las cosechas de granos y forrajes tropicales es posible debido la diferencia en el tiempo y el espacio, para la biomasa entre especies (Yokoyama; Kluthcouski 2003). El consorcio de especies forrajeras con maíz representa una importante alternativa para aumento del rendimiento del grano, y una aportación de residuos en el suelo y los nutrientes, proporcionando una mayor rentabilidad económica de la soja/maíz (Ceccon *et al*., 2009).

Las gramíneas tienen alta relación C/N, que mejora las propiedades físicas del suelo y la degradación de su paja es lenta, el suministro de nutrientes y aumentar la calidad del suelo se mide y tiene un efecto prolongado (Borghi; Crusciol 2007). Tambien hay que tener en cuenta la barrera física de los rastrojos, evitando así la pérdida de agua y erosión del suelo.

El objetivo del estudio fue evaluar el rendimiento del maíz sembrado solo y asociado con especies gramíneas forrajeras en tres localidad en Mato Grosso do Sul.

Materiales y métodos

Los experimentos se llevaron a cabo en Dourados (20/03/09) Naviraí (19/03/09) y São Gabriel do Oeste (16/03/09), ubicado geográficamente en sus coordenadas y La respectiva altitud: 22°13' S, 54º48' W y 400 m; 23°14'S, 54°10' W y 377m; 19°24'S, 54°33' W y 617 m. Estos suelos son classificados como Hapludox en Dourados, y Typic Distrófico en Naviraí y São Gabriel do Oeste.

El diseño experimental fue de bloques al azar en un factorial 3x10, en tres localidad y diez tratamientos. Uno tratamiento con maíz (*Zea mays* L.) solo y nueve consorciado con especies forrajeras, siendo: 1) maíz y ruziziensis (*Brachiaria ruziziensis*, Germain & Evrard), 2) maíz y decumbens (*Brachiaria decumbens* Stapf.), 3) maíz y piatã (*Brachiaria brizantha* Stapf cv. Piatã), 4) maíz y marandu (*Brachiaria brizantha* Stapf cv. Marandu), 5) maíz y xaraés (*Brachiaria brizantha* Stapf cv. Xaraés), 6) maíz y aruana (*Panicum maximum* Jacq. cv. Aruana), 7) maíz y tanzânia (*Panicum maximum* Jacq. cv. Tanzania), 8) maíz y mombaça (*Panicum maximum* Jacq. cv. Mombaça), 9) Maíz y massai (*Panicum maximum* Jacq. cv. Massai).

La unidad experimental consistió de cuatro surcos de maíz y tres hileras de forraje, de cinco metros de longitud, con cuatro repeticiones.

La desecación de las restantes plantas del cultivo de soja se realizó con herbicida glyphosate en la dose de 1,5 L ha^{-1}.

La fertilización se realizó solo en la siembra, en hileras de maíz a una dose de 250 kg ha^{-1} de la formulación NPK 08-20-20.

En la maduración de maíz se hechó la cosecha de dos hileras de 5 m, que se trilló el grano seco en el medio ambiente, se cuantificado el rendimiento de granos. Para evaluar el peso seco en plantas, fue cortado, incluso con el suelo, una línea de 5 metros de las plantas. Una submuestra se secó en una estufa a 60°C durante 72 horas, y se pesó para determinar el contenido de materia seca.

Los resultados fueron sometidos a análisis de varianza y las medias compararon mediante el teste del Scott-Knott al 5% de probabilidad.

Resultados y discusión

El análisis de varianza mostró interacción ($P<0,05$) entre las especies y localidad para el rendimiento de la masa de la especie. Para el rendimiento de grano hubo efecto solo de localidad.

El rendimiento de masa seca de maíz consorciado en São Gabriel do Oeste, fue menor que en el maíz solteiro, sin embargo, en Dourados y Naviraí no hubo efecto de las especies. El mayor rendimiento de materia seca de forraje se obtuvo mediante Xaraés en Dourados, Tanzania y Marandú en Naviraí. En São Gabriel do Oeste no se observaron diferencias entre las especies (Cuadro 1).

El rendimiento de la masa total (forrajera + maíz) fue mayor en los consorcios en Dourados y Naviraí, sin diferir de maíz solo en San Gabriel do Oeste. Salvo en Naviraí, los valores más bajos se encontraron en monocultivo y el cultivo intercalado con Massai, los mayores rendimientos de masa seca total se obtuvieron con Xaraés en Dourados, Tanzania y Marandú en Naviraí (Cuadro 1).

Estos resultados pueden atribuirse al aumento de las restricciones de agua verificadas en São Gabriel do Oeste, que tiene una menor fertilidad del suelo, con mayores restricciones están en el cultivos intercalados. En años con sequía prolongada en las primeras fases de la cultura, con las consecuentes lluvias normales, donde hay baja población de maíz, el crecimiento de las plantas tiende a ser mayor debido al aumento de la luminosidad recibida, y así competir con el maíz. La competicia de forraje con el maíz puede reducirse al mínimo ajustando la población de maíz (Rocha *et al.*, 2007) y de la forraje (Ceccon, 2008).

El rendimiento del maíz no fue afectado por la especie en asociación. Se ha producido un efecto de la localidad, y los valores más altos de todas las especies en Dourados, sin difieren significativamente de la Ruziziensis, de la Piatã, de lo Tanzania y de lo Massai en Naviraí. Los rendimientos más bajos se observaron en São Gabriel do Oeste (Cuadro 2), debido a la falta de lluvia durante el período del cultivo.

El cultivo consorciado con major poblaciones de forraje puede resultar en la diminución del rendimiento de grano y paja de maíz de invierno.

El consorcio ofrece mayor rendimiento total de paja, sobre todo

Cuadro 1. Rendimiento de masa del rastrojo del maíz, de forraje y total, en cultivo solo y asociado, en tres localidad del Mato Grosso do Sul, Brasil, 2009.

Especies	rastrojos del maíz			rastrojos de forraje			masa total del rastrojos		
	kg ha^{-1}								
				Dourados					
Maiz+Ruziziensis	2.352	a	B	3.613	b	A	5.965	b	A
Maiz+Decumbens	2.665	a	A	2.285	c	A	4.950	c	A
Maiz+Piatã	2.681	a	A	3.230	b	A	5.912	b	A
Maiz+Marandu	2.909	a	A	3.500	b	A	6.409	b	A
Maiz+Xaraés	2.356	a	A	5.775	a	A	8.131	a	A
Maiz+Aruana	2.192	a	B	2.279	c	A	4.471	c	A
Maiz+Tanzânia	2.405	a	A	3.392	b	A	5.797	b	A
Maiz+Mombaça	2.282	a	A	4.307	b	A	6.589	b	A
Maiz+Massai	2.341	a	A	919	d	A	3.260	d	A
Maiz solo	3.006	a	B	0	d	A	3.006	d	B
Promedio	2.519			2.930			5.449		
				Naviraí					
Maiz+Ruziziensis	2.800	a	A	2.638	b	A	5.438	b	A
Maiz+Decumbens	2.257	a	A	3.118	b	A	5.375	b	A
Maiz+Piatã	2.051	a	A	2.706	b	A	4.757	b	B
Maiz+Marandu	2.242	a	A	3.684	a	A	5.925	a	A
Maiz+Xaraés	2.075	a	A	2.565	b	B	4.640	b	B
Maiz+Aruana	2.208	a	B	2.030	b	A	4.239	b	A
Maiz+Tanzânia	2.718	a	A	4.173	a	A	6.891	a	A
Maiz+Mombaça	1.750	a	A	3.010	b	B	4.760	b	B
Maiz+Massai	2.264	a	A	866	c	A	3.129	c	A
Maiz solo	2.333	a	B	0	c	A	2.333	c	B
Promedio	2.270			2.479			4.749		
				São Gabriel do Oeste					
Maiz+Ruziziensis	1.343	c	B	1.398	a	B	2.741	a	B
Maiz+Decumbens	1.746	c	A	1.769	a	A	3.514	a	B
Maiz+Piatã	2.506	b	A	1.133	a	B	3.638	a	B
Maiz+Marandu	2.681	b	A	1.059	a	B	3.740	a	B
Maiz+Xaraés	2.750	b	A	1.364	a	B	4.114	a	B
Maiz+Aruana	3.342	b	A	1.019	a	A	4.361	a	A
Maiz+Tanzânia	3.349	b	A	1.318	a	B	4.666	a	B
Maiz+Mombaça	2.836	b	A	1.209	a	C	4.045	a	B
Maiz+Massai	2.614	b	A	1.054	a	A	3.668	a	A
Maiz solo	5.950	a	A	0	b	A	5.950	a	A
Promedio	2.912			1.132			4.044		
Promedio general	2.567			2.180			4.747		

Marandú, Xaraés y Tanzania.

Promedio seguido por la misma letra, minúsculas en la columna, si comparaban el tratamiento en cada sitio, y la columna en mayúsculas compara el tratamiento en tres localidad por la prueba de Scott Knott (p <0,05). CV de la masa de maíz: 28,7%; la masa de forraje: 40,2 y el

Cuadro 2. Rendimiento de grano de maíz de invierno solo y consorciado con especies forrajeras, en tres localidad del Mato Grosso do Sul, Brasil, 2009.

Especies	Dourados		Naviraí		São Gabriel do Oeste	
	.....kg ha^{-1}.....					
Maíz+Ruziziensis	3.450	A	3.167	A	410	B
Maíz+Decumbens	3.694	A	2.842	B	571	C
Maíz+Piatã	3.459	A	2.835	A	848	B
Maíz+Marandu	3.777	A	2.659	B	891	C
Maíz+Xaraés	3.876	A	2.822	B	975	C
Maíz+Aruana	3.944	A	2.700	B	1.118	C
Maíz+Tanzânia	3.608	A	3.071	A	1.118	B
Maíz+Mombaça	3.800	A	2.447	B	950	C
Maíz+Massai	3.262	A	2.858	A	894	B
Maíz solo	3.263	A	2.808	A	1.650	B
Promedio	3.613		2.821		945	
C. V. (%)			23,5			

Promedio con la misma letra en la línea, no difieren por el test de Scott-Knott al 5% em cada tratamiento.

peso total: 23,3%.

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EVALUACIÓN Y CLASIFICACIÓN DE TIERRAS AGRÍCOLAS PARA LA CONSERVACIÓN DE SUELOS EN ÁREAS MONTAÑOSAS TROPICALES, SUBCUENCA ALTO MOTATÁN, MÉRIDA-VENEZUELA

Neida Pineda, Jhon González, Gonzalo Segovia, Edgar Jaimes, José Mendoza e Hilda Rodríguez

Grupo de Investigación de Suelos y Aguas. Núcleo Universitario Rafael Rangel.
Universidad de Los Andes. Trujillo, Venezuela.
Email: pineida@ula.ve; gisanurr@ula.ve

Resumen

Se aplicó una metodología que permite evaluar y clasificar tierras en áreas montañosas con fines de conservación de suelos. El área de estudio comprende parcelas ubicadas en los comités de riego Los Caracoles (10500 m^2) y El Rincón del Picacho (59500 m^2), subcuenca Alto Motatán, estado Mérida, Venezuela. Se describieron y analizaron 14 perfiles de suelo, determinándose las características físicas y químicas que permitieron obtener los parámetros para determinar las cualidades de la tierra: índice de productividad (IP) e índice de riesgo de erosión (IRE), a partir de las características del epipedón, ya que los cultivos desarrollados en la zona de estudio son hortícolas, con una capacidad explorativa de las raíces relativamente baja (30-60cm). A partir de estos índices se obtuvo el grado de aptitud de la tierra en cada parcela. Luego, con base en la combinación de los valores de ambos índices se obtuvo las clases de tierras y las prioridades y requerimientos de conservación de suelos. Las parcelas del comité de riego El Rincón del Picacho calificaron con IP de moderado a muy alto con un grado de aptitud que va de marginalmente apto (a_3) a muy apto (a_1), mientras que las parcelas del comité de riego Los Caracoles presentaron un IP de bajo a alto con una aptitud de la tierra que varió de no apto (n) a moderadamente apto (a_2). Las parcelas de ambos comités de riego calificaron con un IRE moderado que a su vez permitió valorar la cualidad de la tierra «Riesgo de Erosión» como moderadamente apta (a_2). Las parcelas de ambos comités de riego clasificaron como tierras en reserva y en condición subcrítica, predominando las primeras en Los Caracoles y las segundas en El Rincón del Picacho. Se recomienda la implementación de prácticas de conservación de suelos, combinando prácticas intensivas de manejo del suelo (labranza conservacionista, abonos verdes), manejo de coberturas

vegetales (cultivos de cobertura, siembras de alta densidad y cultivos asociados) y prácticas moderadas de control de escurrimiento en laderas (cultivos en contorno, cultivos en fajas y barreras vivas).
Palabras clave*:* Productividad del suelo, riesgo de erosión, aptitud de la tierra.

Introducción

La subcuenca Alto Motatán está sujeta a una creciente intervención antrópica, expresada principalmente en una agricultura intensiva, basada en el desarrollo de cultivos hortícolas adaptados a las particulares condiciones agroclimáticas de la zona, con escasa utilización de prácticas de conservación, por lo que surge la necesidad de evaluar y clasificar dichas tierras para luego formular prácticas de conservación y manejo del recurso suelo que contribuyan a reducir la degradación de los recursos naturales.

Puesto que el Índice de Productividad del suelo y el Índice de Riesgo de Erosión de las tierras constituyen las cualidades fundamentales que permiten obtener clases de tierras en zonas de montañas y también determinar los grados de aptitud de las tierras, dichas cualidades representan herramientas útiles para clasificarlas en esta importante área agrícola para luego establecer prioridades y requerimientos en cuanto al tratamiento conservacionista, en el marco de la agricultura sostenible.

Este trabajo tiene como objetivo realizar una clasificación de tierras agrícolas a partir de la estimación del Índice de Productividad y del Riesgo de Erosión, aplicando la metodología de Delgado (2003) en parcelas bajo uso de horticultura de piso alto en los comités de riego «Los Caracoles» y «El Rincón del Picacho», localizados en la subcuenca Alto Motatán, parroquia Andrés Eloy Blanco, municipio Miranda, estado Mérida, Venezuela.

Métodos

Metodología de campo y de laboratorio: 7 perfiles de suelo fueron descritos en parcelas representativas de cada comité de riego, para un total de 14. La profundidad del perfil de suelo dependió del espesor del suelo, desde la superficie hasta el manto rocoso, tomándose muestras de suelo que se analizaron en el laboratorio. De cada parcela se obtuvo las coordenadas UTM, utilizando Geoposicionador Satelital (GPS), para ser referenciadas mediante el programa AutoCAD 2006 (Autodesk 2006) en un mapa topográfico.

Metodología de gabinete: Para el cálculo del Índice de Productividad (IP) y del Índice de Riesgo de Erosión (IRE) se aplicó la metodología para la evaluación de la calidad de las tierras agrícolas con fines de

conservación de suelos en áreas montañosas de los andes venezolanos propuesta por Delgado (2003), que permitió la evaluación y clasificación de las tierras agrícolas (parcelas).

1. Estimación del Índice de Productividad (IP). Para calcular el IP se utilizó el siguiente modelo multifactorial:

$$IP = \sum_{i=1}^{n} (Ai \,.\, Bi \,.\, Ci \,.\, Ki) \qquad (1)$$

donde: IP = Índice de Productividad del suelo, tiene un valor entre 0 y 1, representando el valor 1 la condición óptima del suelo para el crecimiento radical del cultivo indicador. A*i* = factor que evalúa las condiciones que regulan las relaciones agua-aire del horizonte *i*. Se estima a partir de la capacidad de almacenamiento de agua útil y/o a partir del contenido de arcilla y del grado de desarrollo de la estructura del suelo. B*i* = factor que evalúa las condiciones que determinan las resistencias mecánicas a la exploración radical del cultivo en el horizonte *i*. Se evalúa a partir de la densidad aparente relacionándola con la textura del suelo, y/o a partir del contenido volumétrico de fragmentos gruesos. C*i* = factor que evalúa las condiciones que regulan la fertilidad potencial del horizonte *i*. Se estima a partir del pH del suelo obtenido en relación 1:1 y/o a partir de la relación entre la materia orgánica con el contenido de arcilla del horizonte superficial. K*i* = factor que evalúa la importancia relativa del horizonte *i* en el perfil del suelo (factor de ponderación del horizonte respectivo). Se evalúa a partir de la profundidad de enraizamiento del cultivo y la profundidad del epipedón. n = cada uno de los horizontes morfogenéticos del suelo hasta la profundidad efectiva del suelo.

2. Estimación del Índice de Riesgo de Erosión (IRE). Para la cuantificación del riesgo de erosión se utilizó la siguiente fórmula:

$$IRE = \frac{\eta}{10\,(1-\alpha)} \qquad (2)$$

donde: IRE = Índice de Riesgo de Erosión, tiene un valor entre 0 y 1, correspondiendo el valor 1 a un suelo que presenta condiciones potenciales más favorables para que se desarrollen, eventualmente, severos procesos erosivos. α = evalúa el potencial de escorrentía del suelo, a partir de la granulometría y el grado de desarrollo de la estructura del suelo. η = evalúa el impacto de la agresividad de las lluvias en relación con la pendiente del terreno. Para el cálculo de este factor se utilizó el valor de precipitación media anual y el valor de la precipitación media mensual del mes más lluvioso (octubre: 104,4 mm) de la estación Timotes, y la pendiente media del terreno.

3. Grados de aptitud de la productividad del suelo y del riesgo de

erosión. Los grados de aptitud de la tierra se determinaron a partir de una combinación de las metodologías de Delgado (1997 y 2003), una vez obtenido el valor del IP y del IRE. A partir del IP se determinó el grado de aptitud de la cualidad «Productividad del suelo» que comprende las cualidades agronómicas del sistema de evaluación de tierras de la FAO (1985, 1990): condiciones de enraizamiento, aireación, capacidad de retención de nutrientes, pH y toxicidades del suelo. Por otra parte, el valor del IRE se utilizó para evaluar la cualidad «riesgo de erosión».

4. Clasificación de las tierras agrícolas ubicadas en áreas montañosas tropicales. A partir de la combinación entre los IP e IRE obtenidos para cada parcela se logró obtener la clasificación agrícola de las 18 parcelas, utilizando la matriz de clasificación de tierras agrícolas en áreas montañosas tropicales de Delgado (2003). Finalmente, se realizó la representación cartográfica digital de los resultados obtenidos para los IP, IRE y para la clasificación de tierras utilizando el programa AutoCAD 2006 (Autodesk 2006).

Resultados y discusión

En el Cuadro 1 se muestran para cada parcela los valores obtenidos de IP e IRE, con sus respectivos grados de aptitud, y la calificación de la clase de tierra.

Se determinó que las parcelas del comité de riego El Rincón del Picacho presentan una mejor productividad del suelo en comparación con las del comité de riego Los Caracoles, siendo los parámetros que limitan la productividad de la tierra: profundidad efectiva (K), fertilidad potencial (C) y, en menor proporción, las resistencias mecánicas a la exploración radical del cultivo (B) y las condiciones que regulan las relaciones agua-aire (A). Todas las parcelas presentan una moderada aptitud a la cualidad de la tierra «Riesgo de Erosión» por presentar un IRE moderado, ya que la presencia de pendientes pronunciadas y la alta escorrentía existentes en estas parcelas favorecen la erosión hídrica, resultando el factor que evalúa la agresividad climática y topográfica (·) el más determinante para estimar el IRE por presentar valores de 1 ó cercanos a 1.

En las parcelas del comité de riego Los Caracoles predominan las tierras en reserva (R) y en las parcelas del comité de riego El Rincón del Picacho las tierras en condición sub-crítica (S). Se sugiere que las parcelas que clasificaron como tierras en reserva (R), sean mejoradas para que con el tiempo califiquen como tierras en condición subcrítica (S) ya que ellas actualmente están siendo utilizadas para la producción hortícola intensiva con pocas prácticas de mejoramiento y conservación de los suelos que pueden llevarlas, de continuar así, a clasi-

ficar en el futuro como tierras en condición crítica (C); por lo tanto se deben introducir prácticas de conservación y manejo de suelos de acuerdo a las condiciones particulares de cada parcela tales como: labranza conservacionista, incorporación de restos de cosechas, incorporación de abonos orgánicos, abonos verdes, enmiendas para suelos ácidos, rotación de cultivos, cultivos asociados, cultivos tolerantes, barreras vivas, cultivos en fajas, fajinas, muro de piedras, despiedre del terreno, riego por aspersión y riego localizado.

Cuadro 1. Índices de Productividad (IP), Índice de Riesgo de Erosión (IRE) y grados de aptitud de las parcelas de los comités de riego estudiados.

Comité de riego	Perfil	IP	Calificación del IP	Grado de aptitud	IRE	Calificación del IRE	Grado de aptitud	Clase de tierra
Los Caracoles	P-1	0.19	Moderado	a_3	0.28	Moderado	a_2	R
	P-2	0.31	Moderado	a_3	0.28	Moderado	a_2	R
	P-3	0.36	Alto	a_2	0.28	Moderado	a_2	S
	P-4	0.18	Moderado	a_3	0.30	Moderado	a_2	R
	P-5	0.20	Moderado	a_3	0.25	Moderado	a_2	R
	P-6	0.14	Bajo	n	0.26	Moderado	a_2	R
	P-7	0.37	Alto	a_2	0.26	Moderado	a_2	S
El Rincón del Picacho	RP-1	0.19	Moderado	a_3	0.23	Moderado	a_2	R
	RP-2	0.36	Alto	a_2	0.23	Moderado	a_2	S
	RP-3	0.38	Alto	a_2	0.21	Moderado	a_2	S
	RP-4	0.25	Moderado	a_3	0.23	Moderado	a_2	R
	RP-5	0.17	Moderado	a_3	0.22	Moderado	a_2	R
	RP-6	0.59	Muy alto	a_1	0.25	Moderado	a_2	S
	RP-7	0.57	Muy alto	a_1	0.26	Moderado	a_2	S

a_1 = Muy apto; a_2 = Moderadamente apto; a_3 = Marginalmente apto; n = No apto
S = tierras en condición subcrítica; R = tierras en reserva

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DIVERSITY OF RHIZOSPHERE BACTERIA ASSOCIATED WITH ANCIENT CLONES OF CREOSOTE BUSH (*Larrea tridenta*)

[1]Milko A. Jorquera, [1]María de la Luz Mora and [2]David E. Crowley

[1]Center of Plant, Soil Interaction and Natural Resources Biotechnology, Scientific and Biotechnological Bioresource Nucleus, Ave. Francisco Salazar 01145,Temuco, Chile.
[2]Department of Environmental Sciences, The University of California Riverside, Riverside, USA. Tel. 56-45-325467; fax 56-45-325053; Email: mjorquera@ufro.cl.

Summary
Bacterial communities in the plant rhizosphere carry out functions that are essential to plant nutrition, disease suppression and stress protection in terrestrial ecosystems. The use of molecular techniques now offer great promise for exploring the bacterial diversity and learning how bacterial communities function to support plant growth. Here, we studied the bacterial communities that are associated with the roots of the Creosote bush (Larrea tridentata) by using denaturing gradient gel electrophoresis (DGGE). These plants are the predominant shrubs in the Mohave Desert in the USA, and they are considered as oldest living plants on Earth with some individuals having an age of more than 10,000 years. Selective culture methods were also used to evaluate the populations of pseudomonads and endospore-forming bacteria by DGGE. The DGGE analysis of total DNA revealed the presence of members belonging to bacterial phyla Bacteoridetes, Proteobacteria and Firmicutes. In addition, DGGE analysis of culturable bacteria revealed the occurrence of pseudomonads and endospore-forming bacteria. Studies on long term selection and co-evolution of microbial communities with the roots of ancient plants provide fundamental knowledge on how soil microbial communities function for adapting plants to harsh desert environments.
Key words: Bacteria, Creosote bush, DGGE, rhizosphere, Desert

Introduction
A substantial number of the bacteria species in the rhizosphere are mutualistic with their plant hosts and may exert beneficial effects on plant growth, disease suppression and stress protection (Avis *et al*., 2008). Prior research further shows that all plants select for different microbial communities that vary in their species composition. However, our knowledge on plant-bacteria interactions so far has come from studies on agricultural crops and forest tree species, and there is scarce information about bacterial communities in soil under natural vegetation. Bacterial communities under natural vegetation may thus

be specifically adapted to their plant host and the local soil conditions and thereby contribute to the adaptation of their plant hosts to the local environment. A particularly example of a long-adapted bacterial community is that associated with Creosote bush (*Larrea tridentata*), a desert shrub that forms clonal rings in the Mohave Desert, USA. One plant, known as the «*King Clone*» is estimated to be 11,700 years old (Vasek, 1980) and is surrounded by similar aged clones that we have obtained permission to study. The Creosote bush can tolerate extreme environmental stress, such as multiyear droughts, nutrient poor soils for thousands of years. In recent years, DNA-based methods have begun to be applied for the study of plant-bacteria interactions and the application of these methods is now beginning to reveal the many functions of nonculturable soil microorganisms. The objective of this study was to investigate the genetic diversity of bacteria associated with the roots of ancient specimens of Creosote bush.

Materials and methods

Sampling

Samples from two ancient clones of Creosote bush located at the Lucerne Valley (California) were studied (Figure 1). Six samples from plant named as «*King Clone*» (KC) and three samples from younger clone (YC) were taken.

Total bacteria

Total genomic DNA from samples was extracted and DGGE was carried out as described by Jorquera *et al*. (2010) and based on 16S rRNA gene, commonly used in bacterial phylogenetic analyses. Dominant bands in DGGE gels were excised, and then DNA was re-amplified, sequenced and compared with the GenBank database (National Center for Biotechnology Information).

Culturable bacteria

Pseudomonas agar F (PAF) medium was used to culture *Pseudomonas*-related bacteria and endospore-forming bacteria (EFB). For isolation of EFB, the samples were treated at 80°C for 10 minutes and then cultured in PAF medium (Holt and Gerhardt, 1994). Total genomic DNA from culture bacterial populations was extracted and DGGE was carried out as described above. Dominant bands in DGGE gels were excised, and then DNA was re-amplified, sequenced and compared with the GenBank database (National Center for Biotechnology Information).

Results and discussion

The phylogenetic assignment of excised DGGE bands is shown in the Table 1. The results revealed the presence of members belonging to bacterial phyla *Bacteoridetes* (*Chitinophagaceae*, *Flavobacteriaceae* and *Flexibacteraceae*), *Proteobacteria* (*Bradyrhizobiaceae*, *Rhodospirillaceae Pseudomonadaceae*, *Aurantimonadaceae* and *Desulfovibrionaceae*), and *Firmicutes* (*Thermoanaerobacteraceae*). No differences were observed in the DGGE bands pattern between the two plants that were sampled. In relation to culturable bacteria, the presence of pseudomonads (*Pseudomonaceae*) and EFB (*Bacillaceae*) was mainly detected by sequencing of dominants DGGE bands. Currently, few reports are available on the association and role of culturable bacteria with Creosote bush (Herman *et al*., 1995; Garrity *et al*., 1996), and its genomics has not yet been explored. The new knowledge obtained from this research lays the groundwork for future studies to examine the ecology (population size and activity) of these bacteria associated with roots of oldest living plants on Earth.

Conclusions

The findings of present study reveal that ancient clones of Creosote bush harbor a wide diversity of bacteria (mainly *Bacteroidetes, Proteobacteria* and *Firmicutes*) which might play a relevant role in nutrition and health of plant, contributing to the survival of plant for long time periods in extreme environment of the Mojave Desert.

Table 1. Phylogenetic assignment of DGGE bands.

Band[a]	Taxonomic group[b] (accession no. of closest relatives or cloned sequences) *Total DNA*	Similarity (%)[c]
T1	*Bacteroidetes, Sphingobacteria, Chitinophagaceae* (EF606667)	83
T3	*Proteobacteria, Alphaproteobacteria, Bradyrhizobiaceae* (GQ425756)	86
T4	*Proteobacteria, Alphaproteobacteria, Rhodospirillaceae* (AB497746)	84
T5	*Bacteroidetes, Sphingobacteria, Chitinophagaceae* (EF220064)	81
T6	*Proteobacteria, Gammaproteobacteria, Pseudomonadaceae* (GU784934)	97
T7	*Proteobacteria, Alphaproteobacteria, Aurantimonadaceae* (GQ871210)	78
T8	*Proteobacteria, Deltaproteobacteria, Desulfovibrionaceae* (GQ871630)	74
T9	*Proteobacteria, Gammaproteobacteria, Pseudomonadaceae* (GU391475)	97
T10	*Bacteroidetes, Sphingobacteria, Chitinophagaceae* (FJ527527)	94
T11	*Firmicutes, Clostridia, Thermoanaerobacteraceae* (GU375314)	74
T13	*Bacteroidetes, Flavobacteria, Flavobacteriaceae*(FJ805383)	72
T14	*Proteobacteria, Gammaproteobacteria, Pseudomonadaceae* (FJ154997)	77
T15	*Proteobacteria, Gammaproteobacteria* (AM936521)	75
T16	*Bacteroidete, Sphingobacteria, Flexibacteraceae* (EU141784)	83
T17	*Bacteroidetes, Sphingobacteria, Chitinophagaceae* (FJ479213)	89
T18	*Bacteroidete, Sphingobacteria, Flexibacteraceae* (EU141871)	80
T19	*Bacteroidete, Sphingobacteria, Flexibacteraceae* (DQ279363)	91
T20		

(cont.) **Table 1. Phylogenetic assignment of DGGE bands.**

Band[a]	Taxonomic group[b] (accession no. of closest relatives or cloned sequences) *Total DNA*	Similarity (%)[c]
	Culturable bacteria	
C1	*Proteobacteria, Gammaproteobacteria, Pseudomonadaceae* (DQ910438)	98
C3	*Proteobacteria, Gammaproteobacteria, Pseudomonadaceae* (FJ527669)	98
C4	*Proteobacteria, Gammaproteobacteria, Pseudomonadaceae* (GU564701)	98
C5	*Proteobacteria, Gammaproteobacteria, Pseudomonadaceae* (GU564702)	98
C6	*Proteobacteria, Gammaproteobacteria, Pseudomonadaceae* (GU391475)	98
C7	*Proteobacteria, Gammaproteobacteria, Pseudomonadaceae* (GU459175)	96
C8	*Proteobacteria, Gammaproteobacteria, Pseudomonadaceae* (GU784934)	97
C9	*Proteobacteria, Gammaproteobacteria, Pseudomonadaceae* (FJ226759)	90
C10	*Firmicutes, Bacillales, Bacillaceae* (AF423227)	87
C11	*Actinobacteria, Actinomycetales, Micrococcaceae* (EU882856)	81
C12	*Proteobacteria, Gammaproteobacteria, Pseudomonadaceae* (AY303259)	96
C13	*Proteobacteria, Gammaproteobacteria, Pseudomonadaceae* (GU396284)	95
C14	*Proteobacteria, Gammaproteobacteria, Pseudomonadacea* (GU971728)	96
C15	*Proteobacteria, Gammaproteobacteria, Pseudomonadacea* (FN421636)	94
C16	*Proteobacteria, Gammaproteobacteria, Pseudomonadacea* (GU722246)	94
C17	*Proteobacteria, Gammaproteobacteria, Pseudomonadacea* (FJ639236)	98
C18	*Proteobacteria, Gammaproteobacteria, Pseudomonadacea* (GU000498)	98
C19	*Proteobacteria, Gammaproteobacteria, Pseudomonadacea* (AJ512403)	87
C20	*Proteobacteria, Gammaproteobacteria, Pseudomonadacea* (GU784939)	96
B1	*Firmicutes, Bacillales, Bacillaceae* (GU384331)	94
B2	*Firmicutes, Bacillales, Bacillaceae* (GU826153)	97
B3	*Firmicutes, Bacillales, Bacillaceae* (HM104233)	99
B4	*Firmicutes, Bacillales, Bacillaceae* (EU867383)	90
B5	*Firmicutes, Bacillales, Bacillaceae* (FN298320)	99
B6	*Proteobacteria, Gammaproteobacteria, Enterobacteriaceae* (HM008951)	84
B7	*Firmicutes, Bacillales, Bacillaceae* (AY176766)	91
B8	*Firmicutes, Bacillales, Bacillaceae* (AY572480)	100
B9	*Firmicutes, Bacillales, Bacillaceae* (FJ639202)	99
B10	*Firmicutes, Bacillales, Bacillaceae* (GU321095)	99
B11	*Firmicutes, Bacillales, Bacillaceae* (FJ973534)	98
B12	*Firmicutes, Bacillales, Bacillaceae* (FJ943256)	91
B13	*Firmicutes, Bacillales, Bacillaceae* (DQ289059)	99
B14	*Firmicutes, Bacillales, Bacillaceae* (FJ373035)	98
B15	*Proteobacteria, Gammaproteobacteria, Pseudomonadaceae* (GU124698)	86
B16	*Proteobacteria, Gammaproteobacteria, Pseudomonadaceae* (HM011997)	100
B17	*Proteobacteria, Gammaproteobacteria, Pseudomonadaceae* (GU367870)	100
B18	*Firmicutes, Bacillales, Bacillaceae* (HM104232)	100
B19	*Firmicutes, Bacillales, Bacillaceae* (GU471201)	100
B20	*Firmicutes, Bacillales, Bacillaceae* (CP000485)	98

[a]Code of DGGE bands. [b]The phylogenetic assignment is based on sequence analysis by the RDP classifier (http://rdp.cme.msu.edu/classifier/classifier.jsp) or GenBank database (http://www.ncbi.nlm.nih.gov). It is given the phylum as well as the lowest predictable phylogenetic rank. [c]Based on partial sequencing of 16S rRNA gene and comparison with those present in GenBank by using Blastn.

Figure 1. (A) Ancient clone of Creosote bush located at the Lucerne Valley. (B) Sampling.

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EVALUACIÓN DE SISTEMAS DE LABRANZA CONSERVACIONISTA PARA LA MITIGACIÓN DE LA EROSIÓN HÍDRICA EN UN SUELO ALFISOL DE CLIMA MEDITERRÁNEO

Ingrid Martínez[1], Christian Prat[2], Carlos Ovalle[3], Erick Zagal[1], Neal Stolpe[1], Hamil Uribe[3], Alejandro del Pozo[4]

Universidad de Concepción (1)
Institut de Recherche pour le Développement (IRD) (2)
Instituto de Investigaciones Agropecuarias (3)
Universidad de Talca (4)
Email: imartinez@inia.cl

Resumen

La compactación del suelo, la distribución e intensidad de las lluvias y las prácticas de manejo inadecuadas en zonas de pendiente, han ocasionado que la erosión hídrica sea la principal causa de degradación de los suelos en la zona mediterránea de Chile.

Nuestros objetivos fueron comparar *(i)* el escurrimiento superficial bajo cuatro sistemas conservacionistas de labranza con un sistema tradicional, *(ii)* cuantificar las pérdida de suelo en las técnicas evaluadas y *(ii)* monitorear la compactación del suelo en estos sistemas de labranza. Las prácticas conservacionistas seleccionadas fueron: Labranza Tradicional (Lt), Cero Labranza (Cl), Cero Labranza con Subsolado (Cl+Sb) Cero Labranza con Franjas vivas (Cl+Fv) y Cero Labranza con Curvas Desviación (Cl+Cd). Durante tres años, se registraron los escurrimientos superficiales y la carga en sedimentos después de cada lluvia, de parcelas de 1000m^2 (50*20m) con una pendiente de 15% con suelos de tipo Umbric Acrisols (ACum). Se registró la compactación de los suelos en 2008 y 2009 gracias a un penetrómetro digital. Los resultados de tres años de estudio indicaron que los sistemas conservacionistas presentaron los niveles más bajo de pérdida de suelo. Sin embargo, las tasas de pérdidas de suelo en todos los tratamientos son bajísimos (> 1 ton ha^{-1}). El coeficiente de escurrimiento (Kr) superficial es mas alto en el sistema tradicional (entre 50 a 60%) que en los conservacionistas (<30%), especialmente en los meses de precipitaciones más intensas como se registraron en la temporada 2008. Estos resultados indican que a pesar del tamaño de las parcelas, no se logró registrar procesos de erosión regresiva que son los que actualmente, marcan el paisaje de la región, pero sí, confirman la importancia de tener medidas de protección del suelo. Entre aquellas, los resultados indican que la principal es dejar rastrojos a la superficie, ya que, en el caso del subsolado, su efecto disminuyó

fuertemente la compactación de los suelos durante los primeros tres años en comparación a los otros tratamientos, pero al tercer año, este efecto es ya poco notable.

Introducción

La acelerada erosión es un problema que tiene un severo impacto económico y ambiental, que a su vez afecta los factores claves que reducen los rendimientos y, por lo tanto, la economía de áreas ocupadas principalmente por pequeños agricultores. En Chile, el 42% de los suelos en la zona centro sur del país se encuentra en severa y muy severa erosión (CIREN, 2006), como resultado del uso de sistemas de labranza inadecuados en zonas de pendiente (comunes en esta zona), donde la distribución e intensidad de las lluvias concentradas en los meses de invierno son los principales agentes erosivos. Análisis de climatología, revelan que hay una ascendente tendencia a incrementar la intensidad de las lluvias lo que resulta en una mayor pérdida de suelo y escurrimiento (Pruski y Nearing, 2002). El encostramiento superficial de suelos Alfisoles en regiones semiáridas al reducir la infiltración (ya reducida de estos suelos) incrementa no sólo el escurrimiento, sino limita la disponibilidad de agua para los cultivos y por lo tanto, influye directamente sobre los rendimientos (Rao *et al*., 1998).

Consecuencia de lo anterior, la pérdida de los primeros horizontes del suelo ha dejado disponible los horizontes inferiores que presentan mayores niveles de compactación y menor capacidad de retención de humedad, obligando a aplicar técnicas de labranza conservacionistas para la mitigación de la erosión hídrica en estas áreas altamente vulnerables. En zonas semiáridas similares a las nuestras se han estudiado distintas técnicas conservacionistas en cero labranza como la adopción del subsolado (Jin *et al*., 2007) o el uso de franjas vivas y las curvas de desviación (Gebreegziabher *et al*., 2009). Todas ellas han sido señaladas como técnicas que a largo plazo intensifican los procesos de conservación de agua y propiedades físicas del suelo. Estudios de erosión en Chile, se han realizado principalmente usando la metodología Wischmeier en parcelas con dimensiones que oscilan entre los 40 y 100m^2, con una longitud menor a los 20m (Rodríguez *et al*. 2000; Peña, 1986), lo que no toma suficientemente en cuenta los efectos de erosión regresiva. Por esto, trabajamos en parcelas con una mayor dimensión, en las que se incorpore el efecto del largo de la pendiente en los procesos erosivos al comparar *(i)* el escurrimiento superficial bajo cuatro técnicas conservacionistas a un sistema de labranza tradicional, *(ii)* cuantificar las pérdida de suelo en las técnicas eva-

luadas y *(ii)* monitorear la compactación del suelo en estos sistemas de labranza durante el período de estudio.

Materiales y métodos

El estudio se desarrolló en la Estación Experimental Cauquenes de INIA (35°97S, 72°24W). Esta zona presenta una precipitación mensual de 695mm concentradas el 80% en los meses de invierno. El suelo es clasificado como Umbric Acrisols (IUSS Working Group WRB, 2006; Stolpe *et al*., 2008) con un contenido de materia orgánica inferior a 1,5% y una densidad aparente de 1,7 Mg m^3 durante los primeros 20cm de profundidad. Las prácticas conservacionistas seleccionadas fueron: Labranza Tradicional (Lt), Cero Labranza (Cl), Cero Labranza con Subsolado (Cl+Sb) Cero Labranza con Franjas vivas (Cl+Fv) y Cero Labranza con Curvas Desviación (Cl+Cd). El experimento abarcó un área de 0.5ha, divididas en los cinco tratamientos de 20m * 50m en una zona con una pendiente de 15%. Durante tres años de estudio (2007-2009) fueron evaluadas la pérdida de sedimentos y el escurrimiento. Bajo cada tratamiento, dos estanques con una capacidad de 1m^3 cada uno, fueron instalados. Después de cada lluvia, se colectaron las muestras de sedimento y agua en estos estanques. Se pudo así, obtener una relación entre el suelo perdido por evento, así como el coeficiente de escurrimiento (Kr) en relación al agua caída. La compactación del suelo fue medida en el año 2008 y 2009, a una profundidad de 20cm con valores de compactación obtenidos cada 2,5cm, mediante el empleo de un penetrómetro digital de punta cónica (Field Scout SC900). Se consideró una rotación de cultivo avena-trigo-avena durante el período experimental.

Resultados y discusión

Los sedimentos colectados en los estanques, indicaron que el material erosionado por el proceso de escurrimiento durante el 2007 fue menor a los 0,1 ton ha^{-1} debido a las bajas precipitaciones de ese año. En 2008, el tratamiento Lt presentó una pérdida de suelo anual de 0,7 ton ha^{-1} que correspondió principalmente al mes de julio, mes en el que se registraron las más altas intensidades de lluvia, en cambio, los sistemas conservacionistas presentaron una pérdida de suelo entre 0,10 a 0,17 ton ha^{-1}, valores que se mantuvieron en la temporada siguiente para los cinco tratamientos en estudio. Estos valores, cualquier sea el tratamiento, son sumamente bajas, lo que *a priori*, no explica ni el paisaje erosionado de la región, ni las necesidades de gastar dinero en prácticas anti erosivas. Durante las tres temporadas fue posible observar que el aumento de la cubierta ve-

getal disminuyó las pérdidas de suelo y el escurrimiento, protegiendo el suelo del impacto de la lluvia y de ser erosionado, sin embargo, en esta zona las principales lluvias se concentran principalmente cuando la cubierta vegetal es mínima. Por esto, el uso de una cubierta usando los rastrojos es sumamente recomendable.

El agua caída durante las tres temporadas de estudio fue bastante variable en distribución e intensidad, con precipitaciones anuales de 372, 768 y 536 mm para los años 2007, 2008 y 2009, respectivamente. Esta variabilidad, afectó el Kr para los distintos sistemas de labranza. Durante el año 2007, sólo se registraron tres eventos de lluvia que ocasionaron escurrimiento, alcanzando un Kr menor al 10%. En el año 2008, en cambio, ocurrieron 14 eventos de lluvia en la zona de estudio, alcanzando un Kr de un 52% para el tratamiento Lt durante el mes de junio que registró las precipitaciones de mayor intensidad, a diferencia de los sistemas conservacionistas que fluctuó entre un 20 y un 29%, estas diferencias fueron mayores durante el mes de julio, donde el sistema Lt registró un Kr de un 58% y los sistemas conservacionistas un Kr inferior al 7%. Para el año 2009 el sistema Lt registró un Kr de 36%, mientras que los sistemas conservacionistas fluctuaron entre 14 y 48%. En la Fig. 1 se presentan los valores de Kr mensuales en relación al agua caída durante los tres años de estudio.

Los beneficios de la práctica del subsolado y su efecto en la compactación del suelo en el sistema Cl+Sb fueron significativos al resto de los tratamientos durante las dos temporadas evaluadas al presentar los más bajos niveles de compactación. Sin embargo, se observó un importante aumento en el año 2009, al alcanzar el umbral crítico de 2000KPa para el crecimiento radicular (Letey, 1985) cerca de los 12,5cm de profundidad, a diferencia del año 2008, cuyo umbral fue alcanzado a los 17,5 cm de profundidad.

Durante los dos primeros años de estudio los sistemas conservacionistas han presentado la mejor alternativa de mitigación de la erosión hídrica y rehabilitación de estos suelos al presentar una menor pérdida de sedimentos y escurrimiento, especialmente en años con mayor intensidad y cantidad de precipitaciones anuales. El sistema de Cl+Sb ha disminuido la fuerte compactación durante los primeros 20cm de profundidad, en suelos que presentan una alta densidad aparente, proporcionando un mejor desarrollo radicular para los cultivos, sin embargo, los resultados indican que al tercer año este efecto disminuye fuertemente.

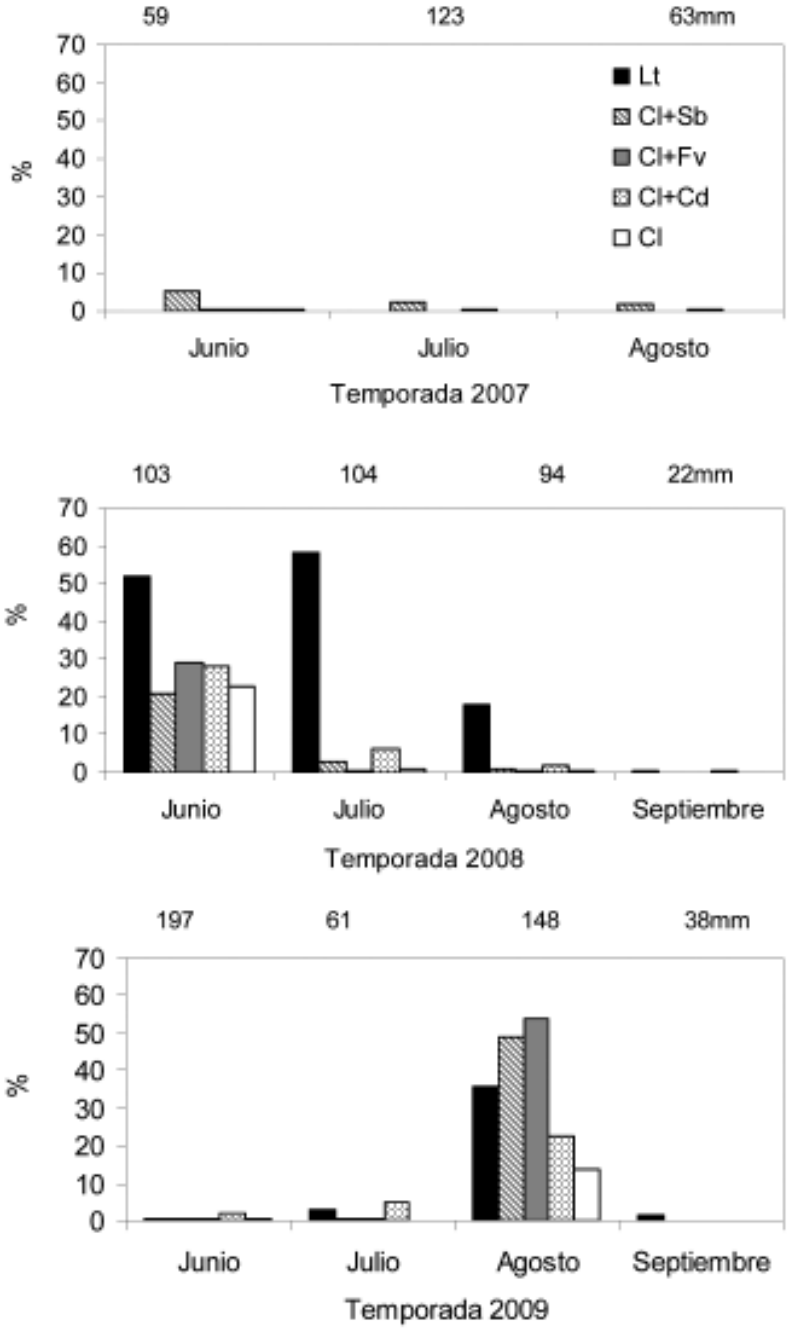

Figure 1. Coeficiente de escurrimiento (Kr) mensual en relación al agua caída para los diferentes sistemas de labranza durante las temporadas 2007- a 2009. Lt=Labranza tradicional, Cl=Cero Labranza. Cl+Sb=Cero Labranza+subsolado, Cl+Fv= Cero Labranza+franjas vivas, Cl+Cd= Cero labranza+curva desviación.

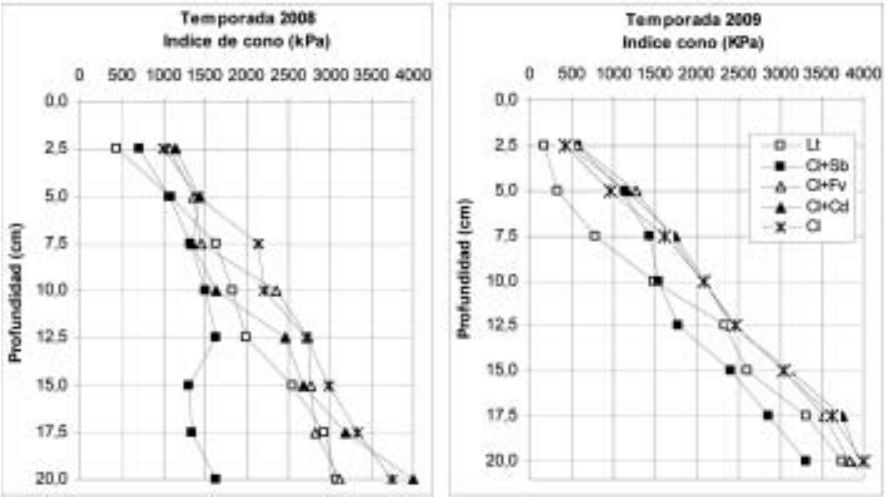

Figure 2. Perfil de resistencia mecánica a la penetración medida como índice de cono (KPa) en profundidad. Lt=Labranza tradicional, Cl=Cero Labranza. Cl+Sb=Cero Labranza+subsolado, Cl+Fv= Cero Labranza+franjas vivas, Cl+Cd= Cero labranza+curva desviación.

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THE SIGNIFICANT PROGRAM FOR CONVERSION OF CROPLAND TO FOREST IN CHINA

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Hong Ma[1]; Ju Hongbo[2]

[1]Senior Engineer. Institute of Forest Resource Information Technique Chinese Academy of Forestry Tel: +86-10-62889159 Fax: +86-10-62888315 Email: mahong@caf.ac.cn
[2]TPN1 Task Manager, UNCCD Director General. Institute of Forest Resource Information Technique Chinese Academy of ForestryTel: +86-10-62889160 Fax: +86-10-62888315

Abstract

Deforestation, soil erosion and desertification, is the main problem to cause the ecological environment degeneration in China, also it's the source to increase the frequency of flooding and serious sandstorms. The planting of annual crops and the grazing of livestock on deforested lands with a steep slope is the most direct reason to lead soil erosion in China.

In 1999, the Chinese government took a strategy: launched the Six Key National Forest Programs in China aiming at combating desertification, improving national ecological environment, and promoting the sustainable economic and social development, and to bring soil erosion and flooding under control. The Programs include:

(1) Natural forest protection project
(2) Program for Conversion of Cropland to Forest
(3) Three North Shelterbelt Development Program and the project and the harnessing the wind and sand source areas in Beijing and Tianjin
(4) Shelterbelt system construction project in the Yangtzi River valley
(5) Wildlife and plant conservation and nature reserve construction project
(6) Intensively-management plantation project

The Conversion of Cropland to Forest, which is one of most significant actions.

Key words: Land degradation, Desertification, Flooding, Soil erosion, The Conversion of Cropland to Forest

Introduction

The Program for Conversion of Cropland to Forest included several types of lands which eligible the standard:

(1) The land that has serious soil erosion and wind erosion.
(2) The degenerated steep slope farmland. (gradient >25º)
(3) The drought land and the serious desertification land.
(4) The land that is of ecological significance yet with low grain yield. [1]

The main feature of the policy for Conversion of Cropland to Forest is that the Chinese Government provides free grain and cash payments for participating farmers. The Government supplied the using funds and the saplings in the Program.

Another feature of the Program relates to the payment of agricultural tax. If the payment of grain made under the Program is greater than the average grain output from croplands that have been converted and are subject to the agricultural tax, then the extent of the grain payment is reduced by the amount of the agricultural tax. [2]

The Program for Conversion of Cropland to Forest has played the positive impetus role for the economy development in the rural area, and it has made the evidence: The land use pattern has been changed in a certain extent, the soil erosion has been reduced, the area of forestry has been increased, the quality of the farmland has been corresponding enhanced and the ecological environment has been improved effectively.

The policy promoted economy development in the local area where the program being actualized, the economic efficiency is appearing gradually. The program has increased the net incomes of farmers.

At present, the climate change has begun to a global acknowledged fact. The world must begin to adapt to the effects of climate change urgently or face a bill of many billions of dollars and a heavy toll in human suffering within a few decades. **Fiona Harvey in Brussels, April 10, 2007**

The United Nations Intergovernmental Panel on Climate Change said. Climate change could lead to 50m people becoming refugees as soon as 2010.

Climate change can occur as a result of both natural and man-made forces. The important measure to influence climate changes warm is to absorb the carbon dioxide through forest, i.e. Using the forest photosynthesis to mitigate the climate to change warm.

In the past 9 years, there is 364,000,000 Chinese acres have been converted to forests. The carbon dioxide, which could be absorbed by forests, is equal to the carbon dioxide, which was exhausted by 3,000,000 automobiles in 11 years in Beijing. The program for conversion of cropland to forest has made the significant contribution to mitigate the climate changes warm. **National Forestry Bureau official Mr. Li-yucai Oct. 2007.**

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COMBATING DESERTIFICATION AND SUSTAINABLE LAND USE - A CASE STUDY IN INNER MOGOLIA

Zhang Fengrong

College of Resources and Environmental Sciences. China Agricultural University No. 2 Western Rd. Yuanmingyuan. Beijing, China 100193. Tel. 86-10-62732643, Fax. 86-10-62733596 E-mail Zhangfr@cau.edu.cn

Summary

It is well known that unsuitable land use is the cause of desertification in semiarid area. However the natural environment and the big population pressure on land are the background of desertification. It is essential for making the land use sustainable, to decrease the population pressure on land, readjust land use structure and take suitable land management methods.

Introduction

Ejinhollo is a county of Inner Mongolia of China, located in the semiarid region where desertification is the most obstacle of sustainable development. Many scholars studied the relationship between land use and desertification in this region (Zhao *et al*., 2000; ZHANG *et al.*, 2002; Ma *et al.*, 2007). These studies illustrated that dry climate is the natural condition of desertification; but, the population pressure on food and unsuitable land use accelerated the process of desertification.

This paper wants to make further study on the causes of desertification, land use changes, sustainable evaluation and make suggestions on sustainable land management / cambating desertification in Ejinhollo county.

Study area and study materials

Ejinhollo is a county of Inner Mongolia of China, between North latitude 38°56'—39° 49' and East longitude 108°58'—110°25'. The climate is semiarid with obvious monsoon characteristics. The annual rainfall is 358 mm. The evaporation is 2535 mm. The humidity is 0.29-0.37. Draught often happens. The Winter and Spring are windy seasons; and the wind is strong. The annual average speed of wind is 3.6m/s. In the east, it is hilly and gully region, the main sediment is loess. Loess is easily eroded by water. In the west part, it is somewhat flat terrain; its bedrock is sandstone dominant. The sandstone is not very consolidated. So the rocks weather easily; it supplies abundant sand. The original vegetation was steppe; and the virgin soil was Kastonzem.

Data, such as GDP, agricultural inputs and outputs, were obtained from the Statistic Bureau of Ejinhollo county. The data of land classification were obtained through the interpretation of landsat images.

Land use changes and desertification

Big population pressure on food and unsuitable land use make the desertification accelerated. Because the climate is typical continental monsoon climate, rainfall fluctuates frequently there is 7 years drought in 10 years. Therefore, it is not suitable to grow crops; it is suitable to pasture in this region. Hundreds years ago, the whole region covers grasses, and it was sheep's heaven. In those days, nomads grazed their sheep and cattle roamed in the vast steppe. With the population increasing, it is obvious that husbandry could not produce enough food for people. So plowing grassland for crops is not avoidable. After plowing, the sandy soil was uncovered, the wind erosion happened. There is contradiction between cultivation and land conservation: The cultivation began in 1697. Farmers who lost their land immigrated to this area to cultivate for survival. In 1949, there were 82133 ha. of farmlands, occupying 13.73% of the total lands. Since the establishing of PRC, cultivation had been taking as an important task, because more and more people need food supply. There were three periods of vast cultivation; they were 1955-1956, 1958-1962, 1070-1973. Because the grain production is not stable, people grow crops as possible as they can for storing food in case of drought year. With cultivation extending, the desertification is getting worse and worse. With population increasing, farmers raised more and more livestock as well.

Overgrazing caused grassland degraded: Before 1978, desertification developed so severe that the agricultural production was greatly decreased; many people even had to move outside this region for survival. Because the mollic epipedon was blowed away; Kastonzem became Arenosol that occupied 61.2% of all soils. Biennial or perennial shrubs and mugwort substituted the annual grasses too.

Other job opportunity decreased the population pressure on land resources: In 1980s, coal mining is developing rapidly in this region. Coal mining makes secondary industry development rapidly. With mining developing, the urbanization developed as well. The GDP value had increasing by times (Figure 1). More and more people get jobs outside agriculture (Figure 2). Many farmers did not depend on agriculture for living, and gave up cultivating the marginal land. The decreased population pressure on lands made desertification slowed down. In return, the improvement of ecological environment made better condition for agricultural development, industrialization and urbanization.

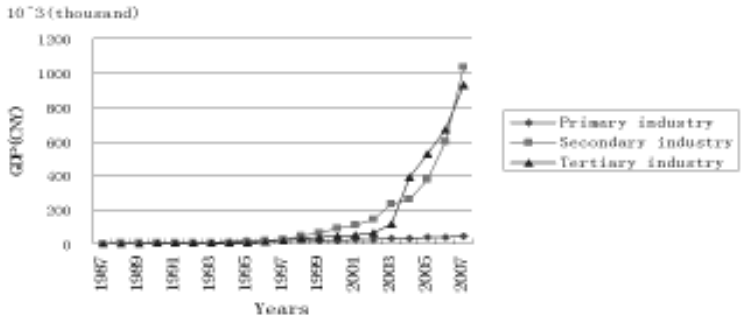

Figure 1. The GDP growth of the primary, secondary and tertiary industries

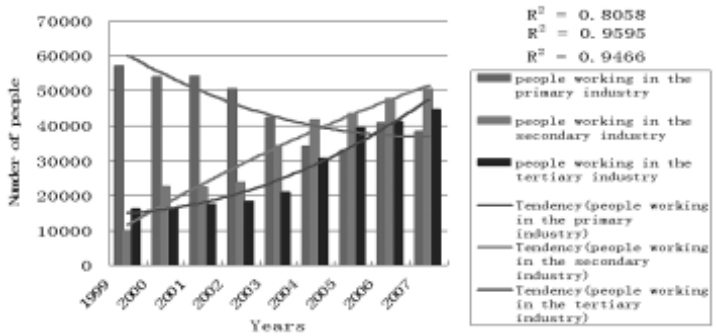

Figure 2. The changes of people working in the various industries

Increasing inputs on farmland and making the unit yield higher: After land tenure reform in 1978, farmers put more investment on agriculture; Government also increases investment on agricultural infrastructures, like constructing irrigation system. Agricultural investment increasement made the yield going up (Figure 3).

Readjusting land use structure: Since 1976, government and people have been doing a series steps and methods to combat desertification; people did their best to grow woods, shrubs for reforestation. Because of farmland yield increasing, farmers did not need cultivating much, reforestation could be going on. The structure of land use had readjusted and desert land had decreased as well in recent 25 years (Figure 4).

Taking suitable land management methods: Suitable and available methods of land use management also were taken for combating desertification and increasing agricultural production. For example, the saving tillage method was taken for preventing wind erosion in Spring and Winter; the grazing was forbidden in early Spring for protecting grassland from over grazing; railing animal husbandry was put in force.

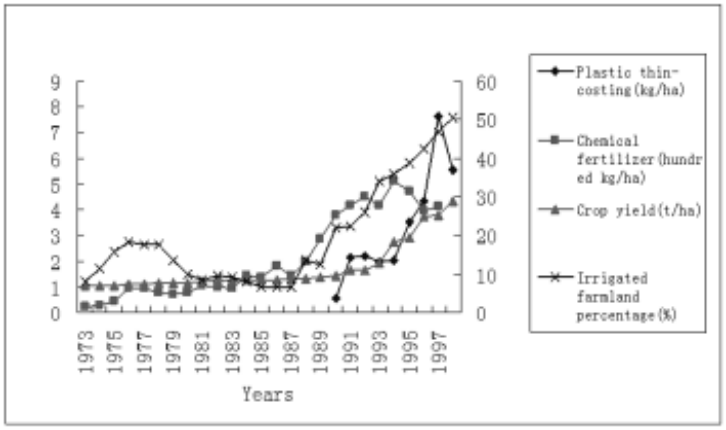

Figure 3. The changes of agricultural inputs and outputs

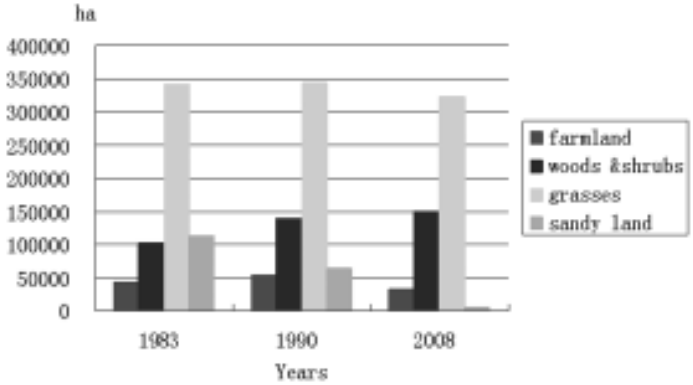

Figure 4. The change of land use structure

The evaluation of land use changes

Fertilizing increased the soil's fertility and farmland's productivity. The irrigation increased the ability against drought and made productivity higher and more stable. With windbreak building and natural plants resuming, vegetation cover increased in all of the seasons, especially the Spring and Winter. Correspondingly, soil erosion was getting controlled and desertification was being slowed down. Farmer's income increased too. Many farmers built new houses, their living standard raised up greatly. All of people understood the causes of desertification and were glad to take reforestation and suitable land use models against desertification. Therefore, the change of land use is sustainable according to the FESLM (FAO, 1993) from 1981 to 2008.

Conclusion and discussion

Promoting industrialization and urbanization, increasing employment chances, decreasing the population pressure on land resources.The bio-productivity and the capacity of supporting human living are very low in semiarid area. When the food demand was over the land supporting capacity, people have to cultivate the grassland. Over-cultivating and over-grazing caused land degradation and desertification. For making sustainable land use and combating desertification, it is essential to give people other survival opportunities, that means, people must find jobs and get incomes outside agriculture. Industrialization and urbanization are the most available ways to increase employment and decrease the population pressure on land resources.

Giving farmer permanent land use right, promoting sustainable land management. Land ownership or tenure is important factor that influences land management. In the commune period from 1958-1977, all of the land belonged to the commune; people had no interesting in sustainable land management. In 1978, China took land tenure reform in rural area. The reform is called Chengbao. Chengbao means that every farmer gets land using right for certain period, farmers can make their own decision on land management and get all of the outputs. Because farmers get using right of the lands, they like to put much investment on the land and pay much attention on soil conservation. This greatly increased output of agriculture and made the land use sustainable. As the land use contract get the end; people might stop or not put much investment on land. So the government should delay the contract deadline, the best choice is to give farmers permanent land use right; this will promote sustainable land management.

Since 1984, reforestation has been taken as an important engineering by the government. The woodland still belongs to the government and is not allotted to individuals. For protecting woodland, the government established a series of law and regulation. These law and regulation have made good effect on preventing woodland from cultivating and firewood cutting. But, there still are the phenomenon of illegal cultivating and wood cutting. For letting farmer have enthusiasm of reforestation and take care of the woods, the permanent using right of woodland should also be given to the farmers as the tenure of farmland and grassland did.

Taking suitable management in agricultural production. Wheat occupies big ratio in grain crops. Also the Spring is dry season. Without irrigation, wheat yield was very low and unstable. The growing time of corn is longer than the growing time of wheat; the growing season of corn is also suit well with rain season. So growing corn can use much more of the solar energy and rain, get high yield.

The water shortage is a restricting factor of irrigating agriculture in Ejinhollo county. But the most of farmlands still take surface irrigation. For changing rainfed land to irrigated land, water saving technique should be extended.

The most of reforested trees are poplar. Because of the simple structure of trees, plant disease and insect pest often happen. So it is good to increase the diversity of trees for combating plant disease and insect pest. Because the wood density is too high, the tendency of water shortage and wilt is appearing in some reforesting area. So the suitable wood coverage and vegetation structure should be taken into consideration. Shrubs are tolerant to drought; they are the good substitute of trees.

Many farmers are illiterate. Vocational education is important to make farmers mastering agricultural techniques.

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QUALITY OF SALSA SEEDLINGS PRODUCED IN SUBSTRATE WITH DIFFERENT LEVELS OF FERTI-IRRIGATION IN DOURADOS - MS.

Islaine C. Fonseca; Thais H. Pereira; Marcos A. Braz Vaz; Antonio L. Neto Neto; Juslei F. da Silva; Elaine C. Galdeia; Guilherme A. Biscaro

Agrarian Science College, Federal University of Grande Dourados - UFGD.
Rodovia Dourados - Itahum, km 12 - Caixa Postal 533, Dourados, Brasil.
islaine_caren@hotmail.com

Summary
The agribusiness production of vegetables is identified with the use of smaller areas but with greater intensity of use. That is the reason why it requires high-tech and refined technological artifacts, which is the case of seedling production in trays and ferti-irrigation. This study evaluated the effect of ferti-irrigation on seedling quality of Parsley «Lisa Graúda Portuguesa» which was conducted at the, Federal University of Grande Dourados (UFGD), in Dourados – MS, during the period of May to August 2009, in trays under environment protection. The experimental design adopted was a randomized blocks, with six doses of fertilizer, in soluble powder, Yogen5® , in irrigation water (0; 1,25; 2,5; 5,0; 10,0; 20,0 g/L) with four replications. There was a ferti-irrigation 30 days after emergence (DAE). The ferti-irrigation affected the development of parsley seedlings, providing an increase in shoot length, fresh and dry weight of roots and shoots. Parsley seedlings of better quality were obtained from the substrate Tropstrato Hortaliça II using the dose of 10 ml/L of fertilizer.
Key words: Petroselinum crispum L., plant nutrition, fertilizer in soluble powder.

Introduction

The parsley (*Petroselinum crispum*) is an Apiacea herb, often used as spice. Adapts better to lower temperatures, sown in the autumn-winter, or during the whole year in the highlands. Culture is undemanding in soil: pH between 6.0 and 6.5, soil fertility with median or low, N, P_2O_5 and K_2O must be applied one or more times depending on the nutritional status of plants (Filgueira 2003).
Produce seedlings of vegetables, like parsley or other vegetables with high quality, became one of the most important stages of the production system, which precisely with the use of new techniques makes cucurbit exploration more competitive and profitable (Reghin *et al.* 2007).

As regards, the production of vegetable seedlings using ferti-irrigation to supply nutrients to plants, it is known that the current literature is very scarce. Thus, in order to produce better quality seedlings, some researches has been developed using the technique of ferti-irrigation. This allows the absorption of nutrients by the plant is closer to what occurs naturally, by providing the same in smaller doses and frequent (Villas Boas *et al.* 2000).

The study determined a viable alternative to produce plants more vigorous and showy, enabling an increase in the final production of salsa using ferti-irrigation, evaluating the quality and characteristics of the seedlings produced according to the substrate and the different levels of ferti-irrigation.

Material and methods

The experiment was conducted between May 5 and August 5, 2009, in a greenhouse at the Agrarian Science College, Federal University of Grande Dourados (UFGD), in Dourados-MS. The local altitude is 446m, latitude 22°11'45'' S and longitude 54°55'18'' W. The experiment was conducted in a greenhouse; the trays were placed on a stand with a width of 1.30 m, located at a height of 1.0 m above the ground. Each plot comprised 32 plants, evaluating the 10 central plants. It was evaluated the cultivar Salsa «Salsa Lisa Graúda Portuguesa»(Perejil Grande Portuguesa – Parsley Geant) of Feltrin® Seeds, with a germination rate of 80% to 100% purity.

The sowing in polyethylene trays with 128 cells was done on 05-05-2009 by placing three seeds in each cell. The experimental design was randomized blocks with six treatments and four replicates and treatments were represented by the doses of soluble powder, Yogen5®, in irrigation water (0, 1.25, 2.5, 5.0, 10.0, 20, 0 g / L) for one liter of water temperatures (24, 23.6 and 23.5, 23.5, 23.3, 23.3 °C), via manually ferti-irrigation 30 days after planting (DAP) in substrate Tropstrato hortaliça II.

The onset of germination occurred at 12 days after planting and pruning was done at 29 days after planting, leaving only one plant per cell. Evaluations were performed at 90 days after planting, which were determined using morphological characteristics of plants: number of leaves (NL), shoot length (SL), root length (RL), fresh weight of shoot (FWS), fresh weight of roots (FWR), shoot dry mass (SDM) and root dry mass (RDM).

The statistical evaluation was performed by the computer program SISVAR, System for Analysis of Variance, in which the averages were subjected to analysis of variance and compared by Tukey test at 5% level of probability and regression analysis.

Results and discussion

The analysis of variance showed significant effects between doses for the variables length, fresh weight and shoot dry mass, fresh weight and root dry mass. The variable number of leaves and root length showed no statistically significant differences, the averages were 3.17 and 9.37, respectively (Table 1).

Regarding NL variable, there was little difference between the averages in relation to doses, thus becoming not significant, and dose 10 as compared to the dose control (dose 0) were equivalent.

For the SL variable, we obtained a quadratic equation, and the highest dosages 10 and 20 g L^{-1} provide higher values, with maximum average value of 10.75 cm for the dosage of 10g/L of fertilizer and 10.25 cm dosing of 20 g L^{-1}. The biggest growth foliar of seedlings is desirable, as the leaves perform the conversion of light energy into chemical energy (Marenco & Lopes 2005), essential for their growth and development.

Regarding the variable fresh weight of shoots (FMAP) of parsley plants, we found a quadratic equation in relation to the doses of fertilizer, the largest value obtained from FWS of 4.93g in dosage of 20 g L^{-1} of fertilizer and 4.49g for the dosage of 10 g L^{-1} There were no significant differences between these doses (Figure 1).

The best way to evaluate the growth of a plant would be the dry mass, because the fresh mass shows water oscillations due to most of the vegetables are formed by water (Taiz and Zeiger 2004). Regarding to the shoot dry mass of plants from parsley (SDM), we found a quadratic equation for the concentrations of fertilizer, the largest amount of dry mass obtained was 1.57 in dosage of 20 g L^{-1} of fertilizer and 1.49 g to 10 g L^{-1} of fertilizer.

Regarding to the fresh and dry weight of roots (FWR and DWR) we found a quadratic equation for the concentrations of fertilizer, and in the FWR, the highest values obtained were 2.25, 2.07 and 1.72 g for dosages of 20, 10 and 5 g L^{-1} of fertilizer. And in the DWR, the highest doses (20 and 10 g L^{-1}) had no differences; it was found dry weight of 1.10 g and 1.05, respectively.

Regarding the variable number of leaves, there was no difference between the averages in relation to the doses but, in dose 10 there was a small improvement in quality. For the variable shoot length, the larger doses of fertilizer (10 and 20 g L^{-1}) resulted in greater growth and performance, which is essential for the production of parsley that is geared towards the production of spice and when the shoot length is higher, better is the product quality. As for length of root, there was no difference.

Table 1. Number of leaves (NL), shoot length (SL), root length (RL), fresh weight of shoot (FWS), shoot dry mass (SDM), fresh weight of roots (FWR) and root dry mass (RDM) of parsley seedlings grown under different fertilizer doses, in Dourados – MS.

Doses	NL	SL	RL	FWS	SDM	FWR	RDM
0	3,75 a	3,75 c	8,50	0,235 c	0,155 c	0,178 c	0,164 c
1,25	3,00 b	6,25 bc	9,25 a	1,080 bc	0,481 bc	0,743 bc	0,606 b
2,5	3,00 b	7,50 ab	9,75 a	1,668 bc	0,621 bc	1,365 ab	0,772 ab
5,0	3,00 b	9,50 ab	9,50 a	3,356 ab	1,142 ab	1,717 a	0,911 ab
10,0	3,25 ab	0,75 a	9,75 a	4,489 a	1,495 a	2,069 a	1,059 a
20,0	3,00 b	0,25 a	9,50 a	4,934 a	1,569 a	2,247 a	1,101 a
CV (%)	8,81	18,35	10,23	44,44	40,56	30,36	23,88

Averages followed by same letter do not differ significantly by Tukey test at 5%.

Conclusion

Parsley seedlings of better quality were obtained from the substrate Tropstrato Hortaliça II using the dose of 10 ml/L of fertilizer.

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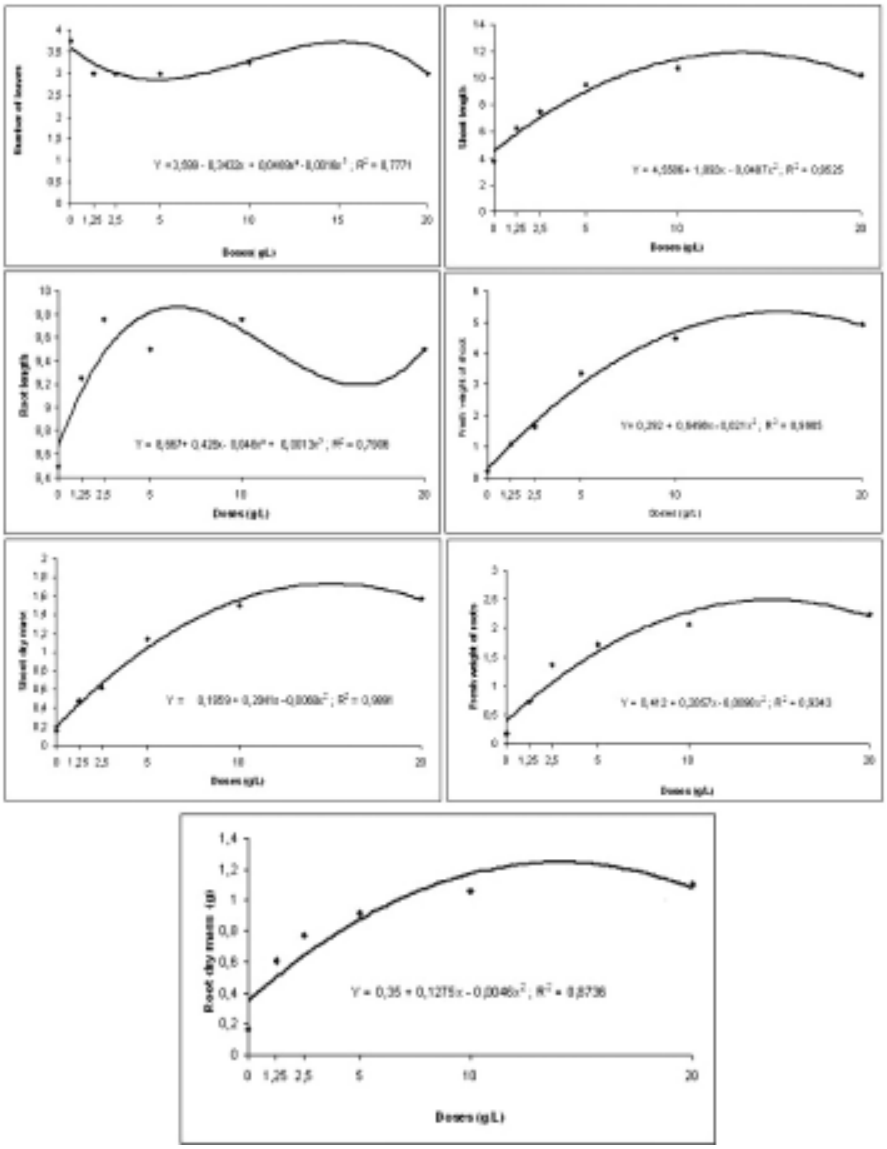

Figure 1. Number of leaves (NL), shoot length (SL), root length (RL), fresh weight of shoot (FWS), shoot dry mass (SDM), fresh weight of roots (FWR) and root dry mass (RDM) of parsley in function of doses of fertilizer. Dourados, MS, 2009.

RECUPERACIÓN DE AGROECOSISTEMAS AFECTADOS POR INUNDACIONES EN CUATRO SECTORES DEL MUNICIPIO ANDRES BELLO, ESTADO TRUJILLO, VENEZUELA

José G. Mendoza [1] jgmendoz@ula.ve; Lesbia Quintero [2] lesbiaquintero@hotmail.com; y Edgar J. Jaimes [1] jaimes@ula.ve

[1] Grupo de Investigación de Suelos y Aguas (GISA), Núcleo Universitario Rafael Rangel (NURR), Universidad de Los Andes (ULA), Venezuela.
[2] Alcaldía del Municipio Andrés Bello, estado Trujillo, Venezuela

Resumen

La degradación progresiva de los sistemas agroecológicos que constituyen las unidades productivas de esta zona, localizados en los sectores: Pele El Ojo, La Atascosa, La Capilla y San Antonio, municipio Andrés Bello del estado Trujillo, Venezuela, aparentemente es irreversible y está asociada con procesos intensivos y no controlados de inundaciones, constituyendo un factor limitante para el desarrollo de esa localidad. El objetivo de este trabajo es proponer estrategias para la recuperación de los agroecosistemas afectados por inundaciones, tomando en cuenta la planificación del uso sostenible de los recursos naturales y la participación ciudadana de los habitantes residentes en los sectores mencionados. Se aplicaron metodologías participativas para identificar problemas, causas y soluciones en áreas de interés de una comunidad en particular. La causa que mayor incidencia en el deterioro ambiental de los sistemas agroecológicos seleccionados está asociada directamente a los desequilibrios existentes entre el hombre y la naturaleza.

Introducción

Las estadísticas muestran que las causas de las inundaciones se relacionan con el incremento de las aguas que escurren sobre la superficie debido a la pérdida de la capacidad de infiltración de agua y obstaculización del flujo en los cursos de aguas. Esto ocurre cuando la corriente alcanza niveles extraordinarios que no pueden ser controlados en los vasos naturales o artificiales que la contienen. Al respecto Pérez (2001) señala que en el estado Trujillo hay una red hidrológica causante de inundaciones que aumentan la tasa de arrastre y depósito de sedimentos. Ante esta situación es necesario seguir investigando sobre el deterioro agroecológico y ambiental en cuencas hidrográficas, como parte de una línea de investigación que ya ha generado resultados importantes en la región andina venezolana (Escalona *et al* 2006, Jaimes *et al* 2006, Jaimes *et al* 2007, Mendoza, 2007, etc.) En ese

sentido, este trabajo propone estrategias para la recuperación de los agroecosistemas afectados por inundaciones, tomando en cuenta la planificación del uso sostenible de los recursos naturales y la participación ciudadana de los habitantes residentes en los sectores Pele El Ojo, La Atascosa, La Capilla y San Antonio.

Materiales y métodos

Es una investigación de campo descriptiva, desarrollada en el municipio Andrés Bello del estado Trujillo (Venezuela), empleando el siguiente procedimiento metodológico:

Selección del área de estudio. Se tomaron en cuenta los siguientes criterios: a) La vulnerabilidad de los sectores a inundaciones; b) La forma y nivel de organización social de las comunidades; c) Potencialidades de desarrollo del área; d) Cercanía entre los sectores objeto de estudio y e) Disposición de los productores a participar en la investigación. Con base en estos criterios se seleccionaron los sectores: Pele El Ojo, La Atascosa, La Capilla y San Antonio.

Caracterización físico-natural y socioeconómica del área de estudio. Se realizó para evaluar los recursos y potencialidades de la zona, la cual se ubica entre las coordenadas UTM 1070000–1063000 LN y 304500–310000 LE. El principal afluente del municipio es el río Paují, seguido del caño Carrillo y completándose con el río Barúa, La Pedregosa, Río Blanco y las quebradas Las Palmas, Puente Hierro, San Antonio, Maporal, Gallo Blanco y Gallo Sucio y los caños San Antonio, Caracas, y Tomoporo. De ellos, en el área de influencia del río La Pedregosa y de las quebradas Las Palmas, Puente Hierro y San Antonio, se ubican los sectores de estudio. Del clima se tiene que la precipitación anual varía entre 1009,8 y 1829,5 mm, la temperatura anual varía entre 27,7 y 28,7 ºC y la evaporación mensual se sitúan entre 140 y 190 mm. Según la clasificación de Zonas de Vida de Holdridge, se identifican el Bosque Seco Tropical, el Bosque muy seco Tropical y el Bosque Seco Premontano. la zona está constituida por dos unidades litológicas: una conformada por sedimentos del cuaternario (del Pleistoceno al Holoceno actual) y la otra definida por formaciones del período terciario (Formación Misoa y Formación Paují). Se destacan suelos Clase II, de buena calidad y aprovechables para una amplia variedad de cultivos, con limitaciones por clima (precipitación), profundidad efectiva y la presencia de sales de sodio. De acuerdo al sistema taxonómico de clasificación, predominan los suelos *Ustropets*, *Ustifluvets* y *Tropaquents*. Entre las características socioeconómicas está una población distribuida en el sector Pele El Ojo con 430 habitantes, en los sectores La Capilla - San Antonio de 200 personas y en el sector La Atascosa con 548 habitantes. Las actividades económi-

cas están orientadas al desarrollo del sector agrícola (ganadería de doble propósito, cultivos permanentes y de subsistencia) y la explotación de minerales no metálicos e hidrocarburos.

Análisis situacional sobre el deterioro ambiental generado por las inundaciones. Se obtuvo información actualizada necesaria para proponer las estrategias dirigidas a cambiar las condiciones que originan las inundaciones, considerándose dos de los principios establecidos en el Enfoque de Marco Lógico (Análisis de la Participación y el Análisis del Problema) y aplicándose el instrumento de las matrices Problema-Causas-Soluciones (Jaimes *et al* 2006), para identificar las causas que mayor incidencia tienen en el deterioro ambiental de los sistemas agroecológicos localizados en las zonas vulnerables a inundaciones.

Elaboración de estrategias para la conservación de agroecosistemas en zonas vulnerables a inundaciones. Entendida estrategia como el conjunto de acciones de comunicación y creación de consenso, acopio y análisis de información, formulación de políticas y planificación y aplicación de medidas, que se lleva a cabo con objeto de permitir que una sociedad conserve su capital natural y logre la sustentabilidad, integrando el desarrollo económico y la conservación del capital natural, se elaboraron las estrategias contenedoras de las principales acciones dirigidas a la conservación de los agroecosistemas en los sectores estudiados.

Resultados y discusión

El análisis situacional se genera a partir de la información obtenida por parte de cada uno de los involucrados producto de las visitas preliminares, las charlas introductorias y la realización de los talleres vivenciales en los cuales se aplicó la matriz Problema-Causas-Soluciones. Como resultado se obtuvo que para el sector Pele El Ojo las causas que más están asociadas al problema de inundación son el taponamiento de caños por las haciendas, las malas canalizaciones, la acumulación de basura en los cauces, la siembra de cultivos en los cauces, la sedimentación de cauces, la poca protección en los taludes de las quebradas, la poca capacidad de los drenajes, la deforestación de la parte alta donde nacen las quebradas y las viviendas construidas al margen de las quebradas y caños. Para el caso de La Atascosa el origen del problema se asoció con la falta de drenajes en los caños, la ubicación de viviendas cerca de los caños, el desbordamiento de alcantarillas, los derrumbes de la carretera, la basura en los caños, los saques de arena, la deforestación, el colapso de la laguna de oxidación y los obstáculos en los caños fuera de la comunidad. Para los sectores La Capilla y San Antonio las causas

incluyeron: disminución de cauces de los caños, taponamiento de caños por las haciendas, falta de drenajes, nivelación de terrenos en fincas, saques de arena, sedimentación de cauces, potreros encajonados, la basura y plantaciones en los cauces de los caños.

Con base en los resultados obtenidos se proponen cuatro estrategias para disminuir la acción antrópica sobre los agroecosistemas y al establecimiento de acciones correctivas integradas por: 1) El uso de prácticas de manejo conservacionista y participativas como base fundamental para el aprovechamiento racional de los recursos naturales; 2) El saneamiento preventivo y protección de las condiciones ambientales de los sistemas hídricos naturales y sistemas de drenajes que comprenden los agroecosistemas; 3) El mejoramiento e implementación de medidas estructurales y sistemas de drenaje de bajo impacto en las zonas vulnerables a inundación, como medidas de protección de los recursos naturales, económicos y sociales de la población y 4) El desarrollo de instrumentos de planificación para el uso racional de los agroecosistemas y mitigación de riesgos de inundaciones.

Conclusiones

Las causas que mayor incidencia tienen en el deterioro ambiental de los sistemas agroecológicos seleccionados están asociadas directamente a los desequilibrios existentes entre el hombre y la naturaleza, destacándose la acumulación de desechos sólidos en los drenajes, extracción de arena, deforestación, siembra de cultivos en los cauces, nivelación de terrenos y carencia de estructuras hidráulicas; por lo que se propone el uso de prácticas agroecológicas, el saneamiento de los sistemas hídricos y sistemas de drenajes, la construcción de obras hidráulicas y la participación de organizaciones gubernamentales y no gubernamentales.

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MÉTODO MULTIFACTORIAL-PARTICIPATIVO PARA LA EVALUACIÓN DEL DETERIORO AMBIENTAL EN DOS SUBCUENCAS DEL ESTADO TRUJILLO, VENEZUELA

Edgar Jaimes [(1)]; jaimes@ula.ve; José Mendoza [(1)], jgmendoz@ula.ve; Yalitza Ramos [(2)]; yalitzar33@hotmail.com; Neida Pineda [(1)], pineida@ula.ve

[(1)] Grupo de Investigación de Suelos y Aguas (GISA); Núcleo Universitario «Rafael Rangel (NURR); Universidad de Los Andes (ULA), Venezuela.
[(2)] Universidad Bolivariana de Venezuela, Extensión estado Trujillo

Resumen

El objetivo general de este trabajo fue evaluar el deterioro agroecológico y ambiental de las microcuencas Río Blanco (RB) y El Socorro (ES), localizadas en las subcuencas de los ríos Escuque y La Palma, respectivamente; ambas tributarias de las cuencas de los ríos Motatán y Caus-Pocó en el estado Trujillo, Venezuela.. Los modelos que conforman el método de estudio son: matriz causa-efecto y el análisis global del deterioro ambiental. Producto de la aplicación de estos métodos, se determinó que la subcuenca Río Blanco exhibe un valor de deterioro asociado a causas o efectos igual a 678 que es mayor al obtenido en la subcuenca El Socorro, es decir un valor de 572. Por su parte, el valor de deterioro máximo (VD_{Max}) para ambas subcuencas es igual a 1296. En consecuencia, el porcentaje de deterioro de las subcuencas en estudio, respecto a este valor máximo de deterioro, fue de 52,3 % y el 44,1 %, respectivamente, indicando estos resultados un significativo deterioro en la primera subcuenca en comparación con la segunda.

Palabras clave: Análisis global del deterioro ambiental; educación ambiental; matriz causa – efecto.

Introducción

La crisis ambiental ha sido caracterizada por diversos autores (Sheng, 1992; Jiménez, 1996; Díaz *et al.*, 2003; Brown, 2003; Colin, 2003 y Rojas, 2004) e instituciones nacionales (MARN, 1998) e internacionales (FAO y PNUMA, 2000). Según Jiménez (1996), el origen de esa crisis ambiental está en el modo de producción capitalista dirigido a la satisfacción de los requerimientos mercantilistas asociados con la producción de bienes y servicios, algunos de los cuales han potenciado una revolución tecnológica e industrial que está estimulando a gran escala una sociedad robótica y cibernética que no está atendiendo debidamente los problemas derivados del deterioro

agroecológico y ambiental que genera su creciente actividad. Un ejemplo palpable de este problema de degradación es el sector de la microcuenca Río Blanco (RB), perteneciente a la subcuenca del río Escuque, que drena sus aguas hacia la cuenca del río Motatán. Esta microcuenca representa la principal fuente hídrica que suministra agua al Municipio Escuque desde el año 1960. Por su parte, la microcuenca El Socorro (ES), localizada en la subcuenca del río La Palma, que aguas abajo alimenta al río Buena Vista, es la fuente hídrica que, desde el año 2004, aporta un complemento significativo de agua para el acueducto La Palma que, por trasvase, es conducida a las áreas urbanas del municipio Escuque.

A partir de esta problemática, la comunidad de Escuque se ha motivado para desarrollar, talleres vivenciales e interactivos, dirigidos al diseño de un plan integral con un enfoque de sustentabilidad que garantice en el tiempo la conservación y el manejo de los espacios, formulando recomendaciones y propuestas dirigidas a la elaboración de un plan de ordenación territorial por parte de los entes gubernamentales con el propósito de ir vislumbrando una solución global al problema ecológico-ambiental que afecta a estas subcuencas productoras de agua.

Materiales y métodos

Partiendo de que el deterioro de los recursos naturales es consecuencia resultante de la acción de un conjunto de factores y procesos naturales y antrópicos y, que el mismo se refleja a través de algunos efectos degradativos del ambiente, se consideró importante desarrollar un método orientado a la identificación de esas causas y efectos relacionados con los cambios que sufren los diferentes ecosistemas y agroecosistemas, en particular las microcuencas objeto de este estudio. Los principales instrumentos de dicha metodología son los siguientes:

Matriz Causa – Efecto. Se fundamenta en el Principio de la Causalidad o Relación Causa – Efecto, entendida como una forma de organizar y representar diferentes ideas sobre el origen de un problema en particular. Para aplicar la Matriz Causa – Efecto, se consideraron algunas estrategias con la finalidad de acceder a las comunidades y motivar su participación en talleres vivenciales en los que se aplicó este instrumento. La matriz está estructurada por un conjunto de filas (causas) y columnas (efectos). El cruce entre las causas y los efectos produce un número determinado de celdas en las que se colocan las valoraciones que el participante considere pertinente asignar, permitiendo cuantificar la relación entre las causas y los efectos con los cuales se relacionan cada una de ellas. Para este caso el

número de celdas fue de 144 producto del análisis de doce causas y doce efectos, es decir 12 X 12 = 144 (Jaimes *et al*, 2007).

Las valoraciones utilizadas en este análisis se clasificaron en: efecto mínimo (valor 1), cuando la intensidad de los procesos degradativos no es apreciable en ninguna parte del sistema; efecto leve (valor 3), en aquellos casos donde la intensidad de los procesos degradativos es ligeramente apreciable en algunas partes del sistema (< 25%); efecto moderado (valor 5), al percibirse que la intensidad de los procesos degradativos es moderadamente apreciable en algunas partes del sistema (25 - 50%); efecto elevado (valor 7), cuando se considera que la intensidad de los procesos degradativos es evidentemente apreciable en gran parte del sistema (50 - 75%); y efecto máximo (valor 9), en aquellos casos donde la intensidad de los procesos degradativos es fácilmente apreciable en la totalidad del sistema (> 75%). Es pertinente acotar que esta valoración porcentual debe ser apreciada bajo el enfoque sistémico y de visión compartida entre los productores, las comunidades, los técnicos y los investigadores que apliquen esta metodología multifactorial y participativa (Jaimes *et al*, 2007).

Análisis Global del Deterioro. Se realizó con base a la integración de la información obtenida de la aplicación de la matriz causa – efecto en cada una de las microcuencas en estudio. Para determinar en forma global el grado de deterioro de una quebrada o microcuenca, asociada con el conjunto de causas que en él inciden, se aplicó la siguiente relación:

$VDC= (£C/V_{(max)}D)*100$ (Ec. 1); (Jaimes *et a*l, 2007), donde VDC = valor de deterioro asociado a las causas, expresado en %; £C=sumatoria de la incidencia de cada causa sobre el nivel de deterioro en la microcuenca en estudio y $V_{(max)}D$ = valor máximo de deterioro que se esperaría en toda microcuenca. Se obtiene asignando la valoración máxima de nueve a cada celda de la matriz causa-efecto, luego, su magnitud sería el producto de 9 x 144 = 1 296.

Una expresión similar a la Ecuación 1, pero referida a los efectos (£E), está representada por la Ecuación 2, esto es:

$VDE = (£E/V_{(max)}D)*100$ (Ec. 2) ; (Jaimes *et al,* 2007), donde VDE = valor de deterioro asociado a los efectos, expresado en %; £E= sumatoria de la incidencia de cada efecto sobre el nivel de deterioro en la microcuenca en estudio; $V_{(max)}D$ = valor máximo de deterioro que se esperaría en la microcuenca, que es igual 1.296.

Resultados y discusión

A) Microcuenca Río Blanco (RB).

Para el caso de esta microcuenca, las causas que más inciden en su deterioro agroecológico y ambiental son, en orden de importancia, las siguientes:

I) Carencia de planes operativos por parte de los organismos gubernamentales mediante los cuales quede explícita la voluntad política de dar respuesta a las comunidades (C_{12}).

II) Falta de gerencia técnica capaz de identificar prioridades en el sector agrícola (C_4).

III) Ausencia de políticas agrícolas y ambientales con un enfoque integral basadas en el plan de ordenamiento territorial (C_3).

De acuerdo con los resultados obtenidos en la matriz causa – efecto se pudo determinar que el orden de importancia bajo el cual inciden las doce causas que fueron identificadas como determinantes del deterioro agroecológico y ambiental de dicho sector, siguen la secuencia decreciente indicada a continuación:

$$\mathbf{C_{12} > C_4 > C_3 > C_1 > C_6 = C_9 = C_{10} = C_{11} > C_5 = C_7 > C_2 > C_8}$$

La incidencia de estas causas está ocasionando, entre otros, los efectos siguientes:

a) Baja productividad y eficiencia de los Sistemas de Producción Agrícola (E_8).

b) Pérdidas en cantidad y calidad de los recursos naturales (E_2).

c) La disminución de la calidad de vida en los centros poblados (E_{12})

d) Contaminación creciente y sostenida de los recursos naturales (E_4)

e) Inadecuado manejo de los desechos contaminantes (E_{11}).

B) Microcuenca El Socorro (ES).

En esta microcuenca el deterioro agroecológico y ambiental expresa su origen a través de las siguientes causas:

I) Carencia de planes operativos por parte de los organismos gubernamentales mediante los cuales quede explícita la voluntad política de dar respuesta a las comunidades (C_{12}).

II) Falta de integración en el diseño y aplicación de los programas educativos referentes a la conservación de los recursos naturales (C_6).

III) Poca observancia de las leyes, reglamentos y ordenanzas en lo referente a la actividad agrícola y en la conservación del ambiente (C_5).

IV) Desvinculación de las comunidades con los sectores pro-

ductivos gubernamentales y de ciencia y tecnología en la solución efectiva de los problemas agroecológicos (C_9). Para este caso, el orden de importancia decreciente de las doce (12) causas fue el siguiente:

$$\mathbf{C_{12} > C_6 > C_5 = C_9 > C_1 = C_2 > C_4 = C_7 > C_{10} > C_3 > C_{11} > C_8}$$

Para esta microcuenca los efectos que más se destacan son los siguientes:

a) Pérdidas en cantidad y calidad de los recursos naturales (E2).
b) Disminución de la calidad de vida en los centros poblados (E12).
c) Disminución del caudal en las fuentes de agua superficiales (E3).
d) Generación de conflictos de uso y manejo de los recursos naturales (E7).

C) Análisis Global del Deterioro de las microcuencas Río Blanco y El Socorro.

Con fundamento en la matriz causa – efecto y aplicando las ecuaciones 1 y 2 se determinó que la microcuenca Río Blanco exhibe un valor de deterioro (VD = 678) mayor que la microcuenca El Socorro (VD = 572), los cuales con respecto al valor de deterioro máximo (VD_{Max} = 1296), representan el 52,3 % y el 44, 1 %, respectivamente. Estos resultados indican un significativo deterioro en la microcuenca Río Blanco y en menor proporción en la microcuenca El Socorro.

De acuerdo con la información aportada por los asistentes al taller, la carencia de planes operativos por parte de los organismos gubernamentales mediante los cuales quede explícita la voluntad política de dar respuesta a las comunidades (C12); es la principal fuente generadora de deterioro agroecológico y ambiental en los dos sectores estudiados. Lo mismo ocurrió con los efectos, toda vez que las pérdidas en cantidad y calidad de los recursos naturales (E2) y la disminución de la calidad de vida en los centros poblados (E12), ocupan los primeros lugares de importancia para los miembros de ambas microcuencas en estudio.

Con base en estos resultados, se recomienda a la Alcaldía del Municipio Escuque, con la intervención de los consejos comunales de participación ciudadana, la definición de un plan de ordenamiento territorial para identificar prioridades y diseñar proyectos productivos viables, factibles y sustentables para las subcuencas de los ríos Escuque y La Palma, tomando en cuenta las acciones propuestas por los participantes en el Taller, tendentes a lograr un conjunto de soluciones a corto y mediano plazo de la problemática agroecológica y ambiental, específicamente en las microcuencas Río Blanco y El Socorro.

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HUMIFICATION DEGREE EVALUATION AND SOIL CARBON BEHAVIOR IN SEWAGE SLUDGE AMENDED AREAS

Bruno Henrique Martins [1,2], Sérgio Gaiad [3], Débora M. B. P. Milori[1], Ladislau Martin-Neto[1]

[1] Embrapa Instrumentação Agropecuária, C.P.741, CEP: 13560-970, São Carlos, SP, Brasil
[2] Universidade de São Paulo, Instituto de Química de São Carlos (IQSC/USP), C.P.780, CEP: 13560-250, São Carlos, SP, Brasil
[3] Embrapa Florestas, C.P. 319, CEP: 83411-000, Colombo, PR, Brasil
e-mail: brunohm@cnpdia.embrapa.br; gaiad@cnpf.embrapa.br; debora@cnpdia.embrapa.br; martin@cnpdia.embrapa.br

Summary

In the latest years, the sewage sludge (SS) amendment practice in agro forestry systems has become an environmental solution avoiding landfill disposal. In the present study, was analyzed the humification degree and carbon content of soil organic matter (SOM) from soils of experimental fields in two different farms under eucalyptus plantation and sewage sludge amendment. The results obtained showed an increase in the humification degree and decrease in carbon content in the samples of the amended area comparing to the no-amended area in one farm, while it was observed an inverse behavior in the other one. Thus, the experiments must continue, once it can be observed probably the occurrence of priming effect related to the SS application, which can lead to loss of structure and soil fertility.

Introduction

The greenhouse effect, an Earth's natural and essential phenomenon, lately has been increased by the anthropogenic intervention, by fossil fuel burning, deforestation, and mostly wrong agricultural tillage, leading to an increase in the atmospheric gases that causes this effect. According to data from International Panel of Climate Changes (IPCC) (2007), in the last years the emission of greenhouse gases (GHG), mostly carbon dioxide (CO_2), has increased nearly 70%.

The correct soil tillage and forestry practices are considered an important tool promoting carbon sequestration, minimizing the GHG emissions and mitigating its atmospheric excess by interaction with some soil organic matter (SOM) fractions, and taking account the photosynthesis process. To Nair *et al*., (2009), according to the tillage, some agro forestry systems can act like a carbon sink, promoting a carbon sequestration. Thus, the carbon content in the soils represents the greater fraction in its geological cycle, being responsible for its

global balance. It is estimated that there is approximately 2300 Petagrams of carbon in soils, which represents nearly three times the atmospheric carbon concentration.

According to González-Pérez *et al,* 2006, SS acts like a source of organic matter to the soil, which application improves fertilization levels and restores some soil physico-chemical properties.

In this way, the purpose of the following study is to evaluate the humification degree and carbon content of SOM in amended areas, comparing to no amended area, analyzing about the benefits and sustainability of sewage sludge use in forestry systems as a tool for soil improving, mitigating GHG emissions and sequestrating atmospheric carbon.

Materials and methods

The experimental field under eucalyptus plantation is installed in two different farms (Entre Rios and Areona) in the city of Itatinga, São Paulo state. Each farm was divided in two different areas, according to the SS amendment. The soil profile in the Entre Rios farm was characterized as an Oxisoil, with a clay content varying between 16 and 20%, while the Areona farm soil is characterized as Quartzarenic Neosoil, with a clay content varying between 5 and 12%. The experimental field under eucalyptus plantation is installed in two different farms (Entre Rios and Areona) in the city of Itatinga, São Paulo state. The two farms are differentiated between each other by its soil characteristics and the beginning of eucalyptus plantation. Each farm was divided in two different areas, according to the SS amendment. The amendment occurred ten days before the plantation, at a volume between 1500 and 2000 kilograms per hectare. The sample identification according to the SS amendment was performed as it follows: ER 60 (Entre Rios farm and SS amended), ER 228 (Entre Rios farm and no SS amended), AN 254 (Areona farm and SS amended) and AN 36 (Areona farm and no SS amended).

The soil samples were collected in the two farms, in three repetitions by depth of analyzed condition, in December, 2009, in the depth 0-10 to 10-20cm, dried at room temperature and subsequently sieved at 0.5 mm mesh. In the sequence, sample pellets were made for the analyses. These sample pellets were made with nearly 0,5 g of weight and submitted to pressure of 10 ton.

The carbon content results were obtained by elemental analysis and the humification degree results by LIF spectroscopy. The measurements were made in triplicate, taking into account depth and condition analyzed in both farms.

Results and discussion

The carbon content results for Entre Rios and Areona farm, as well as some soil physical characteristics, are shown in Table 1.

In the case of the Entre Rios Farm, probably SS amendment increased the microbial activity in soil by high availability of fresh organic matter (Martins *et al.* (2009) what, in a second stage, must have triggered a soil carbon decrease by degradation of stable fractions (Fontaine *et al.*, 2007).

Still, according to Fontaine *et al.* (2007), in their study about stability of organic carbon in soils, increasing of fresh organic matter at depth, could lead to a loss of ancient soil carbon, which leads a decreasing of total soil carbon content as a function of time, promoting the priming effect in soil.

The results obtained for the samples of the Areona farm showed an inverse behavior comparing to the samples of the Entre Rios farm. It was observed that in the SS amended area the values of carbon content were higher than in the no amended area, in all analyzed depths.

Anyway, these results showed an interesting behavior. The soil in Areona is characterized as Quartzarenic Neosoil (a recently generated soil with amounts of quartz in its composition). This kind of soil has a major fraction of sand and low carbon concentration in your profile. This way, it was not expected strong interaction between SS and the organic matter of this soil. However, it was noted that soil tillage with SS amendment in the Areona farm leads to a better carbon accumulation when compared with the same tillage in the Entre Rios farm.

The humification data for the Entre Rios farm samples are illustrated in the Figure 1, while the data for the Areona farm are illustrated in the Figure 2.

The results obtained for the Entre Rios farm samples showed an increase around 100% in the humification degree in the amended areas comparing to the no-amended areas. A hypothesis to explain this behavior in the Entre Rios farm is the possible occurrence of priming effect, affecting soil microbial activity, promoting a higher degradation of labile fractions, and leading to lower carbon content, and thus the higher humification degree (complementing the elemental analysis data).

Still, according to Adani and Tambone, (2005), the SS amendment may aggregate recalcitrant fractions in soil, becoming an integral part of soil organic matter (once SS has in its constitution a high content of organic matter, providing a contribution to SOM), and then, leading to an increase in the humification degree.

However, this situation in the Entre Rios farm is worrying since it may represent, among other factors, loss of soil organic matter by microbial activity, which may cause limitations in soil fertility and structure, and possible carbon loss as CO_2, causing increase in atmospheric GHG concentration, negatively contributing to the global warming scenario.

Table 1. Carbon content results obtained for soil samples from Entre Rios and Areona Farm.

SAMPLE	C Content	Soil Profile	Clay Content	Eucalyptus Plantation
ER 228 0-10 I	1,85 ± 0,02	Oxisoil	16 – 20 %	Nov/2004
ER 228 0-10 II	0,90 ± 0,01	Oxisoil	16 – 20 %	Nov/2004
ER 228 0-10 III	0,98 ± 0,03	Oxisoil	16 – 20 %	Nov/2004
ER 228 10-20 I	1,21 ± 0,01	Oxisoil	16 – 20 %	Nov/2004
ER 228 10-20 II	0,80 ± 0,04	Oxisoil	16 – 20 %	Nov/2004
ER 228 10-20 III	0,67 ± 0,02	Oxisoil	16 – 20 %	Nov/2004
ER 60 0-10 I	0,84 ± 0,03	Oxisoil	16 – 20 %	Apr/2004
ER 60 0-10 II	0,84 ± 0,02	Oxisoil	16 – 20 %	Apr/2004
ER 60 0-10 III	1,18 ± 0,04	Oxisoil	16 – 20 %	Apr/2004
ER 60 10-20 I	0,37 ± 0,02	Oxisoil	16 – 20 %	Apr/2004
ER 60 10-20 II	0,45 ± 0,01	Oxisoil	16 – 20 %	Apr/2004
ER 60 10-20 III	0,60 ± 0,03	Oxisoil	16 – 20 %	Apr/2004
AN 36 0-10 I	0,57 ± 0,03	Quartzarenic Neosoil	5 – 12 %	Mar/2008
AN 36 0-10 II	0,67 ± 0,02	Quartzarenic Neosoil	5 – 12 %	Mar/2008
AN 36 0-10 III	0,70 ± 0,01	Quartzarenic Neosoil	5 – 12 %	Mar/2008
AN 36 10-20 I	0,41 ± 0,05	Quartzarenic Neosoil	5 – 12 %	Mar/2008
AN 36 10-20 II	0,46 ± 0,01	Quartzarenic Neosoil	5 – 12 %	Mar/2008
AN 36 10-20 III	0,45 ± 0,02	Quartzarenic Neosoil	5 – 12 %	Mar/2008
AN 254 0-10 I	0,71 ± 0,01	Quartzarenic Neosoil	5 – 12 %	May/2008
AN 254 0-10 II	0,74 ± 0,03	Quartzarenic Neosoil	5 – 12 %	May/2008
AN 254 0-10 III	0,75 ± 0,02	Quartzarenic Neosoil	5 – 12 %	May/2008
AN 254 10-20 I	0,53 ± 0,03	Quartzarenic Neosoil	5 – 12 %	May/2008
AN 254 10-20 II	0,61 ± 0,04	Quartzarenic Neosoil	5 – 12 %	May/2008
AN 254 10-20 III	0,54 ± 0,01	Quartzarenic Neosoil	5 – 12 %	May/2008

The results for the Areona farm samples showed a decrease in the humification degree in the amended areas around 29% comparing to the no-amended area.

This behavior may be attributed to a possible higher accumulation of more labile carbon fraction, instead of more recalcitrant fraction after the amendment. It may be explained also by the fact that the soil profile, as mentioned before, is a quartzarenic neosoil (major fraction of sand), hence it does not expect to present characteristics its organic matter strongly interacting with the SS amendment.

This way, the lower humification degree behavior complements the increase in the carbon content observed for the samples in this farm. However, it is important to note that soil tillage with SS amendment in the Areona farm leads to a better carbon accumulation when compared with the same tillage in the Entre Rios farm.

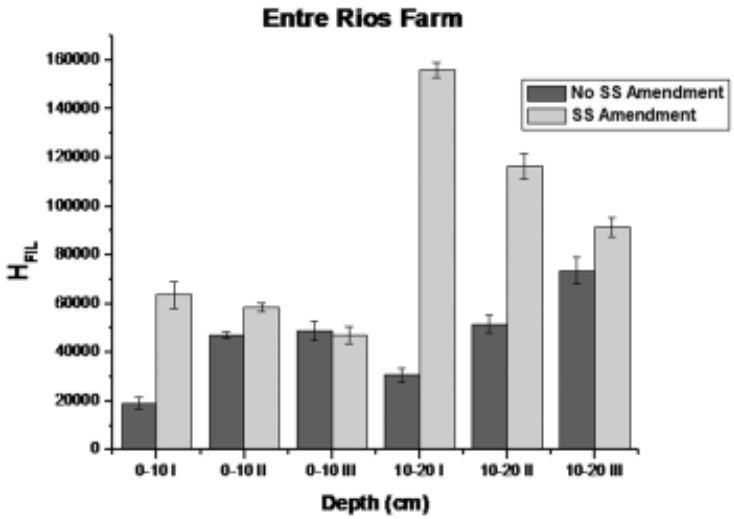

Figure 1 – Humification degree (H_{FIL}) results obtained for Entre Rios farm samples. 0-10 and 10-20 represents the depth and I-III represents the replicates of the samples. In red, values referent to the no-amended area and in green, values referent to the amended area.

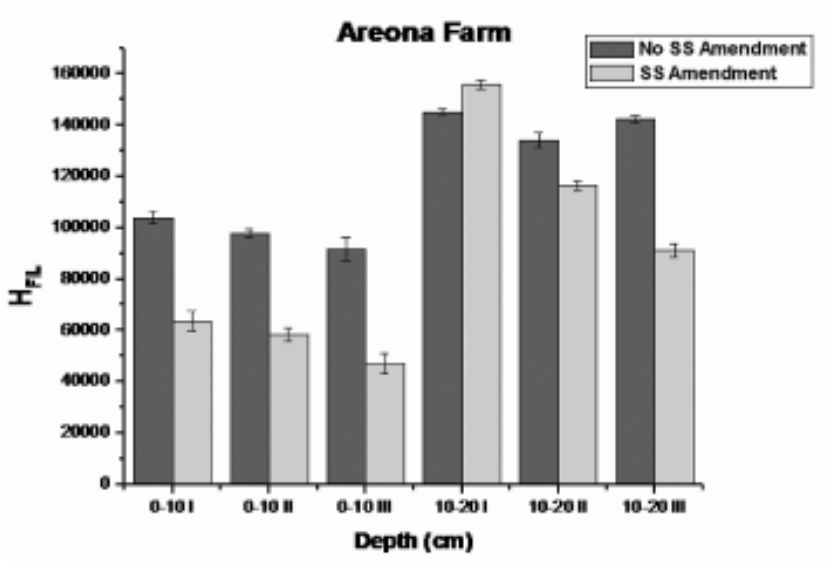

Figure 2 – Humification degree (H_{FIL}) results obtained for Areona farm samples. 0-10 and 10-20 represents the depth and I-III represents the replicates of the samples. In red, values referent to the no-amended area and in green, values referent to the amended area.

Likewise, it is important to evaluate if the difference was due to different soil properties for each farm or if may be attributed to period of the experiment.

Conclusion

Studies of soil amendment using SS are very important to avoid negative environmental consequences, as soil contamination or decreasing of carbon content in soil. This kind of residues management can be positive depending on the situation, and for this reason each case needs to be carefully studied.

Thus, field experiments must continue in both farms to confirm and validate the initials tendencies detected. New alternatives for soil tillage in forestry systems can be suggested to make possible SS soil amendment in sustainable conditions with environmental benefits.

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EFECTO DE LA APLICACIÓN DE BIOSÓLIDOS SOBRE LA CALIDAD DEL SUELO: EVOLUCIÓN TEMPORAL DE SUELO DEGRADADO, REGIÓN DE LA ARAUCANÍA, CHILE.

Alejandra Sepúlveda V.[1], Carolina Inostroza H.[1] & Francisco Encina M.[1]

[1] *Universidad Católica de Temuco, Escuela de Ciencias Ambientales,Chile.*
*asepulve@uct.cl, carolinainostrozah@gmail.com, fencina@uct.*cl.

Resumen

En suelo Inceptisol de la región de la Araucanía, de condición degradado, se determinó la evolución temporal en propiedades del suelo posterior a un evento de aplicación de biosólido. En el sitio de estudio se establecieron dos zonas de muestreo: zona sin aplicación de biosólidos y zona con aplicación de biosólidos, evaluándose parámetros químicos, físicos y biológicos a los 17, 210, 365 y 510 días de aplicado el biosólido. Los resultados muestran cambios relevantes en la calidad de suelo trascurridos tres años desde la aplicación, particularmente en relación al aumento sostenido en el contenido de fósforo, respiración edáfica e infiltración.

Palabras clave: biosólidos, calidad de suelo, suelos degradados.

Introducción

Se entiende por biosólidos al subproducto residual del tratamiento de aguas servidas, los que presentan acumulaciones de sólidos orgánicos sedimentables y semisólidos o líquidos producidos durante el proceso de tratamiento mecánico, biológico y/o químico de purificación de éstas (Marambio & Ortega 2003). Además, poseen gran contenido de materia orgánica, microorganismos, macro y micro nutrientes, elementos traza y agua (Whitehouse *et al.,* 2000). Uno de los principales problemas del tratamiento de aguas residuales es el destino final de los biosólidos. En la actualidad estos han sido depositados en rellenos sanitarios, los que se han tornado insuficientes producto de los crecientes volúmenes producidos, generándose una búsqueda urgente de alternativas de destino y de reutilización de biosólidos. Entre estas, la aplicación de biosólidos al suelo es una práctica aceptada en la mayoría de los países desarrollados, pudiendo esta práctica remediar las deficiencias de ciertos elementos traza que a menudo se presentan en suelos que han sido cultivados por décadas, aportando simultáneamente nitrógeno, fósforo, micronutrientes y materia orgánica al suelo (Bellapart 1996). Sin embrago, el uso benéfico de los biosólidos no se refiere exclusivamente a su uso como fertilizantes tradicionales, sino que también,

como mejoradores de la calidad del suelo. De esta forma, desde la perspectiva de conservación del recurso suelo, el contenido de materia orgánica, propiedades físicas (textura, estructura, estabilidad de agregados, porosidad entre otros) y propiedades químicas del suelo son indicadores de calidad edáfica. La región de la Araucanía posee 2.5 millones de hectáreas erosionadas de las cuales el 35% presenta erosión grave, abarcando el 76% de su superficie agrícola, con ello, la región se sitúa en el segundo lugar nacional en suelos erosionados (Honorato *et al.,* 2001). Desde el ámbito de la ciencia del suelo, el impacto en la calidad del suelo asociado a la aplicación e incorporación de biosólidos en él, no ha sido suficientemente profundizado en el contexto del saber científico nacional. Con la finalidad de aportar información sobre el real efecto de la incorporación de biosólidos en la calidad del sistema suelo, específicamente en suelo orden Inceptisol, región de la Araucanía, se determinó el impacto de la aplicación de biosólidos sobre propiedades físicas, químicas y biológicas del suelo y la evolución temporal de éstas.

Materiales y métodos

El área de estudio se ubica en la comuna de Los Sauces, región de la Araucanía, Chile. El clima predominante en la zona es templado lluvioso con influencia mediterránea, donde las precipitaciones totales anuales superan los 550 mm. En tanto el régimen térmico registra una oscilación de 5°C con una temperatura media anual de 12°C. Los suelos pertenecen al orden Inceptisol, se presentan en posición de terraza aluvial y están formados por sedimentos finos ricos en cuarzo. La textura superficial es franco arcillosa y arcillosa en profundidad.

Los biosólidos aplicados al área de estudio tienen su origen en la planta de tratamiento de aguas servidas de la comuna de Traiguén, región de la Araucanía. Presentan pH básico y alto contenido de materia orgánica. El biosólido se aplicó al suelo una sola vez en una dosis de 30t ha^{-1}, cubriéndose una superficie total de 40 ha. En el sitio de estudio se establecieron dos zonas de muestreo: zona 1, suelo sin aplicación de biosólidos, y zona 2, suelo con aplicación de biosólidos. En la zona 1, se realizaron dos controles, al año 1 (2008) y al año 3 (2010). En la zona 2, se construyeron cuatro parcelas de 20 m^2 cada una, distanciadas 2 m una de otra; las parcelas se diferenciaron según el tiempo transcurrido desde la incorporación del biosólido hasta la fecha de toma de muestras: 17, 170, 385 y 510 días. La técnica de muestreo dentro de cada parcela correspondió a muestreo al azar, con un mínimo de tres réplicas. Se evaluaron propiedades físicas (infiltración y densidad aparente), químicas (mate-

ria orgánica, pH, P, N, S, Al y conductividad eléctrica) y biológicas (respiración edáfica), siguiendo metodología USDA (1999) y lo establecido por la Comisión Nacional de Acreditación de la Sociedad Chilena de la Ciencia del Suelo. Todos los datos obtenidos fueron procesados a través del programa STATGRAPHICS plus 5.1. Para la determinación de las medias se utilizó el estadístico de contraste de rango múltiple con un nivel de confianza de 95%. El método utilizado para discernir entre las medias fue el procedimiento de las menores diferencias significativas de Tukey. Se utilizó además el programa estadístico XLSTAT, específicamente el coeficiente de correlación de Pearson.

Resultados y discusión

Las medias obtenidas de parámetros físicos, químicos y biológicos de suelos se muestran en Cuadro 1. Se observa que los valores de pH de suelo control para ambos periodos de evaluación son similares, sin embargo se encuentran por debajo a los valores descritos por CIREN (2000), cuyos rango varía entre 6,0 y 6,7.

Cuadro 1. Perfiles de medias (intervalo de confianza) de parámetros químicos, físicos y biológicos en suelo sin incorporación y con incorporación de biosólidos

Parámetros	C1	C2	17 días	170 días	385 días	510 días
pH_{H2O}	5.85 ± 0.07	5.80 ±0.01	6.79 ± 0.11	6.67± 0.05	6.40 ± 0.03	5.83 ± 0.02
P disponible (ppm)	15.7 ± 3.21	18.4 ±0.21	35.0 ± 6.08	28.7 ± 11.01	30.5 ± 1.4	48.3 ± 0.40
MO (%)	6.54 ± 2.41	5.50 ± 0.89	10.12 ± 1.51	5.65 ± 1.40	7.92 ± 0.96	7.49 ± 1.21
N disponible (ppm)	19.67 ± 2.30	19.33 ± 1.15	22.33 ± 2.88	18.67 ± 1.52	20.24 ± 0.63	21.72 ± 0.76
S disponible (ppm)	3.97 ± 0.03	4.29± 1.30	42.81 ± 1.20	37.32 ± 2.19	39.72 ± 3.05	10.79 ± 1.07
Al intercambiable ($cmol_c\ kg^{-1}$)	0.004 ± 0.001	0.003 ± 0.001	0.007 ± 0.007	0.012 ± 0.001	0.004 ± 0.002	0.002 ± 0.001
I.N. ($cm\ h^{-1}$)	7.77 ± 0.54	7.38 ± 1.02	6.01 ± 0.95	15.58 ± 1.20	14.71 ± 0.57	10.08 ±0.18
D.A. ($Mg\ m^{-3}$)	0.99 ± 0.05	1.00 ± 0.05	1.18 ± 0.09	1.03 ± 0.07	1.06 ± 0.12	1.01 ± 0.13
C.E. ($dS\ m^{-1}$)	1.03 ± 0.09	1.04 ± 0.01	2.16± 0.01	1.73 ± 0.07	2.34 ±0.0 9	2.98 ±0.0 9
R.E.(KgC(en Co_2) $ha^{-1}d^{-1}$)	15.63 ± 0.44	14.88 ± 0.65	8.62 ± 1.41	62.00 ± 5.97	52.34 ± 4.86	39.51 ± 3.98

(MO: materia orgánica, I.N.: infiltración, D.A.: densidad aparente, C.E.: conductividad eléctrica, R.E.: respiración edáfica).

A los 17 días de incorporación de biosólidos al suelo, existe un aumento significativo en los valores de pH para luego disminuir paulatinamente hasta alcanzar, a los 510 días, valores similares al suelo control. Estos resultados concuerdan con los obtenidos por Tang & Yu (1999) y Ortiz *et al* (1999), quienes observaron que el pH aumenta abruptamente desde la incorporación del residuo y luego disminuye de forma gradual. Además, al incorporar al suelo biosólidos con alta carga de materia orgánica, se produce una reactivación de

las bacterias presentes tanto en los biosólidos como en el suelo, aumentando su metabolismo y disminuyendo los valores de pH del suelo. Los valores de pH presentan una correlación estadísticamente significativa con los valores de S disponible ($p<0.05$, coeficiente de correlación igual a 0.94), con un porcentaje de variabilidad conjunta de 89%. En relación a ello Araujo *et al.,* (2006) y Celis (2007) observaron la existencia de una correlación positiva altamente significativa entre el contenido de lodo estabilizado y el crecimiento bacteriano, señalando que el contenido de materia orgánica que los lodos poseen y la actividad metabólica de las bacterias ocasionan acidificación del medio, debido a la producción de ácidos orgánicos. De esta forma la acción de los microorganismos puede alterar los valores de pH, disminuyéndolo. Este efecto, a su vez, se ve reflejado por una correlación significativa entre los valores de pH y porcentaje de materia orgánica en los suelos estudiados ($p<0.05$, coeficiente de correlación igual a 0.89), con un porcentaje de variabilidad conjunta de 79%.

El aumento en la cantidad de materia orgánica en los suelos posterior a la aplicación de biosólidos tiene un efecto temporal y acumulativo en la disponibilidad de P en los suelos, a distintos periodos de evaluación (Acevedo, 2004). Lo anterior, se ajusta a los resultados obtenidos en que se evidencia un aumento significativo en las concentraciones de P al incorporar biosólidos al suelo. Esto se debe, principalmente, a la descomposición de la materia orgánica presente en los biosólidos, generando mayor disponibilidad de nutrientes. Los resultados de respiración edáfica muestran una disminución significativa a los 17 días de incorporación de biosólidos al suelo. Sin embargo al transcurrir el tiempo de estudio la respiración aumenta de forma considerable manteniéndose en valores mayores al suelo control a través del tiempo. Los autores Quemada & Menacho (1999) obtuvieron similares resultados, observando que la respiración del suelo aumentó al incorporar biosólidos.La velocidad de infiltración de agua en el suelo aumentó notoriamente al incorporar lodos, siendo esto atribuible a cambios en el horizonte superficial del suelo generado por la mayor agregación de partículas del sistema edáfico por acción de la materia orgánica asociada a los lodos, aumentando con ello la macroporosidad. Similares observaciones fueron realizadas por García-Orenes *et al*. (2005). Al inicio de la aplicación de biosólidos (17 días) disminuye la velocidad de infiltración debido a la pérdida de estructura generada por fracturación mecánica del suelo y una saturación de lodo-materia orgánica disponible.

Conclusiones

Los resultados muestran cambios relevantes en la calidad de suelo trascurridos 1,4 años desde la aplicación, particularmente en relación al aumento sostenido en la concentración de P disponible, respiración edáfica e infiltración. Se evidencia la estrecha relación entre tipo y calidad de biosólido incorporado y el estado actual del suelo receptor, encontrándose en este caso, dada la condición degradada del suelo, una respuesta rápida y sostenida en la calidad de éste.

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PÉRDIDA DE CARBONO DURANTE COMPOSTAJE Y LIXIVIACIÓN DE CARBONO ORGÁNICO DISUELTO DESPUÉS DE LA APLICACIÓN DEL COMPOST EN EL SUELO

Claudivan Costa de Lima [1], Eduardo de Sá Mendonça [2], Asunción Roig[3]

[1]Instituto Federal de Educação, Ciencia e Tecnología de Alagoas, Campus Satuba, Satuba,AL, Brasil (claudivanc@yahoo.es);
[2])Departamento de Solos, Universidade Federal de Viçosa, 36570-000, Viçosa, MG, Brasil (esm@ufv.br);
[3]CEBAS-CSIC, Campus Universitario de Espinardo, Apartado de Correos 164, 30100 Espinardo, Murcia, España (aroig@cebas.cesic.es).

Resumen

Se evaluó el efecto de las pérdidas de carbono (C) durante el proceso de compostaje en la lixiviación de carbono orgánico disuelto (COD) después de la incorporación del compost al suelo. Para eso, se instalaron dos ensayos experimentales consecutivos. El primero ensayo consistió en la formulación de ocho compost hechos de bagazo de caña de azúcar, torta de ricino y estiércol de pollo con distintos enriquecimientos minerales. Los compost fueron muestreados a los 0 y 120 días después del inicio del proceso de compostaje y determinadas las pérdidas de C por medio del balance de masa. El segundo ensayo consistió de la aplicación de una dosis de 26 t ha^{-1} de cada compost obtenido que fue añadido al suelo y puesto en columnas. Después de la incubación de los tratamientos, fueron aplicadas 5 láminas de agua correspondiente a una vez el volumen de poros a los 0, 7, 14, 21 y 35 días. El lixiviado se recogió y se determinó el carbono orgánico disuelto (COD). El compost enriquecido con polvos de rocas de silicato mostró mayores pérdidas de C y más baja lixiviación del COD. Los compost hechos con torta de ricino presentaron reducido la pérdida de C durante el proceso de compostaje y pérdidas más grandes de COD cuando se aplicó el dicho compost al suelo.

Palabras clave: balance de carbón, sustancias húmicas, calidad de compost.

Introducción

El compostaje es un proceso de transformación bioxidativo de estabilización de la materia orgánica que se produce en dos etapas. En la primera, los compuestos más simples de C son fácilmente metabolizados y mineralizados por microorganismos. Ocurre en esta ocasión, las pérdidas más intensas de C. En la segunda parte, la

materia orgánica presente en la primera etapa se condensa y se polimeriza, dando lugar a las sustancias húmicas (SH). La aplicación de abono orgánico en el suelo en dosis compatibles con la necesidad de la planta y la capacidad del suelo de retener el material, puede contribuir al aumento de productividad de los cultivos, evitando los riesgos de contaminación del suelo y de los recursos hídricos a través de la pérdida del carbono orgánico disuelto (COD). Este carbono se puede drenar y tener acomplejado metales pesados que se infiltran a través del suelo, contaminando otros ecosistemas.

El objetivo de este estudio fue evaluar el efecto de la pérdida de carbono durante el proceso de compostaje en la lixiviación del carbono orgánico disuelto en virtud de la aplicación de los compost en el suelo.

Material y métodos

Preparación de los compost

Para la formulación de compost se utilizaron bagazo de caña de azúcar (BC), ceniza del bagazo de caña (CBC), estiércol de pollo (EP), torta de filtro (ToF) y torta de ricino (TR). Estos materiales se mezclan para elaborar compost ocho distintos: a) CS: BC + CBC + EP; b) UR: BC + CBC + EP + fertilizante mineral NPK, donde N: urea; c) SA: BC + CBC + EP + fertilizante mineral NPK, donde N: sulfato de amonio; d) SM: BC + CBC + EP + polvo de rocas de serpentinita y micaxisto; e) FN: BC + CBC + EP + fosfato natural; f) TF: BC + ToF; g) M+G: BC + TR + polvo de gneis; h) M-G: BC + TR. Los tratamientos se dispusieron en parcelas subdivididas, con los 8 compost en la parcela principal y 2 parcelas subdivididas en el tiempo, formado por el muestreo del material a los 0 y 120 días de compostaje, codificado como T0 y T1, respectivamente. Estos tratamientos fueron dispuestos en un diseño de bloques al azar con tres repeticiones. El muestreo de estas mezclas se llevó a cabo siguiendo el principio de acuartelamiento, y luego procedió a análisis químicos para ellos.

Pérdidas de carbón durante el proceso de compostaje

Se determinó el carbono orgánico total (Yeomans y Bremner, 1988) y el contenido de materia orgánica total (MOT) por ignición en horno a 550 ° C durante 1 hora. De la masa inicial y final del compost se estimó los cuantitativos de MOT en kg en la fase inicial (MOTT0) y final (MOTT1). Con base en estas estimaciones se obtuvieron los niveles absolutos de carbono (C) en las dos fases, de acuerdo con las ecuaciones siguientes:

$$Masa\,C_{T0} = \left(\frac{\%C_{T0} * MOT_{T0}(kg)}{100} \right)$$

$$Masa\,C_{T1} = \left(\frac{\%C_{T1} * MOT_{T1}(kg)}{100} \right)$$

El porcentaje de pérdida de carbono se obtiene calculando la diferencia entre la masa del elemento (C) de la fase inicial (T0) y al final del proceso de compostaje (T1), de acuerdo con la ecuación siguiente:

$$\%Pérdidas = \left(\frac{Masa\,C_{T0} - Masa\,C_{T1}}{Masa\,C_{T0}} \right) * 100$$

Lixiviación de carbono

Las muestras Calcisol Petric, en el municipio de Jumilla, provincia de Murcia, España, se recogieron a una profundidad de 0 a 20 cm del suelo, pasaron por tamiz de 2,0 mm, a continuación, fueron envasadas en tubos de PVC con un diámetro de 5 cm. Los tratamientos consistieron en la aplicación de una dosis equivalente a 26 t ha^{-1} de los ocho compuestos obtenidos en la primera etapa de esta investigación. Después de la incubación de estos materiales por un período de 7 días, con una humedad del 70% de la capacidad de campo, que se sometieron a cinco láminas del agua correspondiente a una vez que el volumen de poros, intercaladas cada 7 días. El lixiviado fue recogido y almacenado para su posterior análisis. Esto ensayo, por lo tanto, fue arreglado en parcelas subdivididas en el tiempo y distribuidos en diseño experimental de bloques al azar con tres repeticiones. Las parcelas fueron compuesta por 9 tratamientos (8 compost + testigo) y las sub parcelas, por 5 períodos de aplicación de las láminas de agua: 0, 7, 14, 21 y 35 días después de la incubación. Los líquidos recogidos fueron sometidos a la determinación de carbono utilizando el equipo analizador de carbono orgánico total - TOC-5050A.

Resultados y discusión

La magnitud de la pérdida de C de los compost osciló según el tratamiento (Figura 1). La pérdida más grande de C se registró en tratamiento SM en el orden de un 91% y la menor fue del tratamiento M-G con un 71%, indicando que tanto la naturaleza de los materiales utilizados en el compostaje como el enriquecimiento de minerales afecta a la mineralización de C. El enriquecimiento con polvo de rocas de silicato contenido en el compost SM favoreció a la oxidación abiótica de la materia orgánica. Esta oxidación es resultante de la acción de agentes oxidantes como el Ni, Fe y Mn presente en estas rocas que actúan como catalizadores para la oxidación de la MO de los compost (Griffith y Schnitzer, 1989).

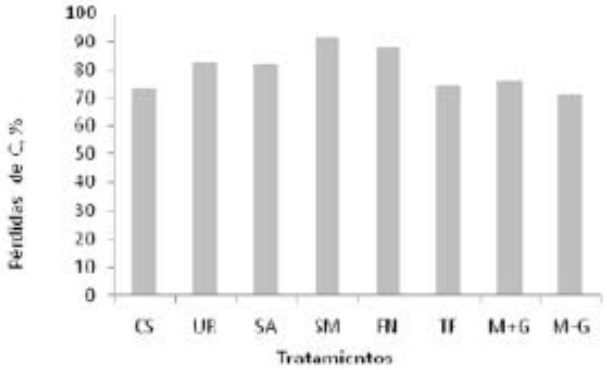

Figura 1. Pérdidas de carbono de compost hechos con diferentes materiales y enriquecimiento mineral durante el proceso de compostaje.

Las pérdidas de carbono orgánico disuelto (COD) disminuyeron con el tiempo, mientras que las pérdidas fueron más pronunciadas durante la aplicación de la primera lámina de agua (Figura 2). En todos los tratamientos, las pérdidas de COD fueron superiores a del testigo. En tratamientos a base de ricino (M+G y M-G), la lixiviación de COD fue mayor que de los tratamientos con estiércol de pollo (CS, UR, SA, SM, FN) y torta de filtro (TF). Los compost madurado contienen sustancias húmicas como los AF (Hsu & Lo, 1999), que componen el COD. Sin embargo, el COD es constituido también por otras fracciones orgánicas tales como polisacáridos, polifenoles y diversas sustancias alifáticas de bajo peso molecular fácilmente degradables (Kuiters y Denneman, 1987). Por esta razón, el COD se correlacionó mejor con el contenido de carbono orgánico total de los compost (r = 0,72 **) que con el AF (r = 0,32 ns).

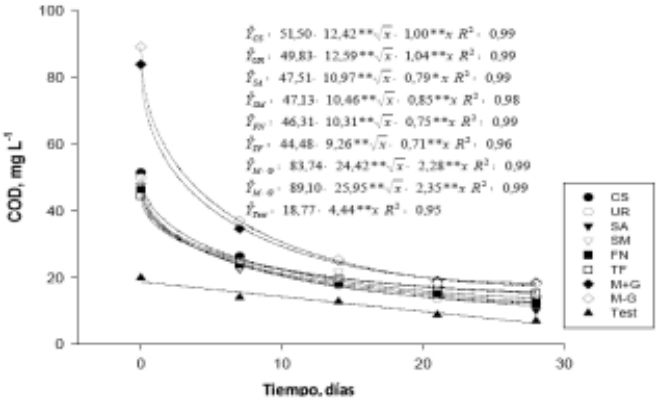

Figura 2. Carbono orgánico disuelto (COD) de los lixiviados recorridos después de aplicación de láminas de agua, en el suelo fertilizado con 26 t ha^{-1} de compost hechos con diferentes materiales y enriquecimiento de minerales, en el tiempo.

Se encontró una correlación negativa entre las pérdidas de carbono durante el proceso de compostaje y la lixiviación del COD a través del suelo en virtud de la incorporación de compost (r = -0,90 **). Esto indica que el carbono más lábil que no se oxida durante el compostaje, queda en el compost madurado y se pierde más fácilmente por lixiviación cuando se añade el compost al suelo. Esto indica que la gestión del proceso de compostaje debe llevarse a cabo para permitir una oxidación más intensa del C durante el proceso de compostaje. Eso puede evitar la pérdida de C por lixiviación decurrente de la incorporación del compost al suelo, ya que dichas pérdidas pueden causar la contaminación de otros ecosistemas a través de la agua. Esta oxidación de materia orgánica puede ser estimulada por lo enriquecimiento mineral con polvos de rocas de silicato, lo que contribuye, adicionalmente, a la formulación de compost con mayor concentración de nutrientes.

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GRAZING LAND MANAGEMENT IN SEMI-ARID AUSTRALIA

Hossein Ghadiri[1*], Gholamreza Sanjari[1], Bofu Yu[2], Cyril Ciesiolka

[1]Griffith School of Environment, Griffith University, Nathan 4111, Australia
[2]School of Engineering, Griffith University, Nathan 4111, Australia
**Corresponding author: h.ghadiri@griffith.edu.au*

Summary

In this study the traditional system of Continuous grazing was compared with the new technique of Cell grazing on a large grazing paddock in south-east Queensland. Results show large quantities of soil and soluble nutrients being lost to the receiving water bodies under the traditional system of Continuous grazing. The concentrations of sediment, organic matter and plant nutrients in the runoff leaving paddock were significantly reduced when the rotational system of Cell grazing was adopted. The new Cell grazing system also reduced erosion, sediment transport and surface runoff as compared with the Continuous grazing. The presence of a higher quantities of litter and above ground organic materials on lands under Cell grazing reduced hoof pressure and soil compaction, which in turn resulted in higher infiltration of rain water, lower surface runoff and reduced soil erosion and nutrient loss into surface water resources. It appears as though the long rest period for the land, provided under the Cell grazing system, is largely responsible for all above beneficial impacts on grazing lands, animal feed production and down-steam water quality.

Introduction

Sustainable utilization of grazing lands requires management strategies that do not compromise the capacity of soil to function over a long-term period (Liebig *et al.* 2006). This can be achieved by adopting correct grazing practice for lands of given set of soil, vegetation, landscape and atmospheric characteristics.

Continuous grazing has been the only form of grazing system adopted in Australia since hard-hoofed grazing animals were introduced to this continent. Recently a new system of high-intensity, short period grazing followed by a long period of rest, known as «Cell grazing» or «Time Control grazing» has been introduced to this country (McCosker 2000). This new system has become popular amongst Australian graziers but not much local research has been carried out on its suitability for Australia and its impact on the fragile Australian ecosystem.

Studies on feed production, the accumulation of plant residue, changes in soil carbon and nitrogen, changes in soil physical characteristics such as compaction and bulk density in response to grazing management have been mostly focused on different types of continuous grazing under a variety of stocking rates (Manley *et al.* 1995; Mathews *et al.* 1996; Ruess and Mcnaughton 1987; Dormaar *et al.* 1990; Dormaar and Willms 1990a; Rodd *et al.*, 1999; da Silva *et al.*, 2003) but not between different grazing system.

This paper reports on some of the results obtained from a large scale field experiment carried out over a 6 years period on a grazing paddock in Queensland, Australia during which the effects of the two grazing systems of Continuous» and «Cell» grazing on all aspects of pasture production, residue build up and soil physical and chemical properties were studied and the impacts of the two grazing systems compared.

Materials and methods

The study area is located on the large sheep grazing property of «Currajong», 300 km west of Brisbane in a semi-arid region of southeast Queensland, Australia (28º 33' S, 151º 33' E , altitude 675 m), with an average annual rainfall of 645 mm (Fig 1). Vegetation in the area is native perennial grasses dominated mostly by Queensland blue grass (*Dichanthium sericem*), different wire grasses including Aristida vegans and Barbed wire grass (*Cymbopogon refractus*) plus some remnant native gum trees. Soils in the study area shallow with mostly clay to clay loam in texture (Table 1).

Fig 1: Location map of the study area

This field study was conducted on a commercial pasture property which was in the process of converting from long term Continuous grazing system to Cell grazing. It thus provided us with an opportunity to study the impacts of the new grazing system on soil, water, vegetation, nutrient and sediment changes in comparison with continuous grazing.

The application of Cell grazing system required the large sections of the property to be sub-divided into a number of smaller paddocks (cells) using electric fences. Two such cells ranging in area from 84 to 250 hectares were used for this experiment; one for Cell grazing and the other for continuous grazing. The paddocks assigned to the grazing treatments were each divided into two sections based on the physiographic features of the land (slope and soil depth) (Table 1). Two sub-treatments of C1 and C2 were converted to Cell grazing in 2001 and C3 and C4 remained under Continuous grazing. Each sub-catchment was equipped with an H-Flume with automatic sampler, and all other necessary sampling, flow measuring and data recording instruments.

Table 1. A summary of soil characteristics in the study area

Grazing	Soil depth	Slope	Size fraction (%)			pH	EC
treatments	cm	%	sand	silt	clay		mS
Cell grazing							
C1	40	10.2	34.6	28.7	36.7	5.9	0.07
C2	28	15.3	28.1	34.0	38.0	5.4	0.03
Continuous grazing							
C3	27	14.8	45.6	25.3	29.1	5.1	0.06
C4	42	10.0	31.6	31.0	37.4	5.9	0.08

Stock numbers were kept close to the optimum within each cell. The stocking rates for the two management treatments were 12.6 and 1.6 dse/ha (dry sheep equivalent) for «Cell» and «Continuous» grazing respectively. Standard methods of soil, sediment, nutrients plants and surface residue analysis were used for samples collected during the 6-year duration of this research project.

Results and discussions

The results show an overall increase in total organic carbon and nitrogen under the Cell grazing treatment from 2001 to 2006, while no changes were observed in these variables under the Continuous grazing treatment over the same period (Fig 2). However it appears that the 6 years period of this study hasn't been long enough for these changes to be statistically significant. The main reasons for such an increase in soil carbon and nitrogen under Cell grazing system appears

to be the higher rate of grass growth and long rest periods. The same two factors also contributed to the higher accumulation of ground litter under Cell grazing. These results appear to be consistent with those of Southorn (2002). He attributed the accumulated soil carbon to the larger proportion of plant material being incorporated into the soil under Cell grazing over continuous grazing. Gillen *et al.* (1991) suggested that the long period of rest is a key driver in the recovery of grazed species and this has played a major role to substantially increasing the above ground organic material followed by its subsequent incorporation into the soil resulting in increased soil organic matter.

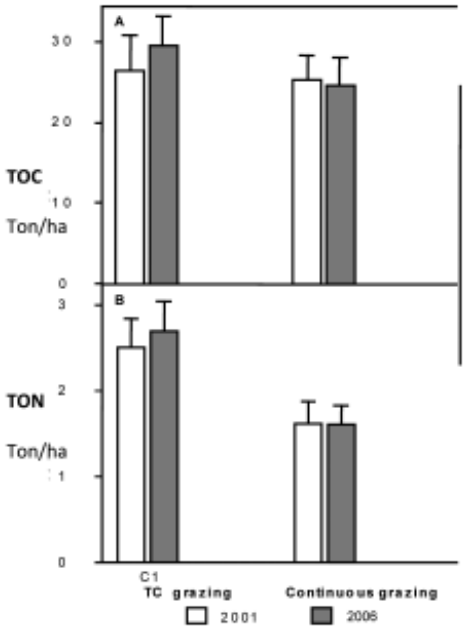

Figure 2: Changes in TOC and TON in Cell and Continuous grazing systems over the study period

Less animals treading under Cell grazing have probably had a positive indirect effect on soil carbon and nitrogen by providing a better soil physical and biological condition for a faster grass recovery following each grazing episode. Taking the average hoof print size of the grazing animal into consideration, it was found that around 22% of the pasture area is trampled on under the continuous grazing system while this fraction is only 7% for Cell grazing. Results on the changes of herbage production under the two grazing management systems over time show that although herbage mass accumulation is strongly influenced by the variation in rainfall, Cell grazing shows a higher overall trend

of herbage mass production than continuous grazing. It is clear from these results that there is a noticeable improvement in the physical and chemical properties of soil under Cell grazing, which translates directly into higher herbage production.

The results on the effect of grazing systems on soil erosion, sediment loss, sediment concentration and runoff rate indicate that all these factors were reduced significantly under the Cell grazing system when compared with continuous grazing, irrespective of the size of rain events. These effects were more pronounced in the catchments with soils of greater depths and on gentler slopes. Comparing the results of the first period of the study (2001 – 2003 when transition was taking place) with the second (2004 – 2006 when the full impact of Cell grazing was expected) show that under Cell grazing both runoff and sediment loss decreased significantly from the first period to the second despite a 5% increase in the total rain over the second period (Fig 3). In the catchment under continuous grazing, however, there was some increase in runoff and soil loss in the second period compared with the first, which suggest that this grazing technique is detrimental to pasture productivity and the health of the soil in the region. The mass curves shown in Fig 4 indicate that the observed improvement in soil physical condition and plant cover, which result in reduced rates soil erosion, sediment loss and runoff will continue with time beyond the life of this project as the Cell grazing takes hold.

Conclusion

Cell grazing which involves short periods of intensive grazing followed by long rest periods, over time, increases the above ground biomass and protects the soil from compaction, hoof damage and erosion over continuous grazing in the region. This practice also reduces the

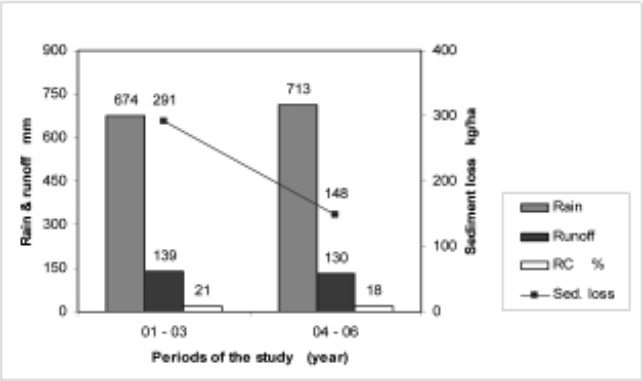

Figure 3. Changes of rainfall, runoff, and sediment loss in the two periods of the study for Cell grazing.

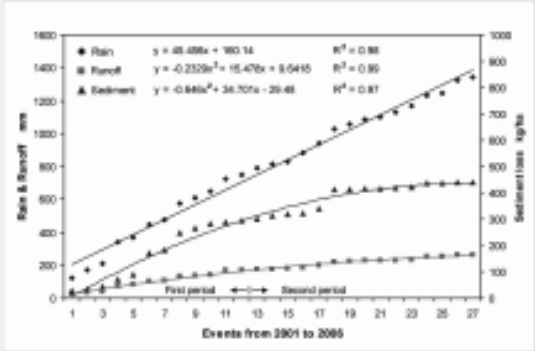

Figure 4. Mass curves of rainfall, runoff and sediment loss for all the rainfall events recorded from 2001 to 2006 in the Cell grazing paddocks.

potential for contamination of downstream water quality through up taking by increased grass mass of soluble nutrients which would have been otherwise washed away by runoff. Compared with the continuous grazing, Cell grazing also increased the level of organic carbon and nitrogen in the soil thus contributing to better grass growth and improved soil physical characteristics.

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ANTHROPOGENIC RADIOISOTOPES TO ESTIMATE RATES OF SOIL REDISTRIBUTION BY WIND

R. Scott Van Pelt[1], Michael E. Ketterer[2], Jerry C. Ritchie[3], Ted M. Zobeck[4]

[1]USDA-ARS Wind Erosion and Water Conservation Research Unit, 302 W. I-20, Big Spring, TX USA, Ph:1-432/263-0293,Fx:1-432/263-3154 :scott.vanpelt@ars.usda.gov
[2]Dept. of Chemistry and Biochemistry, Northern Arizona University, Flagstaff, AZ USA
[3]USDA-ARS Hydrology and Remote Sensing Lab., Beltsville, MD USA (deceased)
[4]USDA-ARS Wind Erosion and Water Conservation Research Unit, Lubbock, TX USA

Abstract

Erosion of soil by wind and water is a degrading process that affects millions of hectares worldwide. Atmospheric testing of nuclear weapons and the resulting fallout of anthropogenic radioisotopes, particularly Cesium 137 (^{137}Cs), has made possible the estimation of mean soil redistribution rates. The peak fallout levels occurred in the early 1960s. ^{137}Cs has a relatively short half-life of 30.2 years, limiting its use for future studies. Radioisotopes of Plutonium were also created during the period of atmospheric testing and were deposited onto the earth's surface at 1/50th the rate of Cesium 137. The half-lives of Plutonium 239 (^{239}Pu)and Plutonium 240 (^{240}Pu)are 24,100 years and 6,500 years, respectively, making them ideal tracers for future erosion estimates. We sampled a system of locations with documented wind erosion and deposition histories by depth and analyzed the samples for ^{137}Cs and for $^{239+240}$Pu. Models developed for ^{137}Cs predicted redistribution rates very well when a particle size correction factor of 1.18 was used for eroding surfaces. $^{239+240}$Pu activities and distribution patterns correlated very well with those of ^{137}Cs, strongly indicating the usefulness of these radioisotopes for future studies of soil redistribution in semi-arid environments.

Introduction

Wind erosion is a soil degrading process that affects over one-half billion hectares of land worldwide and is a major causative factor in desertification (Lal, 1994). Recent advances in modeling erosion processes have resulted in the development of computer models to predict erosion based on local weather, soil texture, and crop and soil management practices (Fryrear *et al*., 1998; Hagen, 2004). While these models have been employed to estimate the long-term soil loss in agricultural fields, their accuracy varies with location and year (Van Pelt and Zobeck, 2004; Hagen, 2004). In spite of these advances, few quantitative estimates of past soil erosion rates exist.

Above-ground nuclear weapons testing during the period from 1945 to 1964 resulted in the creation and stratospheric release of several new radioisotopes including Cesium 137 and Plutonium 239 and Plutonium 240 ($^{239+240}$Pu). The first measurable ^{137}Cs was reported in 1954 and subsequent pulses in 1958 and, most notably, 1963 are responsible for almost all the ^{137}Cs received in stratospheric fallout to date (Ritchie and McHenry, 1990). The passage of the Nuclear Test Ban Treaty in 1963 ended atmospheric testing of nuclear weapons, resulting in a very rapid use of stockpiled weapons and a very sharp peak of fallout in 1964. By the late 1970s, stratospheric fallout of ^{137}Cs had essentially ended (Walling and He, 1999), providing a very convenient time-specific addition to the soil. The temporal pattern of $^{239+240}$Pu fallout was essentially the same as for ^{137}Cs, but the total amount was originally only 2 % of that for ^{137}Cs resulting in a present day amount that is 4 % that of ^{137}Cs (Huh and Su, 2004).

^{137}Cs and $^{239+240}$Pu are strongly adsorbed on the soil solid phase matrix of organic material and mineral particles and do not move readily in the soil solution. Thus changes in the activities of these radioisotopes with respect to total quantities or depth in the profile is assumed to be an indicator of soil redistribution (Ritchie and McHenry, 1990; Walling and Quine, 1991; Chappell *et al*., 1998). The local changes in radioisotope activity was originally assumed to be directly proportional to soil redistribution (de Jong *et al*., 1982; Walling and Quine, 1990), but subsequent model development reflected the preferential adsorption of the radioisotopes on the finer soil particles and the pattern of deposition from 1954 to the late 1970s (Walling and He, 1999, 2001). The radioisotope-based models have been used primarily to assess soil redistribution by water and fewer studies have addressed redistribution by wind (Chappell, 1998; Van Pelt *et al*., 2007). Van Pelt *et al*. (2007) demonstrated that radioisotope-based models developed for estimating rates of soil redistribution by water could also be used to estimate rates of wind-driven soil redistribution with an acceptable rate of accuracy.

^{137}Cs has a half-life of 30.2 years, and less than half the original inventory due to stratospheric fallout is still present in the soil. Further, releases of ^{137}Cs from nuclear accidents such as in Chenobyl in 1986 have resulted in decreased utility of ^{137}Cs as a soil redistribution tracer in many parts of the world. ^{239}Pu has a half-life of 24,100 years and ^{240}Pu has a half-life of 6,500 years, making these two radioisotopes potentially ideal soil redistribution tracers for future studies. ^{240}Pu to ^{239}Pu ratio from stratospheric fallout is approximately 0.18 ± 0.014 and thus significant deviations of this ratio may be assumed to be from local sources of contamination (Ketterer *et al*., 2002). $^{239+240}$Pu

can also be extracted from soil, concentrated using exchange resins, and analyzed with an ICP/MS, thus requiring smaller sample sizes and less time to obtain repeatable measurements of activity than gamma spectrometry. We initiated this study to investigate if $^{239+240}Pu$ could be used as a surrogate for ^{137}Cs as an anthropogenic radioisotopic tracer useful for estimating rates of soil redistribution in semi-arid agricultural landscapes.

Methods and materials

The study site was located at the USDA-ARS Big Spring Field Station near Big Spring, Texas, USA. The soils are Amarillo fine sandy loam (fine-loamy, mixed, thermic, superactive Aridic Paleustalf). Mean precipitation for the area is less than 500 mm and is received primarily during the growing season from late April to early October. The dry season coincides with the fallow period and high wind speeds during the winter and early spring result in blowing sand and fugitive dust.

Soil samples were obtained from a series of adjacent field with know wind erosion and position histories using split spoon cores and measured using gamma spectrometry. The results of measured ^{137}Cs activities and radioisotope-based model validation using measured erosion histories has been reported (Van Pelt *et al*., 2007). These samples were split using a spinning riffler to a sample size of approximately 0.025 kg. The split sub-samples were dry ashed at 550°C for 24 h. in uncovered ceramic crucibles, cooled, and placed in borosilicate glass jars with Teflon-lined lids.

A 0.0028 Bq spike of NIST 4334/g of ^{242}Pu solution was added to each sample as a Pu recovery efficiency indicator. The spiked mixtures were leached at 80°C with 50 ml of 16 M HNO_3 for 16 h. The volume was adjusted to 100 ml using distilled water and filtered through a 0.45 ¼m nitrocellulose filter, 2 g $NaNO_2$ was added to each filtrate to reduce the species of Pu to $Pu^{(IV)}$, 0.15 g of TEVA resin beads (EIChrom, Darien IL) added and the mixtures shaken occasionally for 3 h.

Pipet tips were prepared with a small ball of glass wool in the bottom and the mixtures were carefully funneled into the tips to collect the resin beads. The resin beads were leached with 25 ml of 2 M HNO_3 to remove U followed by 15 ml of 8 M HCl to remove Th and then rinsed with 10 ml of 2 M HNO_3. Pu was eluted off the resin beads using 2 ml of 0.05 M $NaNO_2$ solution to yield approximately 2 ml of solution for injecting into the ICP/MS torch chamber. Repeated injections provided an estimate of measurement repeatability.

Results and discussion

Van Pelt *et al*. (2007) found that ^{137}Cs measurements for soil profiles of fields with documented erosion and deposition histories agreed very well with the predictions of the models made available by Walling and He (2001). The ^{137}Cs activities, with depth, are presented in Fig. 1. The reference site exhibits the commonly observed pattern of shallow incorporation of ^{137}Cs with an increase just below the surface due to illuviation of surface clays and rapid infiltration during the original deposition period. The tilled fields exhibit the pattern observed when the soil is mixed to a depth of 0.3 m as was the case using moldboard plows during much of the cropping history. Using the best history data on the area cultivated since 1985, the Mass Balance 2 model was trained and a particle size correction factor of 1.18 was fit and used for other model runs on other fields.

For depositional environments, two patterns emerged. In the case of near–field deposition of saltation material, the relatively coarse nature of the particles deposited results in the necessity of a particle size correction factor less than unity. This deposition in this area is also apparent by the depth of ^{137}Cs activity. For the windbreak environment, a particle size correction factor of 2.40 was used to match the and the role of the trees in filtering the much finer material in transport is evidenced by the greatly increased (almost doubled) activity in the surface horizons and yet only 0.07 m of sediment accumulation was observed at the site from 1954 to 2002 based on burial of an irrigation pipe storage structure.

The $^{239+240}Pu$ activities for the soil profiles based on the spilts of the same soil samples used in the ^{137}Cs study indicate almost identical patterns with depth. From the curves presented in Fig. 2, the rapid decrease of radioisotope activity with depth is evident in the undisturbed reference and windbreak sites and the mixing of the surface soils is evident in the tilled since 1985, tilled since 1915, and in the rapidly eroded area. The depth of burial of the originally incorporated radioisotope is also evident in the near-field depositional area as is the doubled activity in the surface horizons under the windbreak trees.

In order to more closely evaluate the match of the patterns between these two groups of anthropogenic radioisotopes, we plotted the activity of ^{137}Cs against the activity for $^{239+240}Pu$ and regressed the activities for $^{239+240}Pu$ as a function of the ^{137}Cs activities. This plot is presented in Fig. 3.

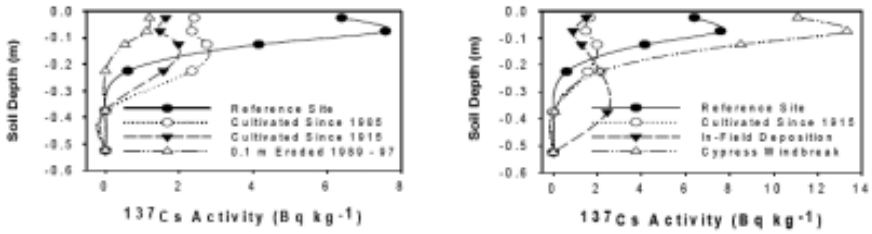

Figure 1. ^{137}Cs activities by depth for the series of soil profiles from fields with documented erosion and deposition histories at the Big Spring Field Station.

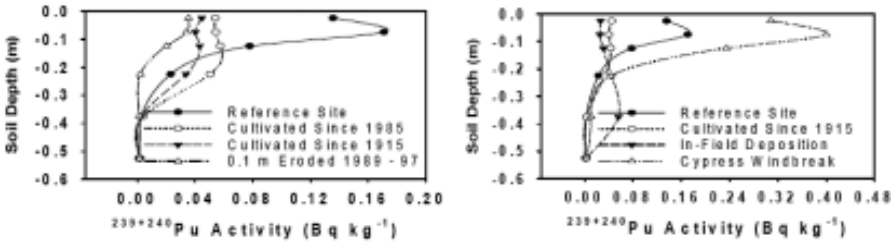

Figure 2. $^{239\text{-}240}$Pu activities by depth for the series of soil profiles from fields with documented erosion and deposition histories at the Big Spring Field Station.

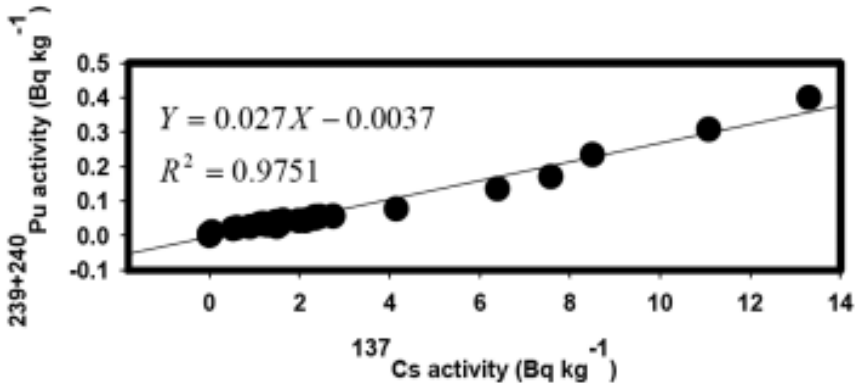

Figure 3. Comparison of $^{239\text{-}240}$ Pu activities of split samples with the activities of ^{137}Cs for whole samples.

Conclusions

$^{239+240}$Pu appears to be a good surrogate anthropogenic isotope to replace ^{137}Cs in future erosion studies. Existing radioisotope-based models will need to be modified to incorporate ^{239,240}Pu as a radioisotope option.

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INOCULATION OF A BACTERIAL STRAIN ISOLATED FROM AN AS-POLLUTED SOIL, ARBUSCULAR MYCORRHIZA AND ORGANIC MATTER ENHANCE PLANT GROWTH AND NUTRITION UNDER As-TOXICITY

Marcelo Pedrosa Gomes[(1)]; Pedro Luiz Silva De Miranda[(1)]; Priscila Aparecida Dos Santos Moura[(2)]; Clésia Cristina Nascentes[(2)]; Maria Rita Scotti [(1)]

[(1)]Departamento de Botânica/Instituto de Ciências Biológicas, Universidade Federal de Minas Gerais, Brazil. E-mail address: smuzzi@icb.ufmg.br
[(2)] Departamento de Química, Universidade Federal de Minas Gerais, Brazil.

Summary

Contamination of soil, water resources and groundwater by arsenic is a serious environmental problem that requires technological solution. Nowadays, the employment of clean technologies like phytorremediation is a world wild concern. The aim of the study was to evaluate the effect of bacterial strain isolated from an As-polluted soil and arbuscular micorrhiza fungi (AMF) inoculation and organic fertilization on growth, nutrition status and symbiotic development of *Anadenanthera peregrina* young plants cultivated on arsenic contaminated soil. The experiment consisted of four factor randomized: contaminated soil (CS), organic matter (OM), rhizobia (Rh) and AMF. The treatments were as followed: T1 - CS; T2 - CS + OM; T3 CS + AMF; T4 – CS + Rh; T5 – CS + OM + AMF; T6 – CS + OM + Rh; T7 – CS + OM + Rh + AMF; T8- CS + Rh + AMF. Fertilized treatments gained 1/3 (v:v) of organic matter. It was used 12 plants per treatment and 120 days after inoculation, it was evaluated the growth and the root and shoot nutritional status of the plants. The benefic and synergic effect of the dual inoculation and organic fertilization can be verified on the T7 plants that showed the highest registers on height, shoot dry matter production, phosphorous levels and nitrogen root levels, therefore, this technique could be indicated on phytorremediation of arsenic contaminated soil programs.

Key words: As-contamination, phytoremediation, *Anadenanthera peregrina.*

Introduction

Arsenic is a common metalloid in the Earth's crust, and it can be locally abundant from anthropogenic activities such as mining, smelting and other industrial and agricultural activities, or naturally abundant (Mandal and Suzuki 2002). Under certain exposure

conditions, some forms of arsenic are toxic and can be carcinogenic (Karim 2000). Environmental contamination by As is a serious threat to humam health in many parts of the word, and it can enter the human food chain through plants and animals (Liu *et al.* 2005; Mandal and Suzuki 2002), moreover, represents a additional risk of groundwater contamination (Dary *et al.* 2010).

The common physic-chemical techniques used for remediation of soil or sediments polluted by metals are expensive and unsuitable in cases of extensive areas (Dary et al. 2010), therefore, biotechnological approaches have received a great deal of attention in the recent years. Phytoremediation, the use of plants for metal reclamation, emerges then as an environmental friendly proposal, and may be the most cost-effective treatment for metal polluted soils, especially in the case of extensive pollution (Dary *et al.* 2010).

Rhizoremediation, a specific type of phytoremediation that involves both plants and their associated rhizosphere microbes (Khan 2009) represent, nowadays, a great strategy for the management of contaminated soils. It can occur naturally, or can be actuated by deliberately introducing specific microbes.

Arbuscular mycorrhizal (AM) are the most widespread mutualistic symbiotic association between micro-organisms and the higher plants. There is growing evidence that arbuscular mycorrhiza fungi (AMF) infection can exert protective effects on host plants under condition of trace element/metal/metalloid contamination (Ahmed *et al*., 2006). AMF play major roles in acquisition, particularly of phosphorus in the form of $H_2PO_4^-$ (Pi) (Smith and Read 2008). Arsenate (As(V)) is an analogue of Pi, so it might be expected that mycorrhizas would enhance uptake of both (Smith *et al.* 2010), that provides the use of this inoculation in remediation programs. Similarly to AMF, the *Rhizobium*-legume symbiosis has been proposed as a tool for rhizoremediation of As, by increasing the plant nitrogen nutrition and interacting with AMF complementing its activity. Indeed, AMF and organic matter have a strong role in plant tolerance as shown in literature. (Vodnika *et al*. 2008).

In this study we have tested on *Anadenthera peregrina* the effect of inoculation with rhizobia isolated from contaminated soil, AMF and organic matter (OM) on As tolerance in terms of plant growth, nutrient uptake and symbiotic development.

Materials and methods

The soil used was characterized by Andrade (2008) as containing high concentrations of arsenic (539,33+17,96 ppm). The fungal inoculums, with 250 spores mainly of *Acaulospora* genus, came from

Laboratory of Plant-Microorganism Interactions (ICB/UFMG). The bacterial strain used was the *BH-ICB*-A8a, previously selected to be an efficient nitrogen fixing and As-tolerant (Andrade 2008).
After the sterilization and germination of the seeds on Petri dishes, *A. peregrina* seedlings were transplanted to pots containing 1 L of substrate prepared according to each treatment, and kept in a greenhouse with daily irrigation.
The experiment consisted of four factor randomized: contaminated soil (CS), organic matter (OM), rhizobia (Rh) and AMF. The treatments were as followed: T1 - CS; T2 - CS + OM; T3 CS + AMF; T4 – CS + Rh; T5 – CS + OM + AMF; T6 – CS + OM + Rh; T7 – CS + OM + Rh + AMF; T8- CS + Rh + AMF. It was used four plants per block for a total of 12 plants per treatment. For treatments without organic matter (OM), the substrate was a mixture of contaminated soil, sand, vermiculite in the proportions 1:1:0,5 (v:v:v), while for the OM-treatments the mixture was soil, sand, vermiculite and OM, in proportions 1:1:0,5:0,5 (v:v:v:v).
At harvest the root system was separated from the shoot and dry weights were measured after drying in a forced-draught oven at 60 °C for three days. Shoot and root concentrations of N (Oliveira, 1986) and P (Sarruge e Haag, 1974) were determined after wet digestion of the air-dried plant samples with H_2SO_4 + H_2O_2. The percentage of mycorrhizal root lenght infected was estimated by visual observation of fungal colonization after clearing washed roots in 10% KOH and staining with 0,05% trypan blue in lactophenol (v/v), according to Phillips and Hayman (1970), and the quantification was performed using the grid-line intersect method (Giovannetti and Mosse, 1980). Nodule number was estimated by direct observation using a binocular microscope. Five replicates were made per treatment.
Analyses were performed 120 days after the inoculation and data were submitted to analysis of variance, and means were compared by the Tukey test at the 5% probability level, using statistical application Sisvar 4.3.

Results and discussion

The T7 (CS + OM + Rh + AMF) plants showed the highest root dry weight in contrast with plants of the other treatments and the highest shoot dry weight in contrast with the T1, T3 and T4 plants which confirms the effectiveness of dual microbial inoculation and specially the role of OM input. In relation to the nutrition status, the T7 plants presented a higher content of shoot phosphorous (P), compared with T1, T5, T6 and T8 plants, and the highest root P content. The T7 root nitrogen (N) level was the largest, although it wasn't verified

significantly differences for shoot N among the treatments (Table 1). The efficiency of the deliberately AMF and Rs inoculation can be proved by the increase on the percentage of mycorrhizal root length and nodule number showed by the treatments that received this kind of management (Table 1).

The AMF and OM have an important role in plant growth under arsenic toxic conditions becomes clear, since the OM-treatment T2 and the FMA inoculated treatment showed the same P content of T7. Considering that AMF were inoculated also on the T3, T5 and T8 plants, the results suggest the effective and synergic mycorrhiza population, Rs and OM role on the *A. peregrina* growth under soil As presence. The positive effect of OM input and AMF and plant-growth promoting rhizobacteria inoculation on the growth and biomass production of plants cultivated in the heavy metal presence is greatly reported (Ahmed *et al*., 2006; Liu **et al**., 2005; Redon *et al*., 2009). The triple treatment given to the T7 plants probably enhance the As tolerance that justifies the greater dry weight production of this plants. Therefore, we can conclude that the concomitant dual inoculation and the organic fertilization is clearly related to the growth and good health maintenance on plants growled on As polluted soils.

Table 1. Shoot (DWS) and root (DWR) dry weights, P and N content, percentage of mycorrhizal root length and nodule number of young plants of *Anadenanthera peregrina* submitted to the treatments: T1 - CS; T2 - CS + OM; T3 CS + AMF; T4 – CS + Rh; T5 – CS + OM + AMF; T6 – CS + OM + Rh; T7 – CS + OM + Rh + AMF; T8- CS + Rh + AMF

	Treatments							
	T1	T2	T3	T4	T5	T6	T7	T8
DWS (g)	1,61c	2,09a,b,c	1,84b,c	1,97b,c	2,52a,b,c	2,80a,b	3,06a	2,55a,b,c
DWR (g)	0,60b	0,66b	0,67b	0,76b	0,70b	0,72b	1,69a	0,82b
Shoot P (mg Kg^{-1})	0,18b	0,29a,b	0,34a,b	0,26a,b	0,18b	0,22b	0,39a	0,19b
Root P (mg Kg^{-1})	0,010b	0,009b,c	0,008c	0,007c	0,009c	0,010b,c	0,020a	0,008c
Shoot N (mg Kg^{-1})	27,41a	46,42a	40,93a	29,16a	57,17a	38,67a	27,39a	39,48a
Root N (mg Kg^{-1})	0,87b,c	0,78c	1,05b,c	1,32b,c	1,36b,c	1,66a,b	2,31a	1,33b,c
% AM colonization	21,64b	19,31b	50,78a	16,71b	41,03a	17,91b	44,46a	49,78a
Nodule number	30,33b	36,66b	48,66b	89,00a	50,33b	103,33a	87,00a	85,66a

Means followed by the same letter are not significantly different according to Tukey Test (n=5).

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SOIL AND WATER CONSERVATION MEASURES DESIGNED AND REALIZED IN THE FRAME OF THE LAND CONSOLIDATION PROCESS (AN EXAMPLE STUDY)

Konecná J., Podhrázská J.

Research Institute for Soil and Water Conservation, Dep. for Land Use Planning, Lidická 25/27, 60200 Brno, Czech Republic, tel. 00420541126281, konecna@vumopbrno.cz

Summary

This text proposes to show results and possibilities of enforcement of erosion and flood control measures in an agriculture landscape by means of land consolidation process in the Czech Republic. Soil, water and environment conservation is an important and publicly needful aspect of every complex land consolidation. Successful realization of designed arrangement is presented on the Hubenov cadastre.

Introduction

After the year 1989 state and cooperative farms were disbanded and the soil came back into private hands in the Czech Republic. To excite new private agricultural business and farming it was necessary to clear up the land ownership, consolidate fragmented and narrow parcels, make blocks of fields accessible. For this purpose the process of the land consolidation started. Complex land consolidation in a cadastre is initiated on the land owners´ petition and it is managed by the land offices. Process complies with the land consolidation act N° 139 of 2002. It provides that soil, water and environment conservation is an important and publicly needful aspect of every complex land consolidation. Hence land consolidation creates a space for the designing and realization of the erosion and flood control measures. Land consolidation designs are supported by the state, the EU funds are used for the realization of protective and ecological measures.

Material and methods

Soil and water are two natural media with significant relationships. Their conservation requires complex approach, which respects particularity of both (Uhlírová, 2006). Main goals of water and soil protection are: restriction of soil erosion, sanitation of degraded agricultural soils, support of propitious water content in soil, retardation of surface runoff and increasing of water retention in countryside, improvement of water hygienic quality, restriction of ground silting.

Following protective measures are used, in the frame of complex land use adjustment, to restrict surface runoff and to increase land retention:

- grassing (or forestation) of areas or belts,
- insertion of a road with infiltration belt or interceptive ditch,
- balks with ridges and accompanying greenery,
- retention reservoirs.

Protective measures are multifunctional, with reference to the requirements of nature conservation and improving of landscape aesthetics. Their parameters are dimensioned by the models of erosion soil lost and maximum outflows in a profile.

According to the methodics for the designs of the land consolidation (Dumbrovský *et al.*, 2004, Podhrázská , 2008) water erosion threat is evaluated by means of the Universal Soil Loss Equation, which defines soil loss like a function of relief, soil properties, rainfall force, soil cover and effect of protective measures. Calculated average annual soil loss for agricultural land blocks is compared with the permissible limits, which are:

1 $t.ha^{-1}.year^{-1}$ for shallow soils (to 30 cm),
4 $t.ha^{-1}.year^{-1}$ for middle deep soils (30 - 60 cm),
10 $t.ha^{-1}.year^{-1}$ for deep soils (over 60 cm).

Erosion control measures are chosen and located to decrease annual soil loss below the appropriate limit value.

Several methods are applied for calculation of maximum discharges in outlet profiles of local catchments. Often software based on the CN method (curve numbers) is used. The distinction of the method is that it takes into account natural and anthropic characteristics of the drainage area. Basic input of the method of CN curves is distribution of a precipitation amount at the definite time, providing its space uniform distribution on the catchment's area. Volume of the rainfall is transformed into the outflow volume with the help of numbers of outfall curves; time of outflow concentration is calculated.

Capacity of retention and conducting elements of the flood control system is designed to protect human seats against the centenary rainstorms. In houseless parts of the agricultural landscape there is sufficient, if the designed measure retains rainfall amount with shorter period (2 - 20 years).

Studied cadastre Hubenov

Village Hubenov is situated in the Bohemo – Moravian highlands, in the average altitude 560 m a.s. Area of its cadastre is 256 ha. There predominates agriculture land (74%), forests cover 15% of the area. Relief characterized by long mild slopes, which are rugged by valleys of streams. Soil cover is represented by Dystric Cambisols originated on acid and neutral intruded rocks. Haplic Gleysols range along the streams. All area is significantly threatened by water erosion, annual average soil loss

before the measures realization exceeded 10 t. $ha^{-1}.year^{-1}$ on two large blocks of arable land.
The cadastre is situated on the right bank of a drinking water reservoir. Hence it was necessary to retard sheet runoff of the water from blocks of arable land and reduce transport of eroded soil particles into the reservoir.

Results and discussion

Banks of the drinking water reservoir and the source stream are forested and grassed. There are proclaimed protective zones for a long time and their borders and rules of water quality protection were accepted in the design of land consolidation in the Hubenov cadastre. Reduction of sheet water erosion was solved by building of 3 balks, by grassing of 3 plots and exclusion of growing wide row crops around the balks (Fig. 1). Due to realization of these erosion control measures (Fig. 2) the annual soil loss is reduced below 4 $t.ha^{-1}.year^{-1}$ on the most threatened slopes upward of the reservoir.
System of three retention reservoirs was built up in the thalweg with risk of concentration of runoff to minimize transport of insoluble matters into the drinking water basin (fig. 1 and 3). The dams were dimensioned to retain maximum discharges from centenary rainstorms.
We can state, that measures realized in the Hubenov cadastre in the frame of land consolidation fully meet the requirements of water and soil conservation. Grassed areas, cascade of small water sheets, balks planted with trees well fit the character of the highland landscape and escalate its aesthetic value.

Conclusions

According to the report of the Czech Ministry of Agriculture on the 31st December 2008 it was 914 cadastres with finished project of the complex land consolidation (i.e. 5% of the republic area). Currently projects in 1843 cadastres are running (11% of the republic area). Although the land consolidation process does not advance as quickly as would be requisite, it brings unquestionable positive results. Realized and running projects aim at cadastres with highest interest of farmers to manage their business on available consolidated plots. But it is only one of the points of views. Land use adjustment projects aims simultaneously at the areas of the significant erosion and flood threat, where societal interest is to enforce and build measures of soil and water conservation.

Acknowledgements

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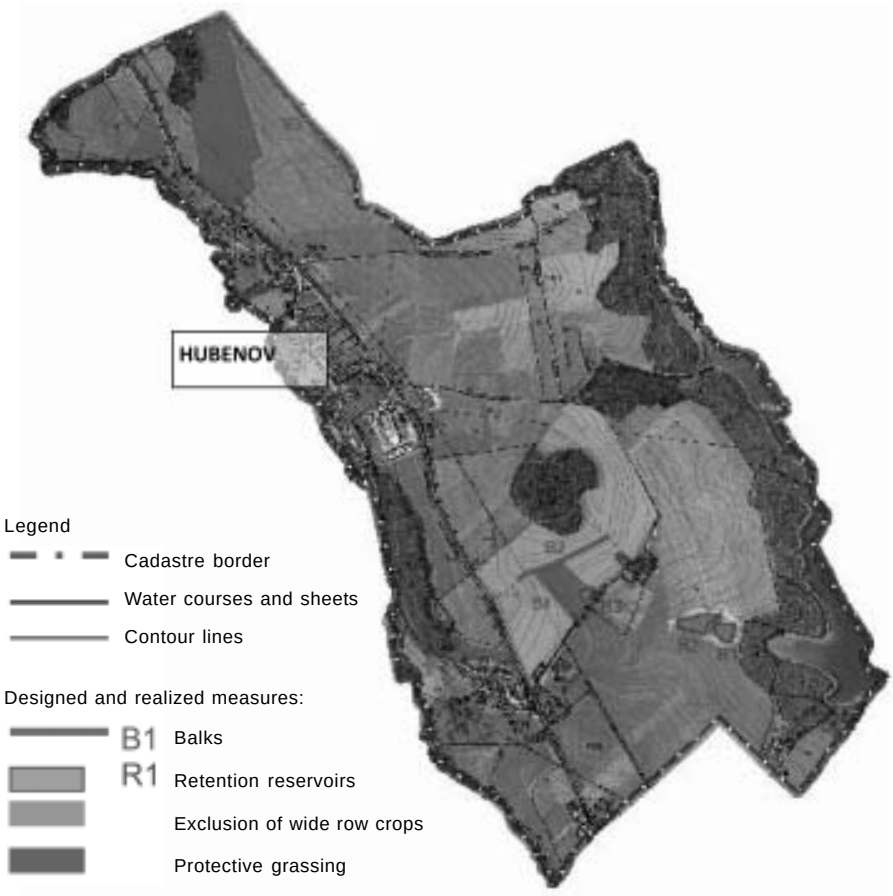

Figure 1. Map of designed and realized measures for soil and water conservation in the Hubenov cadastre

Figure 2. The balk (B2) planted with trees reduces water erosion on the slope and beautifies the landscape

Figure 3. Retention reservoirs (R1, R2) above the forest, which shields the drinking water basin

YIELD OF GREEN MANURE, CORN AND SOYBEAN, AND SOIL CONSERVATION ON INTERCROP SYSTEM OF FAMILY FARMING IN BRAZIL

Gessi Ceccon[1], Alceu Richetti[1], Antonio Luiz Neto Neto[2], Maicon Decian[2], Islaine Caren Fonseca[2], Danieli Pieretti Nunes[3], Aline de Oliveira Matoso[4]

[(1)]Embrapa Agropecuária Oeste, Dourados, Mato Grosso do Sul (MS), Brazil. Researcher, gessi@cpao.embrapa.br, richetti@cpao.embrapa.br;
[(2)]Federal University of Grande Dourados, Dourados, MS, Brazil. Scholarship student, PET-Agronomy SESu/MEC, aln_neto@hotmail.com;
[(3)] University Anhanguera, Dourados, MS, Brazil. Scholarship student, Fundation Agrisus, financial support;
[(4)]Sao Paulo State University «Júlio de Mesquita Filho», Agronomic Science College, Botucatu, Sao Paulo, Brazil. Scholarship student, FAPESP financial support.

Abstract

The objectives of this study were to assess the technical and economical effects of intercropping corn with green manures and *Brachiaria ruziziensis* on the corn grain yield, the green manures seeds yield, the dry matter (DM) accumulation of *B. ruziziensis*, soybean yield in succession, and economic analyze of treatments. The treatments consisted of: 1) Corn; 2) Corn + jack beans (*Canavalia ensiformis* L.); 3) Corn + pigeon pea (*Cajanus cajan (L) Millsp*); 4) Corn + velvet bean (*Mucuna cinereum*); 5) Corn + cowpea (BRS Guariba) + *Stizolobium niveum* after the cowpea harvest; 6) Corn + cowpea (BRS Novaera) + *Mucuna aterrima* after the cowpea harvest; 7) Corn + *Stizolobium niveum*; 8) Corn + *Mucuna pruriens*; and 9) Corn + *Brachiaria ruziziensis*. The experimental was conducted in a randomized block design with four replications and plots consisted of eight rows of six meters in length. The results of this study showed that corn cob and corn grain yields were not affected by the species that were intercropped. The two cowpea cultivars produced 0.47 and 0.56 Mg ha^{-1} grain yield each. *Mucuna pruriens* and *Stizolobium niveum* showed higher grain yield than the other green manures. *B. ruziziensis*, *Mucuna aterrima*, and *Mucuna pruriens* showed the higher amounts of residue and mulching comparing to corn. The soybean showed higher grain yield and lesser weed germination when it was planted after corn intercropped with *Mucuna pruriens*, *Stizolobium niveum*, and *B. ruziziensis*. The systems including cowpea presented higher costs than the others crops. The lower costs were obtained with corn, and intercropping corn with *B. ruziziensis*. Higher incomes were obtained intercropping corn with *Mucuna pruriens*, and also intercropping corn with cowpea and *Stizolobium niveum*. The higher

net return was obtained with corn intercropped with *Mucuna pruriens*. These results lead us to assume that intercrop systems are profitable for the farmer.
Key words: Mucuna, cowpea, seeds.

Introduction

Cropping system diversifications with green manure are considered to increase profitability of crops. Green manure cultivated in rotation with corn increase the organic matter and nitrogen concentration in the soil (Skóra Neto 1993; Amado *et al*. 1999). Additionally, rotation cropping results in better weed control and subsequently higher yields, compared with non-intercropping corn.

In Brazil few researches have been conducted to assess green manure seeds production, specially by intercropping system. Besides technical analysis of intercrop systems, economic analysis is required to measure profitability of each intercrop system. The economic analysis constitutes a routine process that can vary slightly according to different interests that lead to its measure. Melo Filho and Richetti (2003) used system studies and production costs in order to assess competitiveness and economic efficiency of cotton production chain in Mato Grosso do Sul.

Therefore, the objectives of this study were to assess technical and economical of intercropping corn with green manures and *Brachiaria ruziziensis* on the corn and green manure grain yield, the dry matter accumulation of *Brachiaria ruziziensis*, and soybean yield in succession.

Material and methods

The experiment was conducted at Embrapa Agropecuária Oeste, in Dourados, Mato Grosso do Sul State (22º018' S, 53°016' W; elevation 430 m), in a Oxisol. The climate is Cwa according to Köppen classification. Average annual precipitation is between 1,750 and 2,000 mm, with rain concentrated in spring-summer season and rain deficit in autumn-winter season.

The experimental design was a randomized block design with four replications and plots of eight rows of six meter in length. Treatments consisted of: 1) Non-intercropped corn; 2) Corn + jack beans (*Canavalia ensiformis* L.); 3) Corn + pigeon pea (*Cajanus cajan (L) Millsp*); 4) Corn + velvet bean (*Mucuna cinereum*); 5) Corn + cowpea (BRS Guariba) + *Stizolobium niveum* showed after the cowpea harvest; 6) Corn + cowpea (BRS Novaera) + *Mucuna aterrima* showed after the cowpea harvest; 7) Corn + *Stizolobium niveum*; 8) Corn + *Mucuna pruriens*; and 9) Corn + *Brachiaria ruziziensis*.

Corn was planted in October 25th of 2005 with plant populations about of 36,000 plants per hectare in 90-cm inter rows. Fertilizers were applied only on corn crop row using 100 kg ha^{-1} of 08-20-20 N-P-K at sowing and 20 kg ha^{-1} of N 30 days after corn emergence. Green manures were planted on corn crop inter row in different dates. The *S. niveum* and *M. pruriens* were planted 45 days after corn emergence. Jack beans, velvet bean, cowpea, pigeon pea and *B. ruziziensis* were planted on the same day that corn crop.At corn harvest, corn grain yield, corn shoot DM accumulation and green manures shoot DM accumulation were evaluated. At grain milk stage of the corn, 30 leaves opposite the cob were collected to evaluate plant nutrition.

The green manures grains were harvested 3 times in 2006. First was in May (velvet bean and jack beans), second in August (pigeon pea, *M. pruriens* and *S. niveum*) and third in September (*M. aterrima*). The *B. ruziziensis* was cut 15 cm above the ground on December 13th of 2005 (between flowering and ripening of corn), and two more cuts at corn harvest (March 17th and April 26th of 2006). The *B. ruziziensis* residues were collected on September 11th of 2006 sampling 1.0 m^2 of each plot in order to evaluate the DM accumulation.

The soybean was sown after green manures and *B. ruziziensis* harvest on November 05th of 2006, according to Tecnologias… (2004). At 10 after soybean emergence, surface residue was measured at a 45º angle to the rows using the method described by Sloneker and Moldenhauer (1977), while weed density was measured within a randomly selected 1.0-m^2 area (1.0 x 1.0 m) in each plot. Soybean grain yield was did in March of 2007 harvesting 2 rows of 5-m.

The results were analyzed by analysis of variance. The averages were compared using Skott-Knott, and values were statistically different at $P < 0.05$.

Results and discussion

Technical assessment

Corn grain yield was not affected by intercropped crops, presenting yield of 2.17 Mg ha^{-1}

The two cowpea cultivars (BRS Guariba and BRS Novaera) produced 0.47 and 0.56 Mg ha^{-1}, respectively, representing increase of yield grains for familiar sustenance. After cowpea harvest, *S. niveum* and *M. aterrima* were planted and, on the end of their cycles, the grains were harvested. The *M. pruriens* planted 45 days after corn emergence had higher grain yield comparing to others treatments. However, this treatment was not different from the *S. niveum* planted on the same date. The *S. niveum* planted after cowpea harvest had the same yield comparing to it planted 45 after corn emergence. The velvet bean and jack beans had the lowest grain yields of all treatments (Table 1).

Table 1. Performance of corn intercropped with different green manure and *Brachiairia* sp. or not, in Dourados, Mato Grosso do Sul, State, 2006.

Intercrop systems	REC (Mg ha^{-1})	Residue (Mg ha^{-1})	Surface residue (%)	Weeds (Plants m^{-1})	Soybean grains yield (Mg ha^{-1})
1)Corn	-	0.68 d	26 d	145 a	1.55 b
2)Corn + Jack beans	0.19	1.22 c	25 d	124 b	1.60 b
3)Corn + Pigeon pea	0.41	1.18 c	55 c	123 b	1.56 b
4)Corn + Velvet bean	0.15	1.46 b	70 b	135 a	1.58 b
5)Corn + Cowpea + *Stizolobium niveum*	1.02	1.28 c	90 a	37 e	1.26 b
6)Corn + Cowpea + *Mucuna aterrima*	0.81	1.53 b	94 a	41 e	1.43 b
7)Corn + *Stizolobium niveum*	1.09	1.29 c	96 a	75 d	1.87 a
8)Corn + *Mucuna pruriens*	1,53	1.47 b	95 a	100 c	2.08 a
9)Corn + *Brachiaria ruziziensis**	4.27	1.94 a	98 a	40 e	1.84 a
Average	0.74	1.34	72	91	1.64
C.V.(%)	19.7	12.1			11.4

REC: Intercropped crop yield (*) dry matter accumulation in three cuts (12/13/05, 01/30/06, and 03/30/06). Total residue: biomass collected on topsoil before soybean sowing. Values followed by same letter are not significantly different at P < 0.05.

The *B. ruziziensis* produced 4.27 Mg ha^{-1} of total DM. This DM accumulated can be used to feed cattle, specially the biomass harvested after corn harvest, because of shortage forage in that season. This intercrop system presented highest amount of residues on soybean plantation, comparing to other systems (Table 1).

However, all of intercrop systems provided higher residue amount than corn, especially systems intercropping corn with velvet bean, *M. aterrima*, and *M. pruriens*. These intercrop systems also provided higher soil cover and lesser occurrence of weed on soybean crop (Table 1).

Soybean cultivated on summer 2006/2007 showed highest grain yield after corn intercropped with *M. pruriens*, *S. niveum* and *B. ruziziensis* (Table 1). It's possible by increased the mass of aboveground crop residue, that reduced weed infestation and provided protection against soil erosion control.

These results lead us to assume that intercrop system might increase corn grain yield, green manures seeds yield, and DM yield as a feed source, with the advantage of maintaining the soil covered throughout the year.

Economical assessment

The economical assessment was determined by net income analysis. The net income implies the difference between gross income (grain yield of crops studied versus sale price of commercial product) and the total operating costs of each system. Costs with inputs, agricultural operations and product sale were estimated in May of 2007 (the Dollar value was estimated in R$1.77 in relation to Real).

The system corn + cowpea + *S. niveum* and system corn + cowpea + *M. aterrima* including soybean crop, showed higher costs comparing to all systems studied. On the other hand, lowest costs were observed on system non-intercropped corn and corn + *B. ruziziensis* (Table 2).

Higher incomes were obtained on system corn + *M. pruriens,* corn + cowpea + *S. niveum*, and lowest on system non-intercropped corn and corn + Velvet bean (Table 3).

Table 2. Costs of intercrop systems and soybean, per hectare, in 2005/06 and 2006/07 harvests. Dourados, Mato Grosso do Sul, State, Brazil.

Planting systems	Intercrop	Soybean	Total
	US$ ha^{-1}		
Corn	481.15	369.92	851.06
Corn + Jack beans	655.16	369.92	1,025.07
Corn + Pigeon pea	590.19	369.92	960.10
Corn + Velvet bean	650.64	369.92	1,020.55
Corn + Cowpea+*Stizolobium niveum*	824.93	369.92	1,194.85
Corn + Cowpea+*Mucuna aterrima*	824.93	369.92	1,194.85
Corn + *Stizolobium niveum*	691.32	369.92	1,061.23
Corn + *Mucuna pruriens*	691.32	369.92	1,061.23
Corn + *Brachiaria ruziziensis*	520.69	369.92	890.61

	Planting systems	Intercrop	Soybean	Total
		US$ ha^{-1}		
1	Corn	336.32	376.55	712.87
2	Corn + Jack beans	417.68	390.64	808.33
3	Corn + Pigeon pea	736.15	379.23	1,115.38
4	Corn + Velvet bean	357.45	386.03	743.47
5	Corn + Cowpea + *Stizolobium niveum*	1968.18	307.56	2,275.74
6	Corn + Cowpea + *Mucuna aterrima*	1681.23	349.59	2,030.82
7	Corn + *Stizolobium niveum*	1392.48	456.24	1,848.72
8	Corn + *Mucuna pruriens*	1777.51	506.77	2,284.28
9	Corn + *Brachiaria ruziziensis*	351.98	449.19	801.17

Table 3. Income of intercrop systems and soybean, per hectare, in 2005/06 and 2006/07 harvests. Dourados, Mato Grosso do Sul, State, Brazil.

The highest net income was obtained on System corn + *M. pruriens* with US$ 1,223.05 and the lowest on system with corn+velvet bean, showed negative income of US$ -277.08 (Table 4). Systems with non-intercropped corn, corn + Jack beans and corn + *B. ruziziensis* also presented negative net income noting that to plant corn crop as a succession crop without intercrop makes farming not economically profitable. Corn intercropped with cowpea and *M. aterrima*, with *S. niveum*, and with *M. pruriens* showed greater alternatives to technical and economical sustainability for family farmer.

Table 4. Average net income of intercrop systems and soybean, per hectare, in 2005/06 and 206/07 harvests. Dourados, Mato Grosso do Sul, State, Brazil.

	Planting systems	Intercrop	Soybean	Total
		US$ ha^{-1}		
1	Corn	-144.83	6.64	-138.19
2	Corn + Jack beans	-237.47	20.73	-216.75
3	Corn + Pigeon pea	145.97	9.31	155.28
4	Corn + Velvet bean	-293.19	16.11	-277.08
5	Corn + Cowpea+*Stizolobium niveum*	1,143.25	-62.36	1,080.89
6	Corn + Cowpea+*Mucuna aterrima*	856.30	-20.33	835.97
7	Corn + *Stizolobium niveum*	701.16	86.32	787.49
8	Corn + *Mucuna pruriens*	1,086.20	136.85	1,223.05
9	Corn + *Brachiaria ruziziensis*	-168.72	79.28	-89.44

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VEGETATION MONITORING OF LANDSCAPE SCALE WESTERN JUNIPER (*Juniperus occidentalis*) TREATMENTS IN LASSEN COUNTY, CA

Timothy and Crystal Keesey[1]; Thomas W. Esgate[2]

[1]Wildlife and Biological Consultants. Eastside Environmental Consulting. 713-775 Jeter Rd. Janesville, CA 96130 (530) 253-4108 eastsideenvironmental@yahoo.com
[2]Project Director, TSP 03-1001 Certified Conservation Planner for USDA programs Cooperative Sagebrush Steppe Restoration Initiative (CSSRI) 18888 Meadowlark Court Penn Valley, CA 95946 (530) 310-0146 twesgate@sbcglobal.net

Summary

Human activities and shifts in disturbance regimes since Euro-American settlement, including introduction of domestic livestock and exclusion of periodic fire, have resulted in significant losses of sagebrush. Sagebrush is rapidly being converted to western juniper (Juniperus occidentalis) woodland throughout the Intermountain West as a result of these changes in land management. Urgent conservation measures need to be taken to ensure the survival of the sagebrush ecosystem, and ultimately, the survival of birds and other wildlife that depend on the sagebrush biome.

This report discusses the results of a study investigating changes to plant richness, density, and percent cover following the mechanical removal of western juniper from sagebrush habitats.

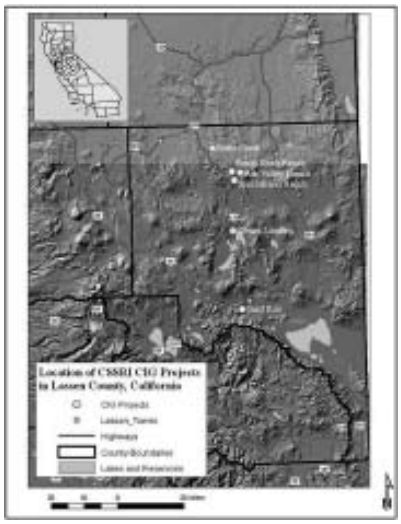
Introduction

In 2005, the Cooperative Sagebrush Steppe Restoration Initiative (CSSRI), a collaborative effort between federal, state, local, and tribal agencies, organizations, and governments in Modoc and Lassen Counties, California, received Natural Resource Conservation Service (NRCS) Conservation Partnership Initiative (CPI) funding. The CPI funding allowed CSSRI to develop plans to treat western juniper expansion into sagebrush scrub habitat, particularly in areas important to greater sage-grouse (*Centrocercus urophasianus*).

In 2006, CSSRI received NRCS Conservation Innovation Grant (CIG) funds to implement the management plans to demonstrate and develop innovative landscape scale mechanical/biomass utilization prescriptions for the treatment of invasive western juniper. CSSRI treatment prescriptions include the use of conventional and modified forestry equipment to remove juniper on grazing lands. The junipers are skidded across the entire landscape rather than on specified skid trails: thus minimizing difficult-to-restore soil compaction and

spreading lesser impact across the whole treatment area. Removed material is chipped and delivered to a biomass power facility to generate renewable energy. Post treatment grazing and management prescriptions are applied to encourage restoration.

In 2007 and 2008 CSSRI implemented western juniper removal projects on over 5,000 acres. Vegetation monitoring transects were established within project areas and data was collected pre-treatment and post-treatment in order to monitor the effects of treatments on plant richness, density, and percent cover.



This study documents the monitoring results from four treatment sites: 1) Butte Creek; 2) Gold Run; 3) Ash Valley; and 4) Stones Landing (see Map 1). Project sites are located in a geologic transition zone: between the Basin and Range Province to the southeast; the Cascade and Klamath Mountains to the west and northwest; and the Sierra Nevada Mountains to the south. This area is characterized by lava plateaus interspersed with mountain valleys and lake basins. The natural vegetation is mainly perennial grasses and sagebrush with scattered juniper and conifers. The elevation of the project areas ranged between 1,375 and 1,675 m a.s.l. Summers are hot and dry; winters and springs are cool with precipitation (avg: 45 cm) falling as snow or rain. The region experienced a drought during the project study period.

The following information supports that the CSSRI project has provided benefits to Producers and the community that include increased forage production, restoration of critical wildlife habitat, an improved water cycle and reductions in hazardous fuel loads, sediment transport and soil erosion.

Methods

CSSRI has developed a monitoring protocol for evaluating the effects of western juniper (*Juniperus occidentalis*) treatment to restore sagebrush scrub habitat. This includes evaluating changes in the richness, density, and percent cover of herbaceous and woody perennial plant species as well as changes in tree species density and canopy cover pre- and post-treatment.

Random 100 meter transects were selected throughout each project site to monitor vegetation changes on the majority of soil types, slopes, aspect and different treatment techniques represented within the treatment area.

Plant species richness, density, and percent cover data were collected from 1 meter-square (1 m^2) quadrats placed along the 100-meter transects. Quadrat data was collected along the 100-meter transects to result in a greater than 80% confidence level and 80% precision using a two-tail t-test. The data recorded from each quadrat includes: a complete species list for determining the richness of each site (species/m2); plant count, in order to determine the density (native species/m2); and an ocular estimation of percent cover, to determine the size of each species rooted within the quadrat, including percent cover estimates for bare ground, rocks, vegetative litter, and animal disturbance. Unknown plant species were collected for identification and invasive noxious weeds identified by the State of California were noted. Densiometer readings were taken at the beginning of each quadrat along the transect to determine relative canopy cover.

Data was collected along each line transect prior to treatment, one-year post treatment, and, for projects implemented in 2007, two-years post treatment.

Discussion

For all sites the total number of native plant species identified in all quadrats along the line transects increased following treatment.

Perennial grass cover decreased the first year post-treatment on all four sites. Perennial grasses were most likely reduced as a result of the disturbance of implementing the treatments, but year two post-treatment data on Butte Creek and Gold Run suggests that perennial grasses become reestablished by year two.

There was a large increase in the richness, density, and percent cover of annual native forbs the 1st year post-treatment on all four sites. Richness and density of perennial forbs increased following treatment and appears to continue increasing in year two based on data from Butte Creek and Gold Run. Year two post-treatment data from Butte Creek and Gold Run shows an increase in perennial forb cover as they become reestablished.

Results

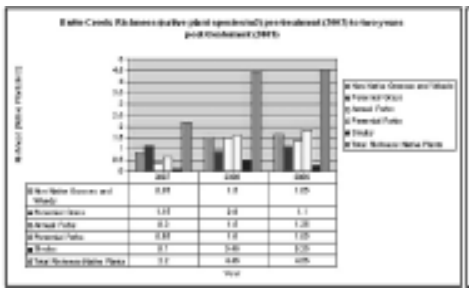
A. Butte Creek

1. Photo Points (Butte Creek):

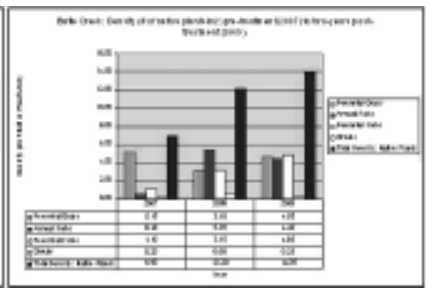
2007 (Pre-Treatment)

2009 (Two Years Post-Treatment)

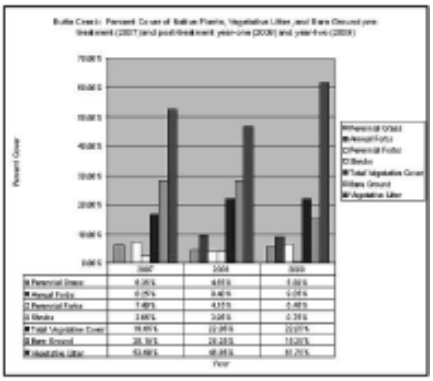
2. Richness (Butte Creek):



3. Density (Butte Creek:



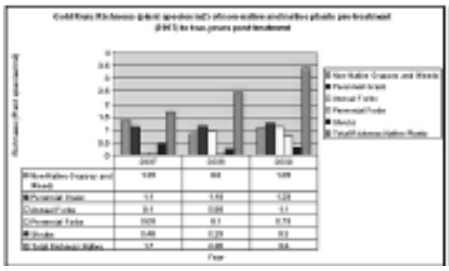
4. Percent Cover (Butte Creek):



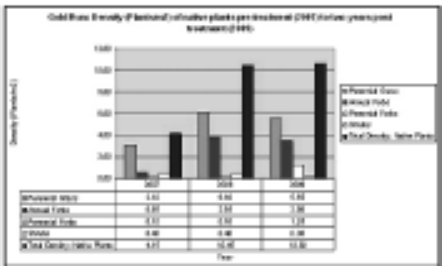
B. Gold Run

1. Photo Points (Gold Run)

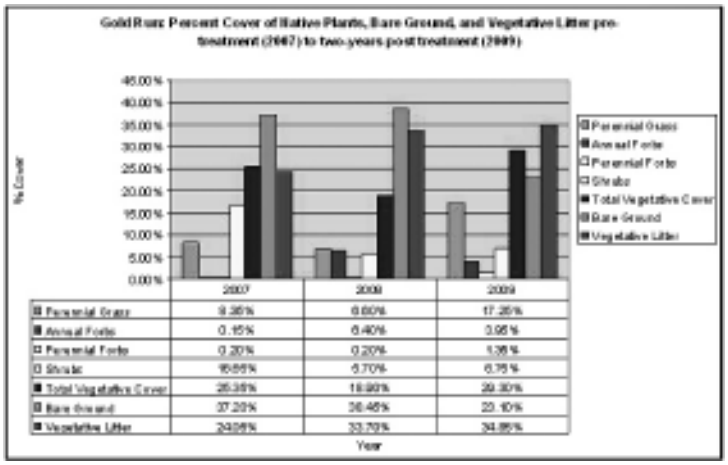
2. Richness (Gold Run)



3. Density (Gold Run)



4. Percent Cover (Gold Run)



The increase in annual and perennial forbs following treatment has implications for the improvement of sage-grouse habitat. Forbs represent 50-60% of juvenile sage-grouse chick diets within the first 16 weeks and 40% of the adult sage-grouse diet between the months of May-October (Dahlgren 2007).

In general, data from the four sites indicated a decline in the richness, density, percent cover, and diversity of shrub species (woody perennials). Shrubs are possibly more impacted by project implementation, though it may be a result of data collection methods. Quadrats along a line transect are generally acceptable for collecting data on grasses and forbs, but not as accurate for woody perennial species. CSSRI has recently added the collection of belt transect data (3m x 100m) as an alternative method for monitoring shrub communities to compare results with the line-transect data. Shrubs appeared stressed pre-treatment, possibly the result of competition with juniper. On both the Butte Creek and Ash Valley sites, resprouting of shrubs that appeared dead before treatment was observed.

For all sites bare ground decreased post-treatment and vegetative litter increased. This should result in reduced soil erosion and improve soil quality and moisture. Studies have found a reduction in soil erosion in sites where there is greater plant diversity and cover, and dispersion (Wood 1988) and in cut versus uncut juniper woodlands (Bates *et al* 2000).

Overall the data suggests that site disturbance from the mechanical treatments allows an opportunity for annual forbs to flourish the first year post treatment. By year two perennial grasses and forbs become reestablished and as succession takes place perennial shrubs should become reestablished as well.

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NATURAL AND ECONOMIC EFFECTS AND ASSESSMENT OF RISK AND UNCERTAINTY OF SUSTAINABLE SOIL MANAGEMENT MODEL IN THE KIJEVSKI POTOK WATERSHED

Miodrag Zlati[1],Mirjana Todosijevi[1], Nada Dragovi[1], StanimirKostadinov[1], Bojana Bogdanovi[1]

[1]Faculty of Forestry, Belgrade University, Kneza Višeslava 1, 11030 Belgrade,Serbia
e-mail: miodrag.zlatic@sfb.rs

Abstract

Morphological unit Kijevski potok is characteristic for occurrence of all the erosion phenomena in the agricultural areas in the Rakovica community, which constitutes the part of the hilly region of the wider Belgrade area. The existing structure of agricultural production indicates that erosion processes in this region have narrowed and also decelerated the yield increase rate which would be possible on natural and economic conditions. In this paper the establishment is discussed of the production model, taking into account the conservation of land resources, the needs of the population and profitability in the case of the hilly morphological unit Kijevski potok. In this sense, agricultural, fruit and forest productions are anticipated from the aspect of sustainable soil management (SSM). The assessment of the long term effects of the planned model has been performed in terms of the internal rate of return (IRR), pay back period (PBP), benefit cost ratio (B/C) and net present value (NPV). soil losses have been estimated according to USLE equation for present way of soil use, as well as for a perspective one - based upon the sustainable soil management (SSM) principles.

Key words: erosion, sustainability, improvement, effects.

Introduction

The morphological unit Kijevski potok is characteristic for incidence of all the erosion phenomena in the agricultural areas of the Rakovica community, which constitutes the part of the hilly region of the wider Belgrade area. On the basis of the detailed terrain reconnaissance it has been established that the main cause of the intensive erosion processes in this region is the inadequate land use (Kostadinov.*et al.*,1988) (Figure 1.) .

Kijevski potok is left tributary of Topciderska river receiving stream with inflowing in the settlement (Zlati, M. *et al*, 2000). Total area of the watershed is 287.90 ha from which agricultural land occupies 72,30%. On the arable land, in which due to small surface areas of

the land pieces and the impossibility to turn the machinery around, tillage is mainly performed along the slopes. The average soil losses from the agricultural surfaces of this morphological unit, according to USLE method amount to 37.21 f_n tha^{-1}. In this paper the effects are shown of the established production model from the aspect of preservation of the land resources.

Figure 1. View on the land use in the Kijevski potok watershe (photo: Zlati M.,2008)

Research methods

Method of evaluation natural effects of planned model

On the basis of terrain reconnaissance, at 10 sample plots of the agricultural soil, soil losses have been estimated according to USLE equation for present way of soil use, as well as for a perspective one - based upon the sustainable soil management (SSM) principles.

Production model

The basic production model was developed from the aspect of sustainable soil managent (SSM), the needs of the population in this area (production lines most frequently applied in practice) and potential economic effects (Zlatic, 1994). Production is primarily planned in a quantitative sense, i.e. the relations are designed between the groups within arable farming (erosion-control crop rotations) and orchard production (classical orchards, orchards with self-terracing, and orchards with classical terraces), as well as pasture and forest areas (Table 1). In the qualitative sense, the lines of production as per crop species are designed. Crop rotation includes cereals like wheat and oats, root crops (corn, soya beans and sunflower) and grasses. Orchard species include apple, pear, peach, apricot, cherry, sour cherry, plum, raspberry, blackberry and walnut.

Quantification of costs and benefits before and after establishing models of production

On the basis of the performed calculations of unit prices of afforestation, establishing orchard terraces and development of fruit plantations, as well as regular production lines, expenses and incomes were quantified before and after performing erosion control works. Labour costs were included in all the calculations of afforestation, orchard establishment, as well as in all production lines of the investigated models. This was calculated according to the technological norms and establishing the necessary labour quantity. Wages were determined through the price of hourly labour.

The quantification consists of the following parts:

- total revenue for the state before land reclamation,
- cost of regular production before land reclamation,
- the value of production including total revenue and residual value of investment features after land reclamation,
- financial investments including erosion control costs and costs of regular production after land reclamation.

The differences of total revenue and costs before and after land reclamation are the starting point for the evaluation of long-term economic effects of these investments.

Table 1. Soil management for sustainability model in hilly regions

SLOPE / Erosion hazard	0°-4°	4°-6°	6°-12°	12°-18°	18°-25°	>25°
NONE ENDANGERED EH<1.00	CR1;O	CR2;O	CR3;O	CR4 / OT	OT	P
WEAK ENDANGERED EH=1.01-2.00	CR5;O	CR6;O	CR7; OST	CR3 / OT	OT / P	P
MEDIUM ENDANGERED EH=2.01-7.00	CR9;O	CR10;O	CR11; OST	CR12 / OT	P	P
STRONG ENDANGERED EH=7.01-28	O	O;P	P	OT	F / P	F
SEVER ENDANGERED EH>28	P	P	P	P	F / P	F

Legend: CR1-12 –erosion control crop rotations; p- pastures; O – classical orchard; OT- orchards with classical terraces; OST – orchards with self terracin; Eh – erosion hazard

Table 2. Changes in land use

Land use type	Species Grown	Before arrangement	After arrangement
		ha	
Arable Lands	Wheat	93.43	27.31
	Oats	2.08	18.80
	Corn	109.45	31.13
	Sunflower	3.12	5.836
	Soybean	-	10.29
	∑	208.06	93.366
Meadow		8.05	24.62
Pastures		13.31	57.78
Orchards	Apple	6.136	7.024
	Pear	2.189	1.88
	Peach	0.496	3.40
	Apricot	0.496	1.70
	Sour cherry	4.697	14.46
	Plum	2.263	15.00
	Sweet cherry	2.469	14.46
	Raspberry	1.576	8.81
	Blackberry	1.576	8.81
	Walnut	0.00	0.00
	∑	21.89	75.54
Afforestation		0.00	0.00
TOTAL		251.31	251.31

Source: original, Kostadinov,*et al*,1988 and Zlati, 1994

Methods of assessment of economic efficiency

The assessment of the long-term effects of the planned model has been performed in terms of the Internal Rate of Return - IRR, Pay Back Period - *PBP*, benefit-cost ratio - B/C and net present value - *NPV* (Gittinger 1982). A period of 15 years has been chosen for the assessment of the economic efficiency according to the average production lifetime of stone-fruit orchard species. The prices have been expressed in EUR for the period May 2007.

Results of research

Changes in land use

According to erosion processes sanation concept and model of production from soil resources preservation aspect, as well as according to soil utilization tendencies, the changes are evident with respect to the state prior to arrangement (**Table 2**).

It can be seen that major changes are related to reduction of arable fields and increase of orchards, as well as to the increase of pastures surface areas. Within the arable areas structure, the surfaces are reduced under wheat and corn, and those with oats and soybeans increased - in particular at higher slope.

Natural effects of establishing sustainable production

The average soil losses from the agricultural surfaces of this morphological unit with the present land use, according to USLE method, amount to 37.21 $t?ha^{-1}$. Taking into consideration the evident previous tillage down the slope, which causes soil loss as mentioned, by the proposed model of production the values of «C» (factor of land use) and «P» (factor of erosion control) in the USLE equation will be reduced several times (Figure 1). Thereby, decreasing the soil losses below the limits of tolerance, it would be on average amount to 1.12 $t?ha^{-1}$ for the whole Kijevski Potok morphological unit.

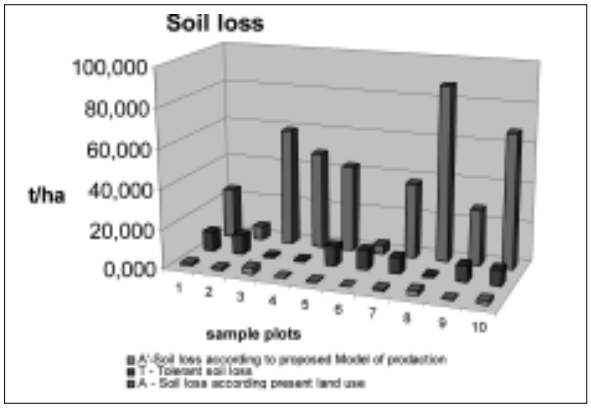

Figure 3. Soil loss on the sample plots of Kijevski Potok watershed. Source: original

Economic Effects of the Planned and Improved Models

Internal Rate of Return (IRR): Cost efficiency of the investments is calculated on the basis of the amount of the discount rate, where the present value of all inputs is equal to the present value of all outputs in the same statement of accounts. It can be seen that the IRR for the Kijevski Potok morphological unit amounts to 25.02% for the planned production (Table 3**)**.

By the comparison of the calculated IRR with the real interest rate, which amounts to 12% for Eastern European countries according to the International Bank for Development, one can conclude that the investment in the soil conservation and in the proposed production variants are cost effective. This statement is based on the fact that, after the credit commitments have been met, a certain percentage for the extended material base results from the increase of the net economic benefit. The accumulation amounts to 13.02% for the planned production.

Pay Back Period (PBP): Contrary to the IRR, which shows the interest rate of the invested capital, PBP shows the period in which the invested capital can be returned. The PBP for the planned production model is

6.5 years (Table 3), one can see satisfactory efficiency. As the credit return period for the majority of Serbian Banks is 10 years, model gives good efficiency.

Benefit-Cost Ratio (B/C): This parameter represents the ratio of the total annual benefit and the total annual costs discounted to the initial instant at a discount rate of 12%. One can see that the Benefit-Cost ratio is 1.45 for the planned production (Table 3). Since the value of this parameter is higher than 1, it is cost-effective to invest into any of the models suggested. It is clear that the accumulation would amount to 0,45 EUR per 1 EUR invested.

Net Present Value (NPV): This parameter represents the sum of total annual benefits discounted to the initial instant, reduced by the total costs discounted to the same instant, at the discount rate of 12% (the real interest rate). According to the calculation of NPV, it can be seen that this parameter amounts to 0,597 million EUR for the planned production (Table 3). Since NPV is well above 0, one can conclude that it is cost effective to invest in the designed erosion control works and the subsequent production models in the region.

Table 3. Parameters of economic efficiency

Model of SSM	PARAMETERS OF ECONOMIC EFFICIENCY			
	IRR (%)	PBP (years)	*B/C*	*NPV* (million EUR)
	25.02	6.50	1.45	0.597

Source: original

Risk and Uncertainty Assessment

The long-term economic effects calculated according to the discount methods are based upon the normal circumstances. However, for a multitude of reasons the perturbations relative to the Benefit-Cost ratio are possible, either if the revenues should increase or reduce, or that the same happens to the costs.

Sensitivity analysis is performed when the calculated parameters of economic efficiency are tested in order to observe what happens to these parameters if costs or benefits are modified. In this case the sensitivity analysis has been performed for the IRR and PBP parameters. The risk of drought is obtained in this analysis.

Sensitivity Analysis of the Internal Rate of Return

The sensitivity of IRR (Table 4) has been measured with respect to the changes of the annual costs and benefits. The examined values of changes of these parameters range from 10% to 30%-50% both positive and negative.

One can see that IRR is most sensitive to the benefit changes. By observation of the negative changes one can see that IRR would be on the rentability limit (at the level of the real discount rate of 12%) if the benefits would be reduced by 31.05**%** with the planned model. In the same sense, cost increases by 51.65%, is acceptable for the quoted model, respectively.

In the case of possible changes of the quoted parameters by 30% in the positive sense, IRR in the case of the increased revenue would amount to 35.06% for the planned production model. In the case of the decreased costs by the same amount of 30%, IRR would amount to 38.5% for the planned production model.

Table 4. Sensitivity analysis of IRR

MODEL		68.95	70	80	90	100	110	120	130	140	151.65
Model of SSM	Costs		38.5	33.2	28.78	**25.02**	21.79	18.97	16.49	14.29	12.00
	Benefits	12.00	12.51	17.09	21.22	**25.02**	28.56	31.9	35.06	38.07	

Source: original

Sensitivity Analysis of PBP of Investments

Sensitivity analysis of PBP (Table 5) has been carried out with respect to the changes of annual benefits and costs of production. By observation of the negative changes, an increase of the production costs by 10% results in PBP of 8.5 years for the planned. This case is shorter than the credit paying off period (10 years), and shorter than the system lifetime (15 years), too.

With the cost increase by 30%, these case is longer than the credit paying off but shorter than the system lifetime.

A benefit decrease by 10% results in PBP of 9 years for the planned, model, which is shorter than credit paying off period. The decrease of benefits by 30%, PBP is 14 years result for the considered model, of SSM.

For the changes in the positive sense, the cost decrease by 30% results in PBP of 5 years for the planned. The benefit increase by 30% results in PBP of 5 years for the model under consideration.

Table 5. Sensitivity analysis of PBP

MODEL		60	70	80	90	100	110	120	130	140	150
Model of SSM	Costs		5	5	6	**6,5**	8.5	10	11	13	15
	Benefits	>15	14	11	9	**6,5**	6	5.5	5		

Source: original

Conclusions

The planned production model sustains the conservation of soil as one of the most important natural resources, since it reduces soil losses below the permissible limits. The average soil losses are estimated to decrease from 37.21 $t\ ha^{-1}$ at present, down to 1.12 $t\ ha^{-1}$ for the conditions following the introduction of the proposed model. The assessment of the investment efficiency, carried out by the discount methods, proves the satisfactory economic efficiency.

The risk and uncertainity assessment also indicate the significant efficiency of investments into the quoted.

According to the calculated economic efficiency parameters and their unmeasurable effects, it can be concluded that in Kijevski Potok morphological unit the investments in sustainable soil management are cost effective and beneficial for environmental conservation.

This model is very acceptable and adaptable for the small farmers, which is the additional reason for people to remain and survive in these areas.

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ASSESSING SOIL MANAGEMENT PRACTICES IN TERMS OF SOIL EROSION CONTROL BY USING FIELD EXPERIMENTS AND MODEL SIMULATIONS

J. Schmidt

The use of soils for agriculture requires to eliminate the natural vegetation cover and to replace it by cultivated plants. Thus the protection of soils with respect to the impact of wind and water is - if not completely suspended - at least occasionally interrupted. As a consequence soil erosion leads to irreversible soil losses, which in turn reduces soil productivity and impairs water quality because of the contamination by sediments and particle-bound pollutants.

Above all accelerated soil erosion is a consequence of the missing permanent ground cover of most arable lands. Under the criterion of soil protection it is crucial to adapt soil management in a way that temporal gaps in soil cover can be avoided. Recent management practices pursue this goal, by abandoning the plow completely. At present following variants exist: The most advanced system is the direct seeding or no till variant, where the seeds are directly sown by cutting a nearly invisible slot through an existing cover of plants or plant residues. The difference to the so-called conventional or conservation tillage practices is the fact that the top soil is not loosened up at all so that the natural soil structure is preserved. In the conservation tillage variant the soil is loosened up superficially at least some centimetres using a rotary tiller, however, without – as by the conventional management – turning around the top horizon completely. In order to cover the soil surface plant residues (mulch) or intermediate cover crops are used in combination with conservation as well with conventional tillage. A disadvantage of conservation and non tillage management practices is the high susceptibility for parasites and plant diseases which results in a high need for pesticides. In order to evaluate the environmental benefits of conservation and non tillage systems it is of crucial importance to estimate their effectiveness in terms of soil erosion control.

In this paper the effectiveness of alternative management strategies is investigated by field tests and comparative model simulations taking different crops and crop stages into account. The field tests are based on plot experiments using a sprinkler type rainfall simulator. The EROSION 3D model (SCHMIDT, J. *et al*. 1997) is applied in order to simulate soil loss and deposition as well as sediment transport into surface water courses on the watershed scale. EROSION 3D is an

event-based model using the momentum flux approach by SCHMIDT (1991). Results of the field tests show, that with increasing plant respectively residue cover soil loss decreases dramatically due to the reduction of raindrop impact and the increased hydraulic roughness at the soil surface. However, regarding the model simulations at the catchment scale it becomes obvious that in spite of the conversion of conventional into conservation tillage erosion rates still exceed tolerable amounts at locations where surface runoff accumulates. Ephemeral water courses, which cannot be reproduced adequately by plot experiments, finally results in the formation of erosional gullies. Only the partial existence of a permanent vegetation cover (e.g. a grassed waterway) is able to avoid these kind of linear erosion features and allows to limit soil loss within the entire catchment to a tolerable amount.

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USO DEL SUELO Y ALTERACIÓN DE ATRIBUTOS FÍSICOS E HÍDRICOS EN ÁREAS DE PRESERVACIÓN PERMANENTE (APP'S) DEL RÍO RIBERA DE IGUAPE, SP - BRASIL.

Reginaldo Barboza da Silva[1] Piero Iori[2]; Pedro Antonio Martins[3] & Francisca A. M. Silva[1]

(1)Profesor Dr., Universidade Estadual Paulista, Rua Nelson Brihi Badur, 430, Registro (SP), CEP 64048-550 rbsilva@registro.unesp.br;
(2) Doctorando del Curso de Posgraduación en Agronomía – Becario Del CNPq - Universidade Federal de Lavras, Lavras, MG, pieroiori@hotmail.com; (3) de graduación del Curso de Agronomía, Universidade Estadual Paulista, CE de Registro pedro@registro.unesp.br

Resumen

Las áreas laterales a los cursos del agua son consideradas áreas de preservación permanente que, según el Código Forestal (Ley N° 4.771/65), deben mantenerse intocables y, en caso que estén degradadas, se debe prever su inmediata recuperación. El uso indebido de los suelos y la falta de tecnologías y manejos apropiados a los ambientes agrícolas y naturales, en especial estas áreas de preservación permanente (APPs), han alterado las propiedades físicas, hídricas y mecánicas del suelo y, por consiguiente, causando la degradación de su estructura. Este trabajo fue realizado con el objetivo de evaluar algunos atributos físicos e hídricos en áreas de preservación permanente con tres manejos del suelo en la cuenca del río Ribera de Iguape, en el estado de São Paulo. Fueron diseñado tres tratamientos representados de la siguiente forma: a) área del cultivo de plátano, b) pastoreo en áreas degradas y c) uso de áreas silvopastoriles, modificándose las propiedades físicas e hídricas del suelo en sus diferentes usos, indicado por la relación de masa y volumen de los constituyentes del suelo, como la infiltración del agua. Las áreas dedicadas al cultivo del plátano fueron las mas afectadas por su impacto negativo, indicando que este cultivo incrementa los niveles de compactación y degradación del suelo, sin embrago las áreas con bajo uso de pasto y bosques, están en proceso más avanzado de mantenimiento de la estructura de los suelos.

Palabras-clave: infiltración del agua, textura, porosidad del suelo

Introducción

El suelo, es un recurso natural básico, es renovable, debe ser conservado o utilizado correctamente (Primavesi, 2002). Mientras, la falta de conocimientos tecnológicos para la utilización adecuada por parte de los agricultores y ganaderas, entre otros, ha provocado su de-

gradación estructural, acelerando el proceso de la erosión, una de las más perjudiciales consecuencias que comprometen directamente los recursos hídricos. Las áreas laterales a los cursos del agua son consideradas áreas de preservación permanente (APP) que, según el Código Forestal (Ley N.° 4.771/65), deben mantenerse sin explotación, en caso que se encuentren en procesos de degradación, se debe planificar las medidas adecuadas para su inmediata recuperación. El uso inadecuado de los suelos, la falta de tecnologías y los manejos inapropiados en estos sistemas agrícolas y naturales, en especial, en estas áreas de preservación permanentes (APPs), han alterado los atributos físicos, hídricos y mecánicos del suelo, por consiguiente, ha causado un proceso de degradación estructural. Estudios que suministren informaciones sobre el real estado de degradación de esas áreas de protección en el Valle del Ribera aún son escasos. Investigaciones que sean dirijidas a evaluar el estado de estos suelos, pueden detectar cambios que un periodo relativamente largo conlleven a su degradación de estas áreas, y sus resultados permitiran organizar estrategias o alternativas tecnológicas para su recuperación en periodos aceptables. Sin embargo, aún es incierto el impacto de los usos y manejos agrícolas utilizados en estas áreas de preservación permanente, especialmente, en la región del Valle del Ribera. Por tanto, este trabajo fue realizado con el objetivo de evaluar algunos atributos físicos e hídricos en áreas de preservación permanente con tres usos del suelo en la subcuencas del río Ribera de Iguape, SP.

Material y métodos

El trabajo fue realizado en la cuenca del Rio Ribera de Iguape, donde está localizado el río Ribera de Iguape y sus afluentes, en el municipio de Registro. El experimento se monto en un área de protección permanente (APP), lateral al río Ribera de Iguape. El suelo del área experimental, según EMBRAPA (2006), es clasificado como Cambissolo Tb Eutrófico A comedido. El clima de la región, de acuerdo Köppen, es el Af, tropical húmedo, con transición para el Cfa, sin estación seca definida, con temperatura media anual de 21°C, aproximadamente y precipitación pluvial media anual de 1.700 mm. Fueron definidas tres área donde se montaron tres tratamientos diseñados de la siguiente forma: 1) área dedicada al cultivo del plátano (banano), 2) pastoreo en áreas degradadas (Pasto) y 3) silvopastoreo en áreas de bosques (árboles). En cada área el muestreo se realizó en malla irregular, seleccionándose 20 puntos. Los análisis fueron realizadas en el Laboratorio de Física y Mecánica de Suelo de la Universidad Estadual Paulista (UNESP), campus

experimental de Registro y en el Laboratorio de Física del Departamento de Ciencia del Suelo de la Universidad Federal de Laboreas (UFLA). La textura fue determinada por el método de la pipeta (Day, 1965), empleándose solución de NaOH como dispersante químico y agitación rápida de 6.000 rpm, por 20 minutos. La arcilla dispersa en agua (ADA) fue determinada también por el método de la pipeta, sin la añadidura de la solución de NaOH, determinándose el índice de floculação (IF) con base en la siguientes expresión (Embrapa, 1997): IF = ((La - ADA) La-1) 100; en que, IF: índice de floculação (%); La: arcilla total (g kg-1); ADA: arcilla dispersa en agua (g kg-1). La porosidad total (PT), así como la macro porosidad y micro porosidad, fue determinada conforme los procedimientos de la Embrapa (1997). Los datos de conductividad hidráulica del suelo no saturado fueron logrados por medio de un Infiltrometro Mini Disco (modelo S) fabricado por la Decagon Devices, Inc.

Resultados y discusión

En Cuadro 1 se representan los valores medios de densidad de partículas, textura, arcilla dispersa en agua y el índice de floculación para las áreas de silvopastoreo, pastos y cultivo del plátano. No hubo diferencias significativas entre los valores de Dp entre las diferentes áreas estudiadas. Esto se debe al hecho de que la Dp es el resultado de la relación entre la cantidad de masa de suelo seco por unidad de volumen de sólido del suelo; por tanto, no incluye la porosidad del suelo y no varia con el uso o manejo del mismo. El suelo estudiado presentó clase textural media. Con relación a lo ADA y IF, hubo diferencias significativas entre las áreas estudiadas. El área de plátano presentó el mayor valor de ADA, siendo superior a las demás áreas evaluadas, la cuales no presentaron diferencias significativas entre ellas. Los mayores valores de ADA sugieren mayor estabilidad de agregados, sin embargo, en este estudio, el área de plátano presenta una mayor categoría de la masa del suelo (Silva, A., 1997), esto demuestra que existe una unión más fuerte entre las partículas y con ello mayor posibilidad de compactación y degradación del suelo. Los mayores valores de IF fueron encontrados en las áreas dedicadas al pastoreo y silvopastores, demostrando que estas áreas están en proceso más avanzado de mantenimiento de la estructura de los suelos, ya que a floculación es la primera condición para la formación de los agregados.

Cuadro 1. Medias de densidad de partículas, textura, arcilla dispersa en agua y índice de floculación para uso de silvopastoreo (bosques), pastoreo en áreas degradada (Pasto) y cultivo de plátano (Plátano).

Variáveis	Mata	Pasto	Plátano
Dp (kg dm^{-3})	2,56	2,60	2,65
A (g kg^{-1})	237	216	294
S (g kg^{-1})	122	146	317
AF (g kg^{-1})	186	212	232
AG (g kg^{-1})	455	426	157
AT (g kg^{-1})	641	638	389
ADA (g kg^{-1})	22 b	27 b	121 a
IF (%)	91a	88 a	59 b

Dp: densidad de partículas; A: arcilla; S: silte, AT: arena total; AG: arena gruesa; AF: arena fina; ADA: arcilla dispersa en agua y IF: índice de floculación. Medias seguidas por misma letra en las líneas no difieren entre sí, por la prueba de Scott-Knott, P<0,05. Media de 20 repeticiones.

Los valores de macroporosidad del suelo en las zonas boscosas difieren del suelo de pastoreo y el de plátano (Figura 1). El valor de la macroporosidad en todas las áreas se comportó inferior al intervalo considerado de crítico según Cocroft & Olsson (1997) de 10 a 15%, pudiendo, según los mismos autores, este suelo presentar problemas de aireación (Figura 1a). Esos bajos valores de macroporosidad pueden representar mayor resistencia mecánica, así como, una menor infiltración del agua en el suelo. La microporosidad, en el área de plátano presentó el mayor valor, en comparación al área de bosque. Los valores altos de microporosidad (Figura 1b) y bajos para macroporosidad indican que existen problemas de compactación. Esto siempre ocurre cuando existe un incremento de la microporosidad y una disminución de la macroporosidad.

Los valores que se observan en la infiltración del agua en el suelo (Figura 2) se vieron influenciados por la humedad, en el momento de la medición. se puede percibir, de acuerdo a la Figura 3, que el mayor valor fue encontrado en el suelo del área dedicada al pasto, esto se debe fundamentalmente a que las raíces, benefician la mayor capacidad de infiltración del agua en el suelo.

Conclusiones

El impacto sobre las propiedades físicas e hídricas del solo en APP fue dependiente del uso del suelo, según evidenciado por la relación de masa y volumen de sus constituyentes. Los atributos investigados en la área bajo el uso de la cultura del plátano fueron los que más sufrieron impacto negativo, indicando que esa área predispone más el suelo a la degradación estructural. Por otro lado, fue constatado que las áreas bajo el uso de pasto y bosques, están en proceso más avanzado de manutención de la estructura del suelo.

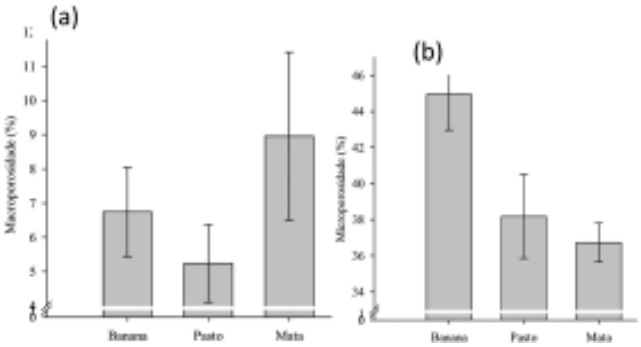

Figura 1. Macroporosidad y microporosidad para suelo bajo uso silvipastoril (Mata), pastagem degradada (Pasto) y cultivo de banana (Plátano). La barra de errores representa el intervalo de confianza del 95%. Medias de 20 repeticiones.

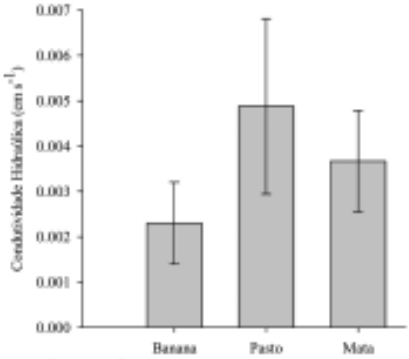

Figura 2. Valores medios para infiltración medidos directamente en el campo con infiltrometro de campo en solo bajo uso silvipastoril (MPIS), pastagem degradada (PDEG) y cultivo de plátano (CBAN). La barra de errores representa el intervalo de confianza del 95%. Medias de 20 repeticiones.

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A FRAMEWORK FOR ASSESSING AGRICULTURAL SOIL QUALITY

Lothar Mueller[a*], Uwe Schindler[a], Bruce c. Ball[b], Elena Smolentseva[c], Chunsheng Hu[d], Graham Shepherd[e], Volker Hennings[f], Peter Schad[g], Axel Behrendt[a], Katharina Helming[a], Karen Tscherning[a], Frank Eulenstein[a]

[a]Leibniz-Centre for Agricultural Landscape Research (ZALF) e. V., Eberswalder Strasse 84, D-15374 Muencheberg, Germany
[b]Crop and Soil Systems Research Group, SAC, West Mains Road, Edinburgh EH9 3JG, UK
[c]Russian Academy of Sciences, Institute of Soil Science and Agrochemistry (ISSA), Sovetskaya 18, Novosibirsk, 630099, Russia
[d]Center for Agricultural Resources Research, Institute of Genetics and Developmental Biology, The Chinese Academy of Sciences. 286 Huaizhong. Rd., Shijiazhuang 050021, Hebei, China
[e]BioAgriNomics Ltd., 6 Parata Street, Palmerston North 4410, New Zealand
[f]Federal Institute for Geosciences and Natural Resources, Geozentrum Hannover, Stilleweg 2, D-30655 Hannover, Germany
[g]Wissenschaftszentrum Weihenstephan, TU München, Freising, Germany

Summary

The capacity of soil to produce plant biomass is closely related to key global issues of the 21st century like food security, climate change and environmental quality. This productivity potential is dependent on maintaining good soil quality. A standardised methodology for assessing agricultural soil quality will be demanded by a growing international community of land users and stakeholders for achieving sustainable high soil productivity. This framework has to meet the following criteria: precise in operation, based on indicators and thresholds of soils, consistently applicable over different scales, potential for use in suitability and capability classifications, adequately crop yield relevant, and capable of being integrated into new land evaluation frameworks of the 21st century. This paper aims to compare current approaches of soil quality evaluation and to test a new approach, the multi-indicator-based Muencheberg Soil Quality Rating (M-SQR), in relation to those criteria. Contrasting soil catenas and profiles were analysed in several agricultural landscapes, located mainly in Germany, Siberia, northern China, New Zealand and Scotland. Soils were classified according. to the World Reference Base for Soil Resources (WRB 2006) and functionally assessed by the Muencheberg Soil Quality Rating. We found that the Muencheberg Soil Quality Rating meets most criteria of such a globally valid framework of overall soil quality evaluation. It contains indicators characterising both crop yield relevant soil texture and structure attributes and the soil moisture and thermal regime.

Methods of visual soil assessment are valuable tools to diagnose management induced variations in soil quality. They can be integrated into this framework. Final scores are correlated with crop yield, indicating that the method has potential as a crop yield estimator for cereals on a global scale. The rating scheme needs further evolution by testing and amending its indicator thresholds. The method also has potential to act as a monitoring tool of agricultural soil quality on cropland and grassland. To provide both a reliable taxonomic and functional soil classification for cropping land and grassland, we recommend a combination of the WRB 2006 with the Muencheberg Soil Quality Rating.

Introduction

Global issues of the 21st century like food security, demands of energy and water, climate change and biodiversity are associated with the sustainable use of soils (Lal, 2009). One of the key soil functions is «food and other biomass production». This productivity function is related to the most common definition of soil quality as «the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation» (Karlen *et al.,* 1997). We start from the hypothesis that a growing community of land users and stakeholders has to achieve a high productivity without any significant detrimental long-term impact on soils and the environment. This implies a demand to assess the quality of soils using internationally standardised frameworks and simple diagnostic tools. A global assessment framework of the overall soil quality and productivity potential has to meet the following requirements (Mueller *et al*., 2010):

- Monitoring tool of the functional status of the soil
- Precise in operation, based on indicators and thresholds of the most functionally relevant attributes
- Consistently applicable over different scales
- Potential for suitability and capability classifications
- Straightforward for use in extension
- Potential as a crop yield estimator and thus acceptable to farmers

The aim of our paper is (i) to analyse and compare some existing approaches of the evaluation of soil quality and potential for soil productivity, and (ii) to test the Muencheberg Soil Quality Rating approach (Mueller *et al*., 2007) regarding the above criteria, and in particular, the correlation with crop yields.

Materials and methods

Materials include (i) a study of the literature regarding soil and land evaluation criteria and (ii) field work to investigate the soil taxonomic and functional classification. Existing approaches of soil quality and productivity-related methods were evaluated regarding the following criteria: scale of validity, field method capability, reliability, relation to soil and climate data, inclusion of soil structure data and plant suitability. Data were analysed on the basis of similarity and displayed using a statistical procedure of multi-dimensional scaling (Procedure MDS, SPSS inc., 1993).

Contrasting soil profiles were analysed in agricultural landscapes, mainly in Germany, western Siberia, northern China, New Zealand and Scotland. Soils were classified according to the World Reference Base for Soil Resources (WRB 2006) and functionally assessed by the Muencheberg Soil Quality Rating (Mueller *et al.*, 2007). Field soil data were surveyed according to the «FAO Guidelines for soil description, 2006». Crop yields and management intensity data came from agricultural research reports of the research stations. In case of farmer´s fields, they were estimated jointly with the farmers.

Results and discussion

Comparison of methods of soil evaluation relevant to soil quality and productivity potentials: Over the past 100 years, specific soil and land evaluation systems targeting soil quality for crop yields have been developed or are under construction. They differ in purpose and performance and their results are rarely comparable or transferrable. The plot of Fig. 1 is a computed distance map based on the methodology of some well known methods. Wide separations indicate dissimilarities of methods. This procedure shows clear separation between traditional soil ratings and dynamic visual assessments of soil quality (VSA, Shepherd, 2000). Traditional soil ratings include the Storie Index Rating (Storie, 1933) and the German and Austrian Soil Rating (Rothkegel, 1950, Bodenaufnahmesysteme, 2001). Crop models and the AEZ methodology (Fischer *et al.*, 2002) are similar both in purpose and in results. They are located far from the centre as these procedures, are not field methods of soil assessment, and are mainly based on climate information. Soil data sets also occupy isolated positions as, although they contain detailed soil information, they do not include climate information and are based on laboratory analyses. The Muencheberg Soil Quality Rating, (Mueller *et al.*, 2007) and also the Canadian Land Suitability Rating System (Agronomic Interpretations Working Group, 1995) are in-between and closer to the centre.

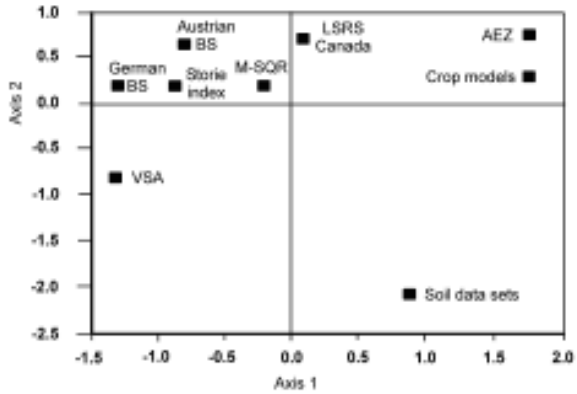

Figure 1. Similarity plot of some soil productivity relevant evaluation schemes (Mueller *et al.*, 2010). German BS = German Soil Rating, Austrian BS = Austrian Soil Rating, M-SQR (Muencheberg Soil Quality Rating), VSA (Visual Soil Assessment), LSRS Canada (Land Suitability Rating System), AEZ (Agro-ecological zoning)

They meet most criteria of a global framework as specified above as they contain information on climate and soil properties relevant to crop yield, and soil structure in particular. They have the potential for consistent ratings of the soil productivity function on a global scale but need to be tested and evolved for this purpose in major agricultural regions.

Soil structure as a criterion of management induced agricultural soil quality: Methods of visual soil structure examination enable semi-quantitative information of soil quality for use in extension and monitoring. Types and sizes of aggregates and abundance of biological macropores were the most reliable criteria as related to measurement data and crop yields. Effects of compaction and differences in soil management could be recognised by visual structure criteria (Batey and McKenzie, 2006, Mueller *et al.*, 2009). Unfavourable visual structure was associated with increased dry bulk density, higher soil strength and lower infiltration rate but correlations were site-specific. Visual methods based on, or supplemented by illustrations, have clear advantages for the reliable assignment of a rating score. The latest development of the Peerlkamp method provided by Ball *et al.* (2007) and the New Zealand Visual Soil Assessment (Shepherd, 2000), are illustrated methods, reliable in use and integrable into overall soil quality rating schemes. An example of rating soil structure using the VSA method is given in Figure 2.

Overall agricultural soil quality and crop yields: Soil texture is correlated with other important functional attributes like water and nutrient storage capacity and thus has become a dominant criterion of all existing functional classification systems. However, in the supra-

regional or global scale, qualifiers of soil internal attributes may explain less than 50% of the crop yield variability only (Table 1). Variations in the soil's moisture and thermal regimes are most crop-yield relevant at those scales and have to be taken into consideration. Depending on land use intensity and the quality of indicator parameterisation, final M-SQR scores may explain between 50 and 80% of the crop yield variability.

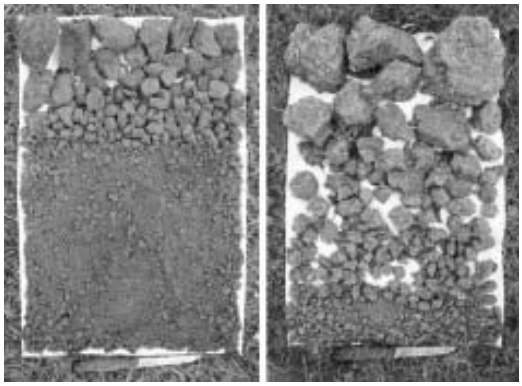

Figure 2. Different feature of soil aggregates under grassland (Structure indicator of the VSA procedure of Shepherd, 2000). Left Fig: Manawatu silt loam (Eutric Fluvisol), moderately good structure, rating of 1.5 (0= worst, 2=best), Right Fig. Kairanga clay (Eutric Gleysol), poor structure, rating of 0

Table 1: Coefficient of determination (B) of regressions between crop yields of cereals and soil classifiers (Mueller *et al.* 2009)

Reference soil groups (RSG) and type of cropping	Variant of classification	B
All RSG, high-input (n=352)	1) Soil internal attributes only (Qualifiers of WRB)	0,20**
	2) Soil attributes and thermal and moisture regime	0,61***
	3) M-SQR-score	0,78***
Phaeozems, Chernozems und Kastanozems, high-input (n=54)	1) Soil internal attributes only (Qualifiers of WRB)	0,00
	2) Soil attributes and thermal and moisture regime	0,65***
	3) M-SQR-score	0,74***
All RSG, Organic und low-input (n=43)	1) Soil internal attributes only (Qualifiers of WRB)	0,36**
	2) Soil attributes and thermal and moisture regime	0,63***
	3) M-SQR-score	0,87***

Conclusion

To provide both a reliable taxonomic and functional soil evaluation and classification for cropping land and grassland, we recommend a combination of the WRB 2006 with the Muencheberg Soil Quality Rating (M-SQR).

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PROPIEDADES BIOQUÍMICAS DE SUELOS DEL SEMIÁRIDO VENEZOLANO

Paolini, Jorge[1]; Aponte, Humberto[2]; Pierina, Atacho[2]

[1]Centro de Ecología, IVIC, Apdo. 21827, Caracas 1020-A (Venezuela) y
[2]Universidad Nacional Experimental «Francisco de Miranda», Santa Ana de Coro, estado Falcón (Venezuela).

Resumen

Las propiedades bioquímicas de 28 suelos de la región semiárida del estado Falcón, (occidente de Venezuela) fueron determinadas con el objetivo de establecer una base de datos referencial y determinar los procesos de degradación del suelo en dicho ambiente. Los suelos estudiados corresponden a dos situaciones: bajo vegetación nativa y cultivados con zábila (*Aloe vera*) y melón (*Cucumis melo*). Los resultados indican que los suelos que mantienen una vegetación natural y que no han sufrido acción antrópica poseen mayores contenidos de carbono orgánico total, carbono hidrosoluble, nitrógeno total y biomasa microbiana y muestran una mayor actividad biológica expresada por las actividades enzimáticas intracelulares y exocelulares que suelos cultivados.

Introducción

A nivel mundial las regiones áridas y semiáridas ocupan un 40 % de la superficie total del planeta. En Venezuela su proporción es de apenas un 5 % del territorio nacional, sin embargo alrededor de un 20 % de la población del país vive en dichas zonas (Comerma y Arias, 1975).

Los suelos frecuentemente poseen bajo niveles de materia orgánica, pH ligeramente ácido a alcalino a nivel superficial, presentan acumulación de carbonato de calcio en el subsuelo, alta CIC, alta saturación con bases, desarrollo del perfil de débil a moderado, texturas medias a gruesas, baja tasa de infiltración, baja permeabilidad, bajo grado de evolución (Aridisoles, Entisoles e Inceptisoles) y baja actividad biológica (Dregner, 1976).

Los parámetros bioquímicos del suelo cada día adquieren una mayor relevancia en el estudio y la caracterización de los suelos ya que son una medida de la actividad metabólica del mismo y por otro lado permiten entender su funcionamiento. Ellos son más sensibles que los parámetros fisicoquímicos a los cambios de uso de la tierra, prácticas de manejo agrícola y forestal, adición de fertilizantes, presencia de agentes degradantes como pesticidas y metales pesados.

El objetivo de este trabajo es el de evaluar algunas propiedades bioquímicas de los suelos de la región semiárida de Venezuela bajo diferente uso agrícola (cultivo de zábila y melón) y compararlas con zonas no perturbadas bajo vegetación densa nativa.

Materiales y métodos

El área de estudio corresponde a la Microcuenca El Socorro-Jadacaquiva ubicada en los municipios Falcón y Los Taques al Noroeste del estado Falcón en la península de Paraguaná. Abarca una superficie de 26.157 ha con un relieve predominantemente de paisaje de altiplanicie con pendientes muy suaves (0-3 %), precipitación promedio anual de 335 mm y evaporación promedio anual de 2770 mm (Fundación CIARA y CIDIAT, 2007).

En el campo se seleccionarón varios sitios de muestreo correpondientes a uso agrícola (n=4 zábila y n=3 melón) y vegetación nativa de matorral espinoso no intervenido (n=7).

Los métodos usados en la determinación de los parámetros fisicoquímicos, bioquímicos y estadísticos se muestran en la Cuadro 1.

Cuadro 1. Análisis fisicoquímicos, bioquímicos y estadisticos aplicados a las 28 muestras. Todas las determinaciones fuerón realizadas por triplicado.

Fisicoquimicos (UCV, 1993)	pH, CE, COT, Nt, Pt, Pdisp, CHS, Textura
Bioquimicos (Alef y Nannipieri, 1995)	Respiración Basal (RB), Cmic(RIS), Deshidro-genasa (DH), Hidrólisis del DAF(DAF), Amonifi-cación de Arginina (AA), Fosfatasa básica (FB), β-glucosidasa (β-Gl), ureasa (Ur), caseinasa (Cas)
Estadisticos	Análisis de Varianza de una sola vía (ANDEVA) y prueba de medias por el test MDS (Mínima Diferencia Significativa)

Resultados y discusión

En los cuadros 2 y 3 se muestran los valores de las medias de las propiedades fisicoquímicas y bioquímicas de los suelos analizadas en este estudio respectivamente. Todos los resultados son reportados como el promedio de tres determinaciones y se expresan en base de suelo seco a 105 ºC.

Cuadro 2. Valores de las propiedades fisicoquímicas de los 28 suelos. Para la misma propiedad diferentes letras indican diferencias significativas (P<0,05).

	pH	CE	COT	Nt	Pt	CHS	Pdisp	Are	Limo	Arc
		(µS/cm	(g/kg)			(mg/kg)		(%)		
VN	7,6a	398b	16,6a	1,91a	0,90ab	195a	24a	52,4b	24,5a	23,1a
Zábila	8,1a	329b	9,8b	0,98b	1,30a	126b	25a	60,7ab	21,6ab	17,7a
Melón	7,0b	1027a	8,0b	0,77b	0,42b	121b	20a	71,1a	15,8b	13,1a

Cuadro 3. Valores de las propiedades bioquímicas de los 28 suelos. Para la misma propiedad diferentes letras indican diferencias significativas (P<0,05).

	RB	Cmic	DH	DAF	AA	FB	β-Gl	Ur	Cas
	(mg C-CO_2/kg*d)	(mg C/kg)	(µg Producto/g*h)						
VN	36,9a	323a	87,9a	82,6a	1,5	485,5a	132,2a	63,9a	57,9a
Zábila	13,8b	209b	29,5b	26,1b	2,3	220,3b	43,2b	30,5b	20,2b
Melón	15,8b	249ab	22,3b	20,9b	2,1	142,8b	42,1b	19,3b	21,1b

En este estudio, los pHs están en el rango neutro a ligeramente alcalino e indican un alto grado de saturación de bases. La conductividad eléctrica (CE) fue mayor en los suelos cultivados con melón, asociado probablemente al manejo intensivo de este cultivo y al riego con aguas de conductividad elevada.

Los suelos bajo vegetación nativa (VN) exhiben las mayores concentraciones de carbono orgánico total (COT), carbono hidrosoluble (CHS) y nitrógeno total (Nt) que los cultivados con melón y zábila, debido a un mayor aporte de materia orgánica via hojarasca del matorral espinoso, y a que en los suelos cultivados ocurre una pérdida de la estructura y la perturbación del equilibrio entre el proceso de humificación y mineralización. Este hecho ya nos sugiere que un cambio de uso de la tierra conlleva a una disminución de dichos parámetros y por consiguiente de la calidad del suelo. Los resultados obtenidos en este estudio para el COT superan a los encontrados por Torres *et al.* (2006) en suelos del Sector El Cebollal, estado Falcón y son similares a los indicados por Malagón (1978) para suelos bajo vegetación nativa en la depresión de Quíbor, estado Lara.

El carbono hidrosoluble corresponde a la fracción más lábil de la materia orgánica del suelo y es un recurso de fácil disponibilidad para el crecimiento microbiano y la descomposición biológica (Cook y Allan, 1992). Su disponibilidad es el principal factor limitante de la respiración en los suelos (Cheng *et al.,* 1996). Esta fracción por su rápida tasa de recambio es más sensible a los cambios de uso de la tierra que el nivel de la materia orgánica del suelo como un todo por lo cual reflejará los cambios en la calidad del suelo más temprana que la materia orgánica del suelo.

Los suelos bajo vegetación nativa densa mostraron significativamente desde el punto de vista estadístico los mayores valores (promedio 195 mg C/kg suelo) comparados con suelos cultivados (promedio 126 mg C/kg suelo para sábila y 121 mg C/kg suelo para melón). En los suelos bajo vegetación nativa hay un aporte importante de materia orgánica vía hojarasca lo cual contribuye al carbono hidrosoluble cosa que no ocurre en los suelos cultivados.

La clase textural dominante de los suelos son franco arenosa, franco arcillo limosa y franca. En el caso de los suelos cultivados los contenidos promedios de limo y arcilla fueron menores a los de los suelos bajo vegetación nativa de la Microcuenca con lo cual podemos inferir que la perdida debe estar asociada a prácticas agrícolas como labranza y erosión hídrica y/o eólica.

La respiración basal (RB) es uno de los parámetros usados con mayor frecuencia para cuantificar la actividad microbiana en términos metabólicos y se considera como un índice general de la fertilidad del suelo y la calidad del mismo, debido a su rápida respuesta a los cambios ambientales, a las técnicas de cultivo y tratamientos así como a los cambios en el uso de la tierra. Esta varió entre 8,3 y 52,8 mg C-CO_2/kg suelo*día y los mayores valores se registraron en los suelos bajo vegetación nativa densa (36,9 ± 10,1 mg C-CO_2/kg suelo*día) con un mayor contenido de COT y carbono hidrosoluble.

Los valores del carbono asociado a la biomasa microbiana (Cmic) para los suelos de la Microcuenca El Socorro y Jadacaquiva variaron entre 92 y 585 mg C/kg suelo con un valor promedio de 333 ± 113 mg C/kg suelo para los suelos bajo vegetación nativa; de 209 ± 81 mg C/kg suelo para cultivo de sábila y 249 ± 98 mg C/kg suelo para cultivo de melón y son similares a los suelos bajo vegetación de manglar del Parque Nacional Laguna de La Restinga (Sánchez-Arias *et al*., 2010) pero inferiores a suelos agrícolas de la cuenca del Lago de Valencia (Ruiz y Paolini, 2004), agrícolas de Turén (Hernández, 1998) y bajo vegetación nativa de la cuenca del río Maracay (Sánchez *et al.,* 2005) usando la metodología aplicada en este estudio.

Todas las actividades enzimáticas a excepción de la amonificación de arginina fuerón mayores en los suelos bajo vegetación nativa que sus contrapartes cultivadas bajo zábila y melón; con lo cual se confirma que las mismas son indicadores más sensibles a los cambios de uso de la tierra en ecosistemas de zonas áridas y semiáridas que las propiedades fisicoquímicas (Dick, 1994; Kandeler *et al.,* 1999). Comparando los resultados obtenidos en este estudio con los reportados en la literatura confirmamos que las actividades enzimáticas en los suelos semiáridos de Venezuela son en algunos similares en algunos casos que los de otras zonas áridas y semiáridas a nivel mundial pero en otros casos inferiores especialmente en aquellos estudios donde a los suelos se les añade enmiendas orgánicas a fin de incrementar el tenor de materia orgánica (Moreno *et al*., 2008; Tejada *et al.,* 2006).

La deshidrogenasa es una enzima que realiza funciones catalíticas intracelulares, por lo cual podría ser un indicador de la actividad de los microorganismos del suelo. Los valores de este estudio son simi-

lares a los reportados para suelos bajo vegetación nativa en estudios en la región semiárida mediterránea española de 61 µg INTF/g*h (Pascual *et al*., 2000) y superan a suelos cultivados con brocolí bajo diferentes manejos agrícolas, que mostraron valores comprendidos entre 1 y 9 µg INTF/g*h (Moreno *et al*., 2008).

La hidrólisis del diacetato de fluorisceína generalmente se usa como un indicador de la actividad hidrolítica total del suelo ya que dicho sustrato es hidrolizado por enzimas como proteasas, lipasas y esterasas; los valores encontrados en este estudio estan en el mismo intervalo reportado por Yuan *et al.* (2007) de 2,9 a 57,7 µg Fluorisceína/g*h para suelos de la China afectados por sales bajo condiciones áridas.

La amonificación de arginina es también otro indicador de la actividad microbiana del suelo y se encuentra estrechamente relacionada con la biomasa microbiana y su actividad (Alef y Nannipieri, 1995). Los valores de este estudio son similares a los reportados por Gómez y Paolini (2001) para suelos bajo vegetación de sabana de los Llanos orientales de Venezuela entre 1 y 3,7 µg N-NH_4/g*h, y superan a los de Yuan *et al.* (2007) de 0,06 a 0,70 µg N-NH_4/g*h en suelos afectados por sales en China.

La fosfatasa básica es una enzima que participa en la mineralización del fósforo orgánico y su mecanismo de acción es básicamente extracelular, es junto con la ureasa de las enzimas hidrolíticas más estudiadas. Los valores de este estudio estan por debajo de los reportados por Pascual *et al.* (2001) y Moreno *et al.* (2008) para suelos de Murcia (España) en ambientes semiáridos.

La β–glucosidasa es una exoenzima hidrolítica que actúa sobre los enlaces glicósidicos y es la enzima limitante de la degradación de celulosa a glucosa. Ella refleja el estado de la materia orgánica y los procesos que ocurren en él. Al igual que la fosfatasa básica los valores de este estudio estan por debajo de los reportados por Pascual *et al* (2001) y Moreno *et al.* (2008) para suelos de Murcia (España) en ambientes semiáridos. Por otro lado la disminución de la actividad de la ²-glucosidasa con la conversión de vegetación nativa a cultivos ha sido indicada por otros autores (Bandick y Dick, 1999; Salam *et al*., 1998; Saviozzi *et al*., 2001).

La ureasa cataliza la hidrólisis de urea a anhidrido carbónico y amonio. Se trata de una enzima de amplia distribución en la naturaleza y ha sido detectada en microorganismos, plantas y animales. Su importancia radica en su participación en el ciclo del nitrógeno además de que la urea es un fertilizante sólido nitrogenado de amplio uso en la agricultura. Tejada *et al.* (2006) para un suelo salino degradado en España indica valor de 18,2 µg N-NH_4/g*h cercano a los

suelos cultivados con zábila y melón pero al ser enmendados los valores se incrementan dependiendo de la dosis entre 28 y 308 µg N-NH_4/g*h; superando lo encontrados en este estudio para la vegetación nativa.

La caseinasa se encarga de catalizar la hidrólisis de polipéptidos a aminoácidos. Al catalizar el paso limitante en los procesos de mineralización del N es importante en el ciclo del nitrógeno. Los valores de este estudio son similares a los reportados por Uçkan y Okur (2003) en suelos semiáridos de Turquía cultivados y bajo pasturas nativas para los meses de mayo (70,4 µg Tirosina/g*h) y septiembre (34 µg Tirosina/g*h) y superan a los encontrados por Paolini (2003) en una toposecuencia de los altos Llanos Centrales de Venezuela, con un intervalo comprendido entre 5 a 55 µg Tirosina/g*h.

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IMPROVED MEASUREMENT OF SOIL HYDRAULIC FUNCTIONS FOR SOIL PHYSICAL QUALITY ASSESSMENT

Uwe Schindler[1], Wolfgang Durner[2], Georg Von Unold[3], Lothar Müeller[1]

[1] Leibniz Centre for Agricultural Landscape Research (ZALF), Eberswalder Str. 84, D-15374 Müncheberg, Germany, uschindler@zalf.de
[2] Institute of GeoEcology, Department of Soil Science and Soil Physics, TU Braunschweig, Germany
[3] UMS GmbH; Gmunder Str. 37,D-81379 München, Germany

Summary

Soil physical quality assessment requires precise measurements of soil physical properties. The evaporation method is a most acknowledged procedure for simultaneous
measuring soil water retention and hydraulic conductivity functions. The measurement range of the conventional procedure is limited on the dry end by water cavitation in the tensiometer, which typically occurs below 100 kPa tension. We present here a new design based on improved tensiometers which resist cavitation to much higher tensions, some reaching values as high as 435 kPa. The new tensiometers enabled the quantification of hydraulic functions up to 293 kPa average tension. Using the air-entry pressure of the tensiometer's porous ceramic cup as additional defined tension value allows a further extension of hydraulic functions up to close to the wilting point.Test results are presented for soil samples of different texture (sand, loam, silt, clay and peat) various origin and variable dry bulk density. The extension of the measurement range provides a more reliable evaluation of water storage properties of soils.

Introduction

Soil physical quality is a main aspect of agricultural soil quality, and water capacity parameters based on the water retention curve are important indicators for their evaluation (Reynolds *et al.*, 2009). Precise measurements of soil hydraulic properties including the water retention function are a precondition for the evaluation of soil physical quality states and for physiological processes in soils. Currently a broad array of methods exists for the determination of soil hydraulic properties in the field or in the laboratory (Klute and Dirksen, 1986; Dane and Hopmans, 2002)). Sandbox (hanging water column) and pressure plate extractor are the common procedures for measuring water retention characteristics in many laboratories. Limitations of the pressure plate extractor include long times for achieving hydraulic equilibrium, and fluctuations of regulated gas pressure during equilibration (Dane and Hopmans, 2002).

The evaporation method is a most acknowledged method, frequently used for simultaneous determination of soil water retention and hydraulic conductivity relationships (Wind, 1966; Schindler, 1980; Plagge, 1991; Wendroth *et al.*, 1993; Simunek *et al.*, 1998; Schindler and Müller, 2006). However, all existing versions of the evaporation method which use water filled tensiometers for soil water potential measurements have the same limitation. Tensiometers usually fail at tensions greater than about 90 kPa. Soil physical quality assessment, however, requires soil hydraulic property measurements at higher tensions.

The objectives of this study are to report on an improved version of the evaporation measurement device and describe methods for extending its tension range.

Evaporation experiments: Figure 1 shows the experimental setup. The tensiometers are installed in upward direction which reduces the amount of tensiometer water flowing into the soil after tensiometer failure (water boiling). For data recording and calculating hydraulic functions, the tensiometer assembly and balance are connected through a bus to a computer.

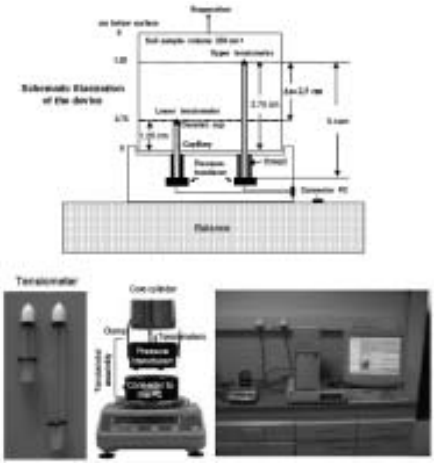

Figure 1. Measurement device (HYPROP: HYdraulic PROPerty Analyzer)

A water saturated 250 cm3 soil core (5 cm high, 8 cm Æ) is connected with the tensiometer assembly (Fig. 1). The assembly is placed on a balance and the sample's surface is exposed to free evaporation. The weight loss and tensions are continually measured in two depths. Assignment of the mean tension to the mean water content results in measured values of the water retention function. Relating the flux through the measurement layer to the hydraulic gradient results in the hydraulic conductivity (Schindler, 1980; Peters and Durner, 2008).

Measurement range extension

Extension by boiling retardation in novel tensiometers (Schindler *et al.*, 2009a)**:** The tensiometers used for our measurements are designed to measure suctions beyond the boiling point of water, due to boiling retardation. To meet this claim, the surface roughness, the size and surface area of the tensiometers are minimized. Rigorous tensiometer degassing is a precondition and allowed tension measurements as high as 435 kPa (Figure 2)

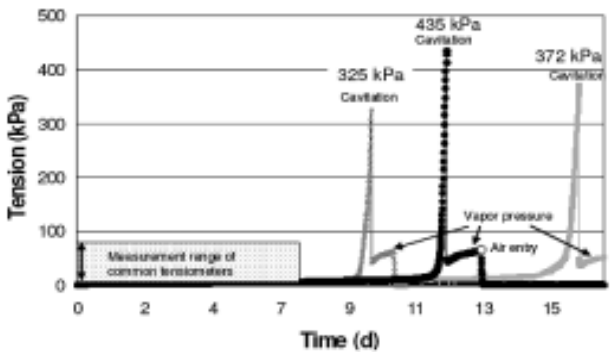

Figure 2. Extended tension range before cavitation, measured in sandy soil samples.

Extension by using the air-entry value of the ceramic (Schindler *et al.*, 2009b)**:** The dynamics of a tensiometric measurement in a drying soil can be divided in three distinct stages (Figure 3, left). In the first stage, the measured tension reflects the matric potential of the surrounding soil. In the case of boiling retardation, we find after cavitation a sudden return to the thermodynamic equilibrium pressure, which is determined by the water's vapor pressure (Figure 2). The second stage is the vapor pressure stage. The third and final stage can be called «air-entry stage». It occurs when the tension in the surrounding soil exceeds the air-entry pressure of the ceramic material (for our tensiometers between 800 and 1500 kPa). The largest continuous pore of the ceramic drains and air enters from the soil into the tensiometer. At this moment, the measured tension collapses towards zero, which is easily visible in the tensiometer reading (Figure 3, left).

The basic idea for extending the measurement range is to use the ceramic's air entry pressure at the well-defined moment of the tension collapse. Any smooth function with higher-order continuity, such as polynomial functions or Hermitian spline interpolation, can be used for interpolation between last reliable values of stage 1 to the initiation point of stage 3 (Figure 3, right). Applying this procedure to both tensiometers extends the data evaluation into the dry range.

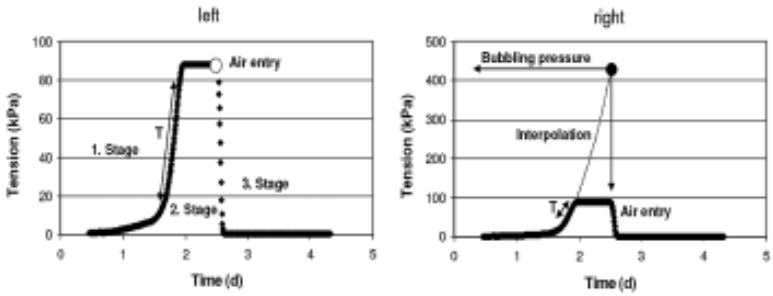

Figure 3. Tension dynamics during evaporation (left) and interpolation to air-entry pressure (right), Clay soil, Campus Novus (Brasilia, SC). T-range for fitting the tension function.

Extended hydraulic functions: Figure 4 shows results of extended hydraulic functions for two soil samples. The measurement range of the hydraulic functions could be extended with high resolution almost by one order of magnitude, close to the permanent wilting point.

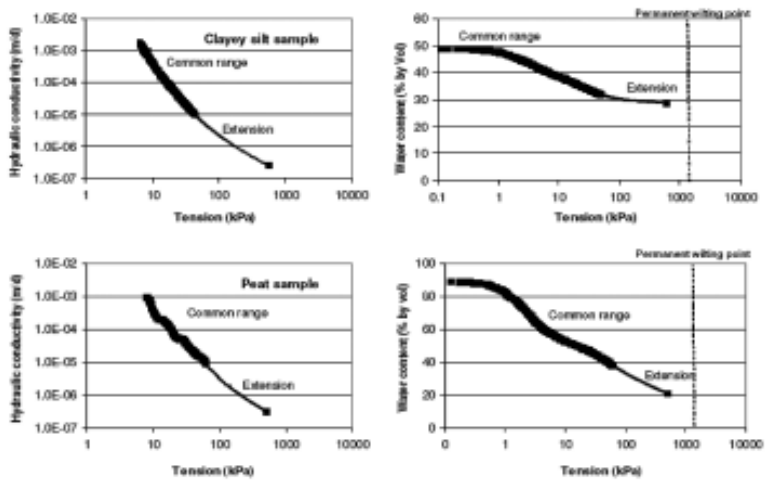

Figure 4. Extended hydraulic conductivity and water retention function. First row: clayey silt, Ust Kamenka (Novosibirsk region, Russia). Second row: peat sample.

Conclusions

The application of newly designed tensiometers and the use of the air-entry pressure of the tensiometer's ceramic allow extending the measurement range of hydraulic functions – water retention curve and hydraulic conductivity function – until close to wilting point. The high resolution allows the accurate quantification of soil water storage and transport properties as basis for unerring soil physical quality assessment.

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EVALUACIÓN BIOLÓGICAS DEL SUELO EN ÁREAS DE PASTOREO Y MAIZ CON DIFERENTES TIEMPOS DE APLICACIÓN DE EXCRETAS DE CERDO

Denilson Dortzbach, Iria Sartor Araújo, Carla Pandolfo, Milton da Veiga

Epagri, denílson@epagri.sc.gov.br

Resumen

Se evaluaron los cambios en C y N de la biomasa microbiana en suelos para pastoreo y áreas de cultivo de maíz con diferentes tiempos de aplicación de excretas de cerdo agrupados en clases de alrededor de 5, 10 y 20 años, comparándolas con las áreas de vegetación natural en la cuenca Coruja/Bonito, estado de Santa Catarina, Brazil. Se evaluaron el carbono y el nitrógeno de la biomasa microbiana del suelo en profundidad 0-10 cm. No fueron observadas diferencias entre los tiempos de aplicación de excretas de cerdo, tanto en las áreas de pastoreo como en las áreas de maíz. El C y N de la biomasa microbiana del suelo fueron menores en el campo de maíz. Los mayores valores de CBM se observaron en los campos y los valores más altos de NBM en los pastos. Los parámetros evaluados resultaron ser buenos indicadores de cambios en el suelo en función del uso.

Palabras clave: abono orgánico, calidad del suelo, microorganismos

Introducción

La retirada de la vegetación original para dar paso a las áreas de pastoreo y a los cultivos anuales a menudo ha mostrado cambios en propiedades físicas, químicas y biológicas del suelo, debido a cambios en las propiedades del suelo, y a la acción directa de estas prácticas sobre los organismos. Estas modificaciones producen quiebras en los ciclos del carbono y nutrientes.

Las excretas de cerdo son una fuente importante de nutrientes para las plantas, especialmente de nitrógeno, que regulan la actividad de descomposición de los microorganismos y la tasa de descomposición (Wardle y Hungría 1994). La biomasa microbiana responde rápidamente a la adición de C y N disponible, funcionando como un importante reservorio de varios nutrientes de las plantas. Su actividad es afectada por las condiciones bióticas y abióticas, y puede ofrecer respuestas rápidas a los cambios en el suelo, siendo posible así su utilización como un indicador de los cambios MO que resulta en el uso y manejo del suelo y por lo tanto indican la calidad del suelo (Rice *et al*. 1996).

El objetivo de este trabajo fue evaluar las alteraciones biológicas del suelo a partir de las estimaciones de C y N de la biomasa microbiana en suelos sometidos a la aplicación de excretas de cerdo en diferentes intervalos de tiempo en las zonas de cultivos anuales y áreas para pastoreo.

Materiales y métodos

El estudio se realizó en parcelas de propiedades rurales situadas en la Cuenca del Coruja Bonito, Municipio de Brazo Norte, Santa Catarina, Brazil, donde la producción de cerdos es la principal actividad económica. El clima en la clasificación Köppen es de tipo Cfa. Las áreas fueron definidas en función del tiempo de aplicación con excreta de cerdo de aproximadamente 5, 10 y 20 años. Se seleccionaron las áreas con bosque nativo, utilizado como referencia (tiempo 0), una zona con cultivos anuales (maíz), área de terreno naturalizados (pastos) con tres repeticiones para cada combinación del uso del sistema y tiempo de aplicación, a excepción del bosque nativo , donde la situación se produjo sólo sin la aplicación de excreta de cerdo.

Las muestras de C y la biomasa microbiana de N fueron colectadas entre 0-10 cm de profundidad, con ocho submuestras, lo que se tradujo en una muestra compuesta. Se usó el método de fumigación-extracción propuesto por Vance et al. (1987) para la determinación de CBM y MBN.

Los datos fueron sometidos a análisis de varianza y comparación de medias mediante la prueba de Tukey ($p < 0,05$) y el análisis de regresión entre el tiempo de aplicación, utilizando el software Statistica 7.0.

Resultados y discusión

No hubo diferencias para o CBM y NBM entre los tiempos de aplicación de excretas de cerdo, tanto en el pasto y las áreas de maíz (Cuadro 1).

Cuadro 1: Los valores de CBM y NBM en la capa de 0-10 cm en los pastos y el maíz a los 0, 5, 10 y 20 años de aplicación de excreta de cerdo.

Tiempo (años)	PASTOREO			MAIZ		
CBM (mg kg^{-1})	NBM (mg kg^{-1})	CBM:NBM	CBM (mg kg^{-1})	NBM (mg kg^{-1})	CBM:NBM	
0	523a	50a	10,46	523a	50a	10,46
5	376a	66a	5,70	175b	30b	5,83
10	392a	68a	5,76	193b	28b	6,89
20	424a	69a	6,14	128b	30b	4,27

El análisis estadístico de los datos sobre el suelo CBM detectó efecto significativo al 5% de probabilidad de uso de la tierra y efecto no es significativo en cuanto al tiempo de aplicación de la excreta de cerdo. El sistema bajo condiciones naturales, utilizado como referencia en el presente estudio, presentó numéricamente el nivel más alto de la CBM en los 0-10 cm, aunque no es estadísticamente diferente del área de pastoreo (Cuadro 1). Marchiori Júnior (1999), analizando el CBM, también encontró niveles similares entre los pastos con 20 o 25 años y los bosques naturales y la reducción de más del 60% en el CBM en las áreas cultivadas con algodón durante 10 años, en relación con los bosques naturales.

Entre los factores responsables de condiciones más favorables para el carbono microbiano en las zonas de vegetación natural, se puede señalar el suministro continuo de materiales orgánicos con diferentes grados de descomposición, la mayor diversidad de flora en el bosque, más grande que la de otros usos valoradas, lo que implica deposición de sustratos orgánicos oxidables con composición variable (D'Andrea *et al.* 2002).

En la Figura 1 se observa en maíz que existe una relación lineal negativa entre las variables con un mayor grado de dependencia estadística entre el CBM y el tiempo de aplicación. Los mayores valores de CBM se observan en el pasto para el cultivo de maíz, debido al sistema radicular activos y abundantes en los pastos durante todo el año, una vez a una profundidad de 0-30 cm, se concentran más del 60% raíz del sistema de pastos. Por otra parte, hay una mayor diversidad de compuestos orgánicos depositados en la rizosfera, que es un factor favorable para la supervivencia y el crecimiento de los diferentes grupos de microorganismos del suelo (D'Andrea *et al*. 2002) .La reducción del nivel de la CBM en el maíz refleja el mayor impacto del cultivo anual en la calidad del suelo. Oliveira (2000) informó que hubo una reducción de hasta el 50% de las áreas de la CBM con los cultivos anuales en las zonas reguladas por los bosques, señalando una disminución significativa en los niveles de la CBM en los sistemas con la interferencia humana, en comparación con el sistema de bosque.

El contenido de NBM se muestra en el Cuadro 1 fue mayor en el pasto, seguido por bosques, que difería de maíz. La mayor cantidad de pastizales en el NBM podría indicar un mayor potencial para la mineralización de nitrógeno, y cuanto mayor sea el contenido de NBM, más rápido su reciclado (Anderson, 2003). Regresiones lineales significativas al 5% de probabilidad mediante la prueba de F, se observaron en el NBM en el maíz. El patrón de la relación de maíz y pastos con el NBM mostraró la misma magnitud, pero cambió de dirección y fue positivo para las áreas de pastoreo y negativo en los cultivos anuales (Figura 2).

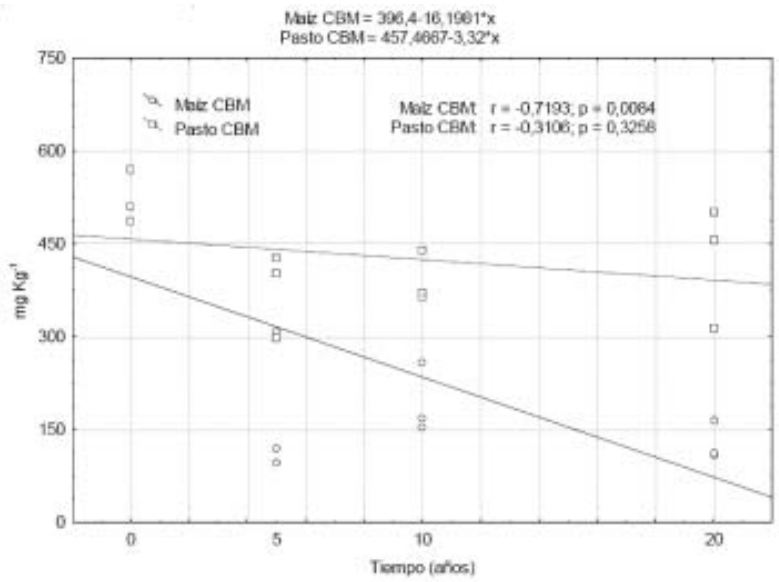

Figura 1. Regresión entre el tiempo (X) mg kg^{-1} CBM (Y)

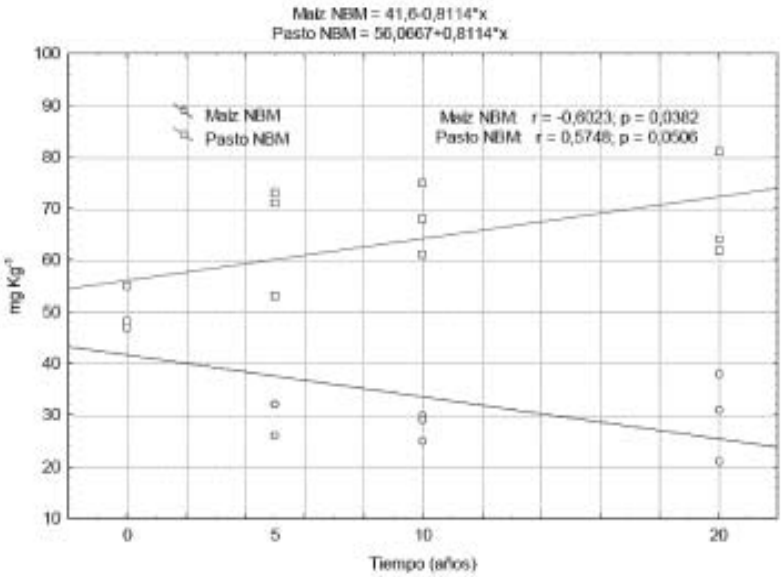

Figura 2. Regresión entre el tiempo (X) mg kg^{-1} NBM (Y)

La relación CBM: MBN fue mucho mayor en la superficie forestal (10,46) con un rango 5,7 a 6,1 en el pasto y 4,3 a 6,9 en el maíz (Tabla 1). Esta relación también se puede utilizar como un índice para expresar la eficiencia de la biomasa microbiana en inmovilizar C y N, lo que refleja la calidad nutricional de la materia orgánica. La biomasa microbiana responde rápidamente a la adición de C y N aplicado al suelo a través de excreta porcina, interfiriendo rápidamente en la biomasa, determinando la descomposición de la MO, la relación C:N, la mineralización y la inmovilización de nutrientes. El rápido retorno de N al suelo por microorganismos contribuye en el proceso de mineralización y se considera importante para el mantenimiento de los ecosistemas naturales (Jenkinson *et al.*, 2004). Los parámetros evaluados resultaron ser buenos indicadores de alteraciones del suelo en función del uso.

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SEDIMENT AND NUTRIENT DELIVERY AND STORAGE IN CHECKDAMSOF AN INTENSIVELY DISTURBED AGRICULTURAL CATCHMENT

A. Navas[1], L. Gaspar[1], G. G.Barberá[2], C. Boix-Fayos[2], J. Albadalejo[2], J. Machín[1], M. Martínez-Mena[2], V.Castillo[2]

[1] Estación Experimental de Aula Dei. CSIC Apartado 13034. 50080 Zaragoza. Spain. anavas@eead.csic.es
[2] Departamento de Conservación de Suelos y Agua, Centro de Edafología y Biología Aplicada del Segura (CEBAS, CSIC) Campus Universitario de Espinardo. Apartado de correos 164, 30100 Espinardo, Murcia. Spain

Summary
Abandonment of agricultural activities affect soil erosion and have other indirect effects such as siltation of reservoirs. To prevent desertification, afforestation and hydrological control works have been a common practice in semiarid SE Spain. In this work the catchment of the Rambla del Cárcavo was selected to examine some features of sediments and nutrients that are delivered an stored in the sections behind a set of check-dams located along the downstream until its outlet into the Cárvavo reservoir on the Segura river. The sediments stored in the check-dams are predominantly fine and along the downstream the percentages of the fine fractions decrease and the coarse fractions tend to increase. The fine sediments are predominantly composed of silt (53 - 67 %) and clay (22 - 43 %). Variations in salinity and carbonates are related with evaporitic and massive marls outcrops, respectively and organic matter contents are related with the distribution of land uses. The pattern of ^{137}Cs follows closely that of clay and is also coincidental with that of the organic matter. Information from sediment composition combined with data from the ^{137}Cs radiotracer that remains strongly fixed to the fine fractions has proven to be efficient to disclose the patterns of sediment mobilization and to assess the source areas of the sediments in the catchment.
Key words: sediments; ^{137}Cs; check-dams; agricultural catchment; Carcavo; SE Spain.

Introduction
In the last decades, large areas in the Mediterranean region experienced a progressive abandonment of agricultural activities. The onset of this process started in the mid-fifties and consequences were increased erosion and other indirect effects causing siltation of reservoirs. The process of transforming lands is generally paralleled

by increases in soil erosion (García-Ruiz, 2010). The set aside of the land, as well as land use changes especially of marginal lands in mountain landscapes is a main environmental concern that affect sediment supplies to water bodies (Navas *et al.*, 2009). To prevent desertification hydrological control works, namely afforestation and check-dam construction, have been a common practice in semiarid SE Spain. Land use changes in catchments also have affected the patterns of sediment mobilization by creating new sources of sediment (Boix-Fayos *et al.*, 2007). These changes suggest the importance of characterizing the patterns of sediment mobilization in agricultural catchments. In the catchment of the Rambla del Cárcavo (Murcia, SE Spain) extensive land abandonment occurred in the mid fifties. To reduce erosion and sediment supplies afforestation and construction of check-dams was done in the 1970's along the downstream until its outlet into the Cárcavo reservoir on the Segura river. In this work the Cárcavo catchment was selected to examine some features of sediments and nutrients that are delivered an stored in the sections behind a set of check-dams located along the downstream. Information derived from some characteristics of sediments and nutrients stored in the check-dams are used in combination with the radiotracer ^{137}Cs to examine the features of the pattern of sediment mobilization occurring in the catchment.

Materials and methods

In the Cárcavo catchment (Figure 1), materials consist of Mesozoic gypsiferous marls and limestone and dolomites at the hills and marls of Tertiary ages at the central depression and bottom valleys. Footslopes of Jurassic ranges have extensive Quaternary colluvia. The catchment is a typical Mediterranean mosaic agricultural landscape. Natural vegetation is dominated by *Stipa tenacissima* grasslands on the colluvia, sparse shrubland on marls and *Pinus halepensis* forest on north-face hillsopes of limestone and colluvia. There are extensive reforestations of pine (*Pinus halepensis*) of 35-40 years, abandoned land covered by scrubland, and agricultural land mainly consisting of orchards (almond and olive trees) that occupy the Quaternary glacis and the marl depression.

Since land abandonment started in the catchment an increase of the forest cover occurred in combination with a decrease in agricultural land. The construction of terraces for the pine plantations appears to have substantially increased soil erosion. On the other hand, the density of soil conservation structures decreased 27% on the period 1956-2005 (Bellin *et al.*, 2009). As a result sediments were retained

and stored in the check-dams along the Rambla del Cárcavo that at present are almost completely infilled (Castillo *et al*., 2007). Along the downstream, the sampling was done in 8 check-dams with three sampling points in each of them (Figure 1). A total of 24 sites were sampled and bulk cores were taken till a depth of 30 cm. Analyses performed were grain size distribution of the coarse fraction (>2 mm) by automatic sieving. In the < 2mm fraction, sand, silt and clay contents were determined by using laser equipment. General properties pH, electrical conductivity and contents of carbonate, gypsum and organic matter were analysed following standard techniques to provide information on the characteristics of the sediments. The content of ^{137}Cs, an artificial radioisotope that remains strongly fixed to the fine fractions and is mobilized with sediments was analysed to assess the source areas of the sediments (Navas *et al*., 2005). Activitiy levels of ^{137}Cs were measured in sediment samples by gamma/ spectrometry using Canberra Xtra with a 30% efficiency detector.

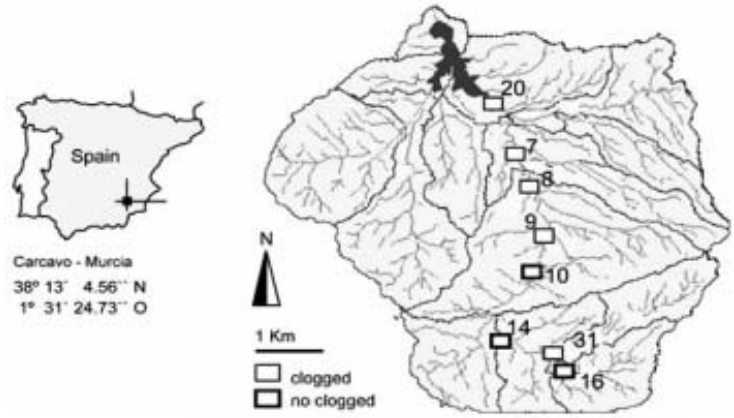

Figure 1. The Cárcavo catchment and location of the check-dams along the downstream.

Results and discussion

The sediments transported and stored in the check-dams are predominantly fine fractions (< 2 mm). Their percentages vary between 99 % at the headwaters and 69 % at the catchment outlet (Table 1). Along the Rambla the percentages of the fine fractions decrease and the opposite is found from the coarse fractions that tend to increase. This pattern depicts the role of check-dams in altering the normal hidrological regime of floods by retaining sediments (Boix-Fayos *et al*., 2007; Castillo *et al*., 2007) and suggest that higher energy of floods concentrate at the lower part of the catchment.

Table 1. Percentages of coarse and fine fractions in the sediments of the check–dams.

	coarse fractions				fine fractions		
	> 12.5	6.3 - 12.5	2.0 - 6.3	<2.0	sand	silt	clay
				%			
D 16	0.08	0.1	0.4	99.5	13.7	64.1	22.3
D 31	2.2	2.7	5.6	89.4	17.0	61.4	21.6
D 14	0.2	2.3	4.7	92.9	2.9	66.8	30.3
D 10	0.7	1.4	2.0	95.9	1.0	56.4	42.7
D 9	6.0	6.5	8.1	79.5	10.6	56.6	32.8
D 8	8.4	10.5	20.8	60.3	16.9	53.2	30.0
D 7	0.02	0.2	0.1	99.7	18.9	55.4	25.6
D 20	5.0	9.0	16.8	69.4	6.7	62.2	31.1

High contents of the coarse fraction are registered at the middle section of the catchment which have thick limestone strata alternating with marls and gypsum. From CD9 to CD8 the coarse fraction increases from 21 to 40%, respectively. Also at the outlet of the catchment high percentages of coarse materials are found in CD20 that could be related to the reworking of the materials previously stored in the destroyed check-dam. As an exception to the general pattern in CD7 sediments are predominantly fine because the source area is composed of massive marls. The fine sediments are predominantly composed of silt (ranges between 53 and 67%) with slightly higher values at the headwaters. Clay contents range between 22 and 43% with the highest content in CD10 at the middle part of the catchment and slightly higher values at the lower portion of the catchment, whereas the opposite is found for the sand fraction.

The pH is alkaline and ranges between 8.33 and 8.75 (Table 2). The salinity varies largely and values range between 0.17 and 4.49 dS m^{-1}. Highest values are found both at the headwater and at the catchment outlet where the maximum occurs. Variations in salinity are related to the presence of evaporitic materials, especially the more soluble salts associated with gypsum outcrops in different parts of the catchment. The carbonate content varies between 35 and 62%, and the maximum is found in CD7 corresponding to the area of massive marls. Gypsum contents range between 1.8 and 4.2% which is the highest content found at the catchment outlet. Variations in salinity are related to the presence of evaporitic materials, especially the more soluble salts associated with gypsum outcrops in different parts of the catchment. Carbonates are more abundant in areas corresponding to massive marls outcrops. The carbon contents are low and show an increasing trend from the headwaters (0.4%) to the middle part of the catchment (CD9) where it reaches 0.8%. Since then to the catchment outlet and corresponding with the area of massive marls carbon contents decrease. This pattern is consistent with the distribution of land uses in the catchment and the predominance of forest of pine trees with

rich organic soils in the upper part of the catchment than at the lower part of the catchment, where badlands on marls are predominant. As found in other semiarid landscapes, soil erosion and subsequent transport of soil particles and of nutrients is one of the major processes affecting the redistribution of soil organic carbon in abandoned agricultural lands (Boix-Fayos *et al.*, 2009).

Table 2. General composition of sediments stored behind the check-dams.

	pH	EC dSm^{-1}	carbonate %	gypsum %	carbon %
D 16	8.33	2.38	45.8	3.2	0.38
D 31	8.75	0.17	42.0	1.8	0.44
D 14	8.41	1.68	42.9	2.8	0.61
D 10	8.49	0.60	35.5	3.5	0.65
D 9	8.49	1.34	53.1	2.9	0.80
D 8	8.70	0.28	54.1	2.5	0.39
D 7	8.49	0.94	62.3	2.4	0.40
D 20	8.33	4.49	53.3	4.2	0.46

The concentration of ^{137}Cs progressively increases from the headwaters (0.34 Bq/kg) to the middle part of the catchment and reaches its highest value of 2 Bq/kg at CD10. The pattern of the radiotracer follows closely that of clay to which is clearly associated. Along the Rambla the distribution of ^{137}Cs is also coincidental with that of the organic matter (Figure 2) in coincidence with other studies in agricultural catchments (Ritchie and McCarty, 2003). The radiotracer appears in the part of the catchment where forest occupies the slopes and soils are better preserved. Since the Rambla flows on the badlands no ^{137}Cs is found indicating that soils on the massive marls are completely eroded.

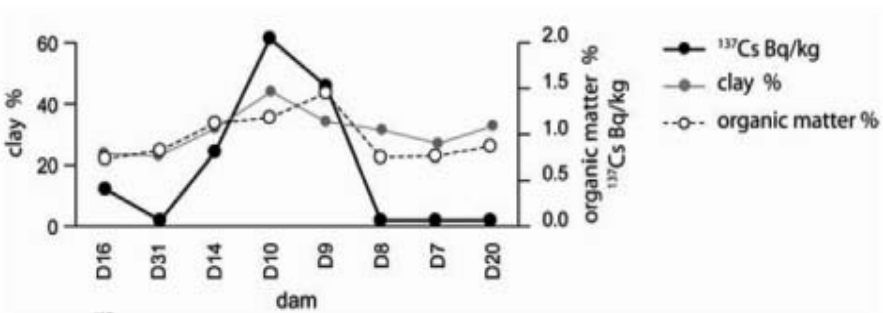

Figure 2. ^{137}Cs activity levels and contents of clay and organic matter in the check-dams.

The materials, sediments and nutrients, transported as suspended or bed-load mainly after storm events are efficiently retained by the check-dams and the length of their transport is limited to the portion of the Rambla between consecutive check-dams. Sediments and nutrients supplied from the slopes by interrill erosion but also by the channel banks, are deposited in the sections created behind the check-dams along the river channel. The characteristics of the sediments together with data on fallout ^{137}Cs suggest that their transport within the catchment is limited by the check-dams and supplies are linked to the correspondent portion of the catchment above each check-dam reflecting the local inputs in the sediment supply and the fragmentation of their transport. The fallout ^{137}Cs indicates that at the headwaters sediments originate from superficial soil horizons through sheet and rill erosion but at the lower parts they appear to come from deeper soil layers removed by gully erosion as no ^{137}Cs was found in the sediments in the lower part of the catchment. The absence of the radioisotope may also indicate that sediment contribution in the lower part of the catchment is mainly supplied by the channel banks. This assumption is also supported by the fact that cultivated land in this lower part occurs on Quaternary glacis overlaying the Tertiary marls. The soils on the glacis are level and soil erosion is expected to be low here.

Afforestation works seem to have significantly contributed to the supply of sediments in the Cárcavo catchment. Then during the time-spam when the surface of soils in the terraces remained bare until they become revegetated also substantial amounts of sediments were delivered. As a result sediments were retained and stored in the check-dams along the Rambla del Cárcavo that at present are almost completely infilled. Nowadays some of the terraces have experienced a substantial increase of the vegetation cover and have reached stability and the pattern of sediment supply can be considered as representative of the actual pattern of delivery and storage probably less affected by the past intense changes.

Conclusions

The results show that sediments and nutrients supplied from the slopes by interrill erosion but also by the channel banks, are deposited in the sections created behind check- dams along the river channel. The characteristics of the sediments together with data on fallout ^{137}Cs suggest that their transport within the catchment is limited by the check-dams and supplies are linked to the correspondent portion of the catchment above each check-dam evidencing the local inputs in the sediment supply and the

fragmentation of their transport. Information derived from this research can be of interest for the rational planning of agricultural lands, because the set aside of the land especially in mountain landscapes have important environmental impacts.

Acknowledgements

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ENVIRONMENTAL CHANGES CAUSED BY HUMAN ACTIVITY AND CLIMATIC CHANGE, DURING LAST 40 YEARS, IN A RIVER BASIN (ITALY): LINK WITH DESERTIFICATION RISK

Donatella Pavanelli[1] , Claudio Cavazza[2]

[1] Department of Earth Sciences and Environment, Bologna University – Italy
e-mail donatella.pavanelli@unibo.it
[2] Reno Catchment Technical Service, Emilia-Romagna Region, Bologna -Italy

Summary

The purpose of this study is to investigate environmental changes occurred in the last forty years, due to agriculture and climate change, in a river basin (Senio) representative of many Italian areas, and linkages with the risk of desertification. The work considers the soil use variations, changes in agricultural crops and changes in water reservoirs, through aerial and satellite images of the years 1972 and 2003, finally compare present-day catchment budget for the Senio river with an estimate of the 1972 catchment budget.

The Senio basin is a typical landscape of North East Apennine (Italy): the clayey lithology is dominant and it is considered hydrogeological risk, the summer is dry and the agriculture is intensive. It is also a typical example of the history of the Apennine landscape, where two phenomena occurred in the Apennines from the 50s until nowadays: the persons moving to cities and valley and the agricultural mechanization. The consequences are evident on land use: abandonment of less productive fields and enlargement of the remaining fields to allow mechanization. Moreover in the half of XX century were carried out numerous of land reclamation for water control, for soil defence

and for the water storage. The study shows a relationship between variations in the time of water reservoirs and the extension and kind of crops variations: in the '70s, the reservoirs had mainly a hydraulic purpose of regulation and surface runoff control and for livestock use. During the last years the new water reservoirs are made near the torrent, they are changed both in size and building characteristics in order to sustain the growing irrigation demands. This critical situation has worsened with the introduction in the 80s with high water needs crops, fruit trees and especially the kiwi (Actinidia). In addition to these changes caused by human activity, it must also consider the climatic variation observed, in particular the increase in average temperature of 1,1°C (1991-2008). The direct cons equence of these changes have greatly reduced the flow of the river Senio. For these causes the basin is considered to desertification risks.

Key word: environmental changes, desertification risks, forcing factors, Apennine basin

Introduction

The definition of desertification risk (UNCCD, United Nations 1994) is: «the land degradation in arid and semiarid and dry sub humid area resulting from various factors, including climatic variations and human activities», the land degradation is defined as a «loss of land's biological and economic productivity and complexity». Based on these definitions, the risk of desertification and the desertification are the product of two groups of factors: predisposing and forcing. Among the main predisposing causes of an area at risk of desertification are the climatic conditions, soil characteristics and morphology, they can be consider therefore environment natural factors. Climatic features can be considered as the active factor, while the fragility soil is a cause passive, these factors are very difficult to alter, while the morphology is a factor which can partially be modified, for example with bioengineering works. Human activities, such as agriculture, water pollution and soil, etc., are forcing the desertification risk, these factors may trigger processes of drought and of desertification into breakable environment. We may think and hope that these forcing factor can be modified to combat desertification. This work aims to study the current environment, put it in comparison with the past to understand the trends and identify possible interventions. Obviously, this methodology can be applied at all scales: both the scale of climate change in small-scale river basin. However, small scale data are more readily available and often the interventions are feasible and the results can be achieved in reasonable time.

The study area concerns the Senio, a Apennines torrent between Tuscany and Emilia -Romagna, about 50 Km south east from Bologna (Fig. 1). The watershed extension is of 271 km^2, it has maximum altitude 1187 m, and it is a typical Apennines setting: its lithology is dominated by sedimentary formations, with clayey lithology, impermeable soils, extensive and severe soil erosion, presence of badlands (*calanchi)* and unstable hillsides. Sandstone and loam rock are present in the higher south part of the basin, whereas clays Pliocene are in the north, often outcropping as gullies. Woods and mainly chestnut woods represent land use at higher altitudes, while at lower altitudes and more fertile lands there are orchards, vineyards, horticultural crops. Climate typical of the Apennines has two maximum precipitation in spring and autumn, the two minimum winter and summer, with a long dry season lasts from June until the August. The annual

average precipitation (1991-2008) is 993 mm (Castel del Rio gauge), few snowfalls occur during winter, in the higher part of the basin, the annual average temperature is 12,4°C

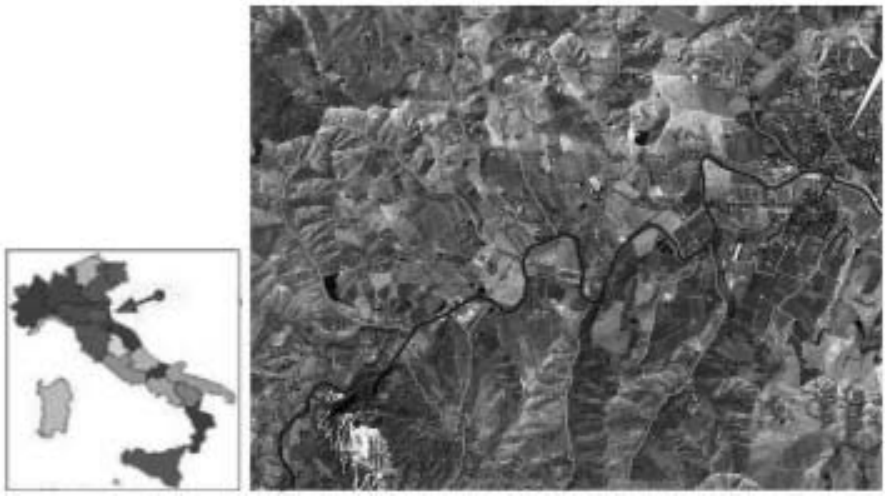

Figure 1. Senio torrent is located in the North East Apennine (Italy), right: satellite image (Ortosat 2003) of a portion of the Senio basin and pattern.

Materials and methods

The water reservoirs and the soil use variations of the Senio basin have been analysed with the support of aerial photos (1972) and of satellite images (ORTOSAT 2003-Quik Bird), with direct measurement, and with GIS Arcview 3.2. The two maps (1972 and 2003) of vegetation cover have been made with photogrammetric interpretation of the aerial photography and satellite images, with focus to orchards and vineyards and of the water reservoirs. The two maps have been overlapped to compare both the spatial distribution and areas of the soil use and water reservoirs. Inflow and outflow of the Senio basin have allowed to estimate the average rate of runoff (1951-77), finally the temperature changes give us an indication of the likely evolution of the climate.

Results and discussion

With regard to climate change shows the comparison of rainfall and temperature of the periods 1961-1990 and 1991-2008 to the basin measuring station of Castel del Rio (216 m. s.l.) (tab. 1) . The data shows an increase in temperature of 0,37°C/10 years, about 9% on the three decades 1961 -1990, accompanied by a reduction in precipitation of 2.3%. The data are particularly significant when compared with other stations of the Emilia Romagna showing similar trends.

Table 1 Comparison of average annual rainfall and of temperature measured at the Castel del Rio gauge (Arpa SIM, Emilia Romagna Region) on two periods.

	1961-1990	1991-2008	difference
Rainfall mm	1016	993	- 23 mm
Temperature °C	11,3	12,4	+ 1,1°C

The estimated mean annual of the rainfall and of the outflow for the period 1951- 78, in the Senio mountain basin, to the measuring station of Castel Bolognese (ARPA SIM, Emilia Romagna Region), are respectively of 1000 mm (rainfall) and 375 mm (outflow), and during summer month July and August the river outflow estimate is about 1500000 m_3. The comparison between inflow and outflow estimated in the two periods 1951-78 and 1987-2004 shows a slight variation in rainfall, while the outflow in the Senio is significantly reduced: 59% in winter and 65% during the spring. The mean annual rate (=outflow/ inflow basin) during the period 1951-78 is 0,37, and the estimated coefficient of average annual runoff for the period, 1987-2004, is 0.20. Respect to the analysis of reservoirs on the two maps of 1972 and 2003, most interesting aspect are: the number of reservoirs has decreased from 269 units to 239 (-30 units); the average size of area of the reservoirs has increased from 917 m^2 to 1929 m^2 (Figure 2), the total area of reservoirs has increased from 246690 to 445701 m^2. The old reservoirs (1972) were mainly on the slopes and in the small basins outlet, precipitation and runoff filled them.
Currently the reservoirs are located on river terraces and near to irrigated crops and are filled with water streams or wells, with pumps. Respect to the analysis of soil use changes on the maps of 1972 and 2003, there was an increase in the area orchards and vineyards, passing from 6.3% to 13.5% in 2003. In general, the most significant changes for the environmental is due, not to the greater extent of fruit trees, but rather to the conversion of orchards and vineyards to tree crops with higher water needs as the Actinide (Kiwi), with serious impact on the water needs (Figure 3). Indeed the Actinide water needs is of 2500 m3/ha (irrigation period : April - September), while for the Peaches trees is about 1500 m^3/ha (June - August) and for Vineyards and others fruits trees is of 1000 m^3/ha.

The amount of water for agricultural use taken from surface water is estimated of 1,600000 m^3 /year, of which 1,000000 m^3 are need for irrigation during the months of July and August. The situation worse when you consider the other uses of surface water : as water for civil use about 350,000 m^3 per year. Despite during the last twenty years many little reservoirs have been realized, they are no longer able to

satisfy agricultural water demand, which is risen exponentially due to introduction of Kiwi (Actinidia) against grapevine and orchard ones. This situation has a strong negative effect on the whole environment, especially on the minimum river flow of Senio, and is a limiting factor to a sustainable development of society.

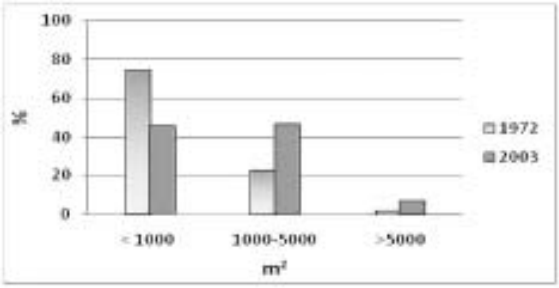

Figure 2. Variation (%) of the water reservoirs during forty years, for three classes of area.

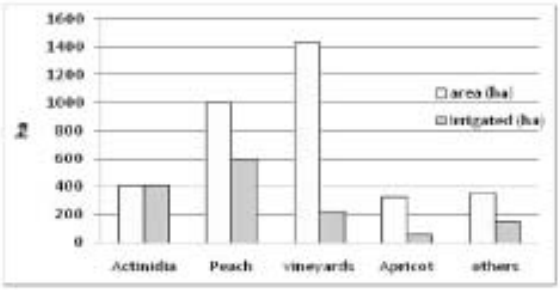

Figure 3. Comparison between the total area and irrigated area of each fruit tree variety (2003) in the Senio basin .

Conclusions

The water reservoirs and the soil use variations (1972-2003) of the Senio basin have been analysed, the study showed the following aspects: abandonment of unproductive fields and enlargement of the crop fields to allow mechanization; abandonment of old hilly water reservoirs built for livestock, for soil defence and for the runoff control and water storage; the introduction of exotic species, like the kiwi, high water demanding; the new water reservoirs are made near the torrent, they are changed both in size and building characteristics in order to sustain the growing irrigation demands during summers.

With regard to climate change, the comparison of rainfall and temperature, periods 1961-1990 and 1991-2008, shows: the temperature increase of 1,1°C in the last thirty years, the trend of rainfall does not seem significantly changed, while the average annual runoff coefficient of Senio basin shows a strong reduction (54%). These observations indicate the trend of an increase in the average volume of reservoirs, due to the difference in use over time. Despite the increase in reservoirs to irrigation, water balance of basin appears to be at the alert level. Depletion of surface water causes a serious impact on minimum flow of the Senio and causes imbalances in the

ecosystem of the river. At last the disappearance of many reservoirs, abandoned and underground, with function of water regime, can have significant repercussions also on the hydrogeological risk. All these changes are going in the direction of critical environmental and risk of desertification. Various hypothesis can be considered in order to reduce the risk of desertification in this area:

- Water demand reduction;
- Optimisation of water management;
- Increase of water storage through realization of new reservoirs and other hydraulic works, to the purpose of cover current water balance deficit.

The first hypothesis seems impractical because it involves a shift to crops with low water demand, possible only with adequate politics and economic incentives. The second hypothesis proposed to improve the efficiency in the use of water, but we are in the presence of a modern agriculture and intensive. The stakeholders are moving towards this latter case: toward the construction of new reservoirs. However, the increased availability of water may lead to an increase in irrigated crops, more profitable, through a difficult process to stop.

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ESTUDO SOBRE A DINÂMICA DO ÍON CÁLCIO NO SOLO DO ATERRO MUNICIPAL DE VOLTA REDONDA

Maryana Antonia Braga Batalha Souza

Pós-Graduação em Engenharia Metalúrgica-EEIMVR-UFF, Volta Redonda – RJ, Brasil, maryana@metal.eeimvr.uff.br

Resumo

O cálcio é um importante nutriente para o solo, porém quando há a infiltração de uma quantidade excessiva se torna nocivo. O transporte do lixiviado de aterros através do solo está sujeito a processos físicos e biológicos, o que torna seu estudo complexo e essencial para prever a poluição das águas subterrâneas. Sendo o cálcio encontrado em quantidades significativas em lixiviado de Aterro, o presente trabalho consiste no estudo da previsão da dinâmica deste íon inorgânico, no solo do Aterro Municipal de Volta Redonda no Estado do Rio de Janeiro. O estudo se baseia no movimento do liquido contaminante (solução) no meio poroso (solo), com a determinação da sua taxa de geração e quantificação de sorção ocorrida entre eles. Para tanto foram realizados ensaios em colunas de PVC, com fluxo de liquido para verificação do comportamento do íon cálcio, quando o mecanismo de transporte utiliza um gradiente hidráulico, ou seja, ocorre um movimento da solução no solo. Os resultados obtidos para as condições de laboratório permitiram demonstrar o movimento do íon cálcio no solo do Aterro Municipal de Volta Redonda e os possíveis impactos originados da infiltração e concentração deste íon no solo.
Palavras-chave: Cálcio, Solo, Mecanismos de Transporte.

Introdução

Embora alguns solos funcionem como filtros naturais, retendo e reciclando grandes quantidades de resíduos, elevadas quantidades de compostos tóxicos podem ser transferidos para os cursos de água e para os aqüíferos (Progeo 2009). Em todo o mundo, a poluição do solo e da água resultante do desenvolvimento urbano e industrial e da agricultura intensiva, constitui um importante tema de investigação. A recuperação dos solos severamente poluídos só pode ser conseguida na maioria das vezes com recurso a tecnologias dispendiosas (Ciência da Terra para a Sociedade 2009).

Atualmente, a comunidade científica enfatiza, com uma freqüência cada vez maior, o estudo da contaminação dos solos de aterros, sanitários ou controlados, causada pela deposição de resíduos sólidos urbanos.

As atividades de destinação final de resíduos sólidos urbanos no município de Volta Redonda vêm sendo feita no local do aterro desde 1986. Não foi realizado nenhum tipo de preparação do solo a fim de receber os resíduos, fazendo com o aterro fosse denominado de lixão. Atualmente a disposição dos resíduos acontece de forma controlada devido a um Termo de Ajuste de Conduta (TAC) (Saaeg 2006). Verifica-se uma redução na importância da política ambiental brasileira (Valente 2000) no nível federal e um aumento em âmbito municipal, em vários estados brasileiros, de experiências nas políticas públicas locais estimulando ações que promovam práticas ambientais centradas na sustentabilidade (Ferreira 1998).

Com a atual necessidade de se lidar com problemas da contaminação do solo e da água subterrânea, faz-se necessário o estudo dos problemas de contaminação por produtos químicos orgânicos e/ou inorgânicos. Estes estudos envolvem a determinação dos parâmetros físicos destes compostos bem como sua dinâmica quando dissolvidos na água subterrânea. Deste modo, propõe-se neste trabalho avaliar o comportamento do íon cálcio presente no lixiviado e no solo do Aterro Municipal de Volta Redonda. Para tanto foram realizados ensaios em coluna de PVC com a utilização do solo do Aterro Municipal de Volta Redonda e três diferentes soluções contaminantes; lixiviado do Aterro Municipal de Volta Redonda, gesso agrícola e água deionizada e destilada com a presença de gradiente hidráulico.

Materiais e métodos

Como mencionado acima, a utilização de três diferentes líquidos durante a lixiviação ocorreu devido à necessidade de avaliação do comportamento do íon frente a distintas concentrações. As amostras de solo utilizadas no experimento são provenientes da jazida que fornece material para cobertura do Aterro Municipal da cidade de Volta Redonda, e foram coletadas em 20 pontos distintos do terreno a uma profundidade de 0,10 a 0,20 m.

O experimento foi realizado em colunas de PVC com diâmetro de 10 cm e uma altura de 30 cm, dos quais 10 cm foram preenchidos com solo do Aterro Municipal de Volta Redonda. Os tubos de PVC foram dispostos na vertical e apoiados em um tampo de madeira de uma mesa de ferro construída especialmente para realização deste ensaio. Na parte inferior das colunas foram colocadas telas de nylon, que tiveram como finalidade sustentar o solo da coluna e os manter na mesma altura durante todo o experimento, permitindo a passagem apenas da solução e não do solo. Na extremidade inferior do tubo foram colocados dois redutores de PVC para que o diâmetro de 100

mm passa-se a 50 mm e depois para 25 mm, a fim de que o lixiviado produzido no experimento fosse coletado com uma maior facilidade. Dentro de primeiro redutor utilizou-se um filtro de papel para sustentação das bolinhas de gude, as bolinhas foram utilizadas para a simulação de uma maior porosidade não encontrada dentro do tubo, porosidade essa encontrada na natureza onde facilita o movimento do lixiviado. Após a montagem de toda estrutura de PVC na mesa auxiliar foi adicionado o solo do Aterro Municipal de Volta Redonda em cada um dos tubos, o qual sofreu apenas uma compactação natural devido à ação da força gravimétrica sobre a massa de solo. A quantidade de solo presente em cada tubo é de 872,41 g, sendo este solo saturado com água destilada e deionizada a 70% da capacidade de campo, sendo a capacidade de campo a quantidade de água restante no solo após o excesso ter sido drenado.

Os ensaios foram realizados num período de cinco dias. Durante a realização dos ensaios a aplicação da solução às colunas foi feita com o auxilio de bicos de garrafas pets com as tampas furadas, de modo que a solução fosse adicionada lentamente no centro da coluna, evitando fluxo pelas paredes laterais. Foi adicionado sobre o solo um volume de 200 mL de solução (lixiviado do aterro, solução de gesso agrícola e água deionizada e destilada). Após o ensaio, o liquido coletado foi devidamente armazenado em recipientes de plástico de 200 mL em ambiente refrigerado e enviados para análise química. O solo contido nos tubos foi retirado e fatiado, com a adição das soluções nas respectivas colunas, ocorreu uma compactação deste solo, fazendo com que a sua altura ocupada no tubo passa-se de 10 cm para 8 cm, totalizando em cada colunas 4 fatias de 2 cm. As colunas de PVC foram desmontadas e o solo fatiado das colunas foi homogeneizado para ser enviado para análise.

Resultados e discussões

Os processos envolvidos entre o lixiviado e o solo do Aterro Municipal de Volta Redonda, tais como sorção e difusão molecular, foram analisados através de ensaios de laboratório e de ensaios em coluna de PVC.

O resultado do ensaio de sorção é apresentado na Figura 1, através do gráfico de concentração de equilíbrio em função da quantidade de massa sorvida, para o íon Ca^{2+}, juntamente com seus valores de coeficiente de distribuição (K_d) e coeficiente de correlação (R^2) para os modelos linear.

Deste modo, apresentam o ajuste dos pontos experimentais ao modelo teórico para isoterma linear, que apresenta um caráter sorcivo para o íon Ca^{2+}.

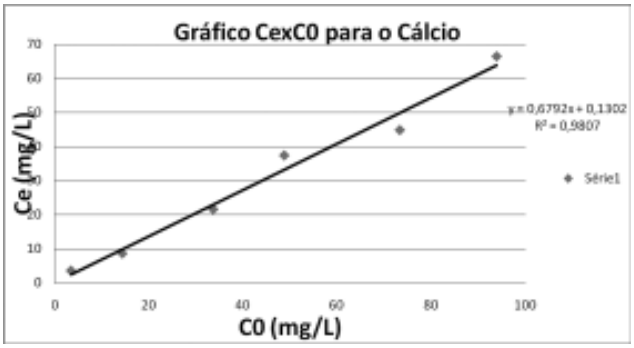
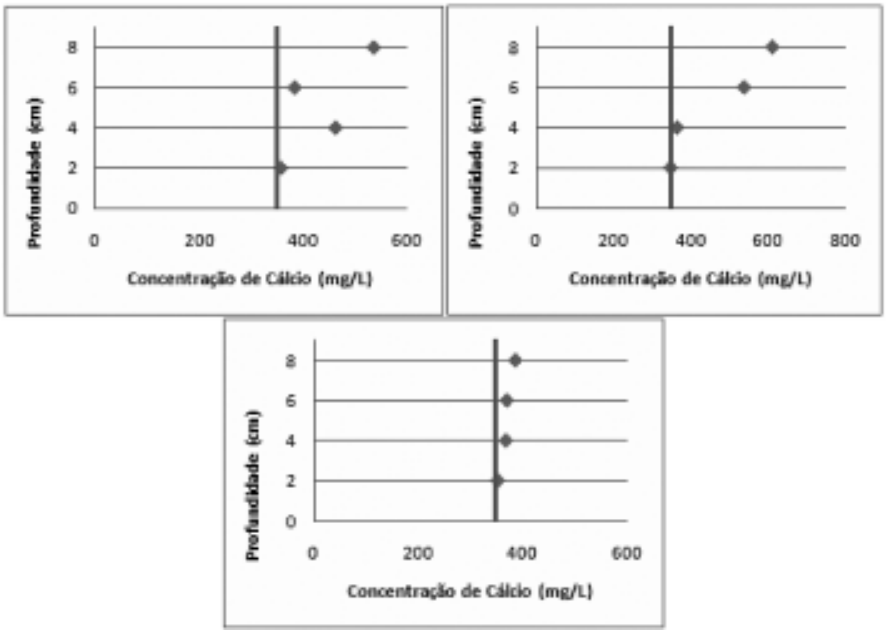


Figura 1 – Gráfico da concentração de equilíbrio do lixiviado em função da quantidade de massa sorvida, para o íon Ca^{2+}.

Os ensaios de coluna foram realizados com amostras de solo com compactação natural e saturado parcialmente (70%), utilizando diferentes soluções contaminantes: lixiviado retirado do Aterro Municipal de Volta Redonda, gesso agrícola diluído em água destilada e água destilada e deionizada. Os ensaios foram realizados num período de 5 dias com recolhimento das amostras ao final deste período. Esse tempo foi determinado através de estudos e testes anteriores a fim de se avaliar a migração do íon cálcio no solo com influência de gradiente hidráulico.

A seguir são apresentados os perfis de contaminação do íon Ca^{+2}, existente na massa bruta de solo (através de análise por digestão) referente às colunas de lixiviado, gesso agrícola e água destilada e deionizada. A coluna de PVC utilizada para os ensaios possui uma altura de 8 cm de solo, fatiada em 4 partes denominadas: topo, meio topo, meio base e base. O valor da concentração inicial, ou concentração de referência, de cada íon na massa bruta do solo é representado nos diagramas através de uma linha vertical e contínua. Observa-se que os perfis para todas as colunas seguem uma mesma tendência. A concentração é maior nos primeiros centímetros, devido a alta concentração deste íon no solo. Já na última fatia (base) de cada uma das colunas, observa-se que a concentração se aproxima à inicial do solo, ou possui concentrações menores.



(a) (b) (c)

Figura 2 - Perfil de contaminação, na presença de lixiviado (a), gesso agrícola (b) e água destilada e deionizada (c), do íon Ca^{+2} nas colunas.

Os ensaios em coluna de PVC mostraram que na massa bruta de solo, contendo o lixiviado do aterro como solução contaminante tende a se aproximar da concentração inicial do solo sem contaminação. O que leva a concluir que ocorre a absorção destes íons pelo solo. Sendo a solução gesso agrícola, o íon cálcio aumenta em relação ao valor contido na amostra de solo sem contaminação, verificando assim, que a solução de gesso agrícola influência no comportamento deste íon contido na massa bruta de solo. Os ensaios realizados com água destilada e deionizada, não apresentaram variação na concentração de cálcio contida na massa bruta de solo.

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ANÁLISIS DE CORRESPONDENCIAS SIMPLE Y DE REGRESIÓN LOGÍSTICA BINARIA DE LAS CAUSAS DE LA DEGRADACIÓN DEL SUELO

J. Víctor Tamariz Flores[1], Gladys Linares Fleites[2], Jesús Ruiz Careaga[2] Rosalìa Castelán Vega [2]

[1]Postgrado de Ciencias Ambientales- ICUAP, 14 Sur 63 01, San Manuel, Puebla, Pue. C.P.72570. Email: jtamariz@siu.buap.mx.
[2]Departamento de Investigación en Ciencias Agrícolas.(DICA) Instituto de Ciencias, Benemérita Universidad Autónoma de Puebla

Resumen

Las relaciones entre el grado de erosión del suelo, su relieve, su profundidad y la pendiente que exhiben, son de gran importancia para realizar enfoques ambientalistas e incorporar conceptos de manejo y conservación de los suelos. En este trabajo se persigue como objetivo la aplicación del Análisis de Correspondencias Simples para determinar las causas de degradación del suelo a partir de algunas de las variables cualitativas que lo caracterizan y modelar el grado de erosión, categorizado en los niveles de bajo y alto, en función del relieve, la pendiente y la profundidad del suelo a través de la Regresión Logística Binaria. Las representaciones gráficas que se obtuvieron con estas técnicas, contribuyen a esclarecer las causas que determinan la degradación del suelo en la zona. El modelo de Regresión Logística obtenido corroboró que en los suelos de relieve montañoso y en pendientes de más de 30%, la degradación del suelo por erosión es muy fuerte por lo que es indispensable la aplicación integral de medidas encaminadas a la conservación de los suelos para que ayuden a disminuir la degradación del recurso, así como, a la recuperación paulatina de las áreas afectadas por la erosión.

Introducción

En el DICA se ha llevado a cabo un estudio de ZAE de la Sierra Norte de Puebla, México, logrando estudiar las posibles causas de degradación del suelo. Con la información disponible se realizó inicialmente un estudio exploratorio a través del Análisis de Correspondencias (Linares, *et al*, 2006). El hecho de que se manejen variables cualitativas confiere una característica distintiva a esta técnica y es que no se utilizan como datos las mediciones individuales, sino frecuencias de una tabla. Si sólo se tiene dos variables cualitativas, cada una de las cuales puede presentar varias modalidades o categorías se utiliza el llamado Análisis de Correspondencia Simples (ACS). La

modelación del grado de erosión de estos suelos en función del relieve, la pendiente y la profundidad, permite confirmar la hipótesis de la existencia de relaciones entre estas características, exploradas por el ACS. El grado de erosión fue categorizado en dos niveles (bajo y alto) por lo que se puede obtener una función de predicción a través de la Regresión Logística Binaria (RLB). En el desarrollo del trabajo se hace una caracterización de la zona de estudio y de la tabla de datos y, posteriormente, se exponen los estudios exploratorios y confirmatorios realizados con las técnicas de ACS y RLB.

Materiales y métodos

La investigación fue desarrollada en el noroeste de la Sierra Norte de Puebla. Para determinar el grado de erosión de los suelos se realizó la prospección edafológica, Después de seleccionar los perfiles más conservados, y que eran representativos de la zona de estudio se tomaron como Perfiles Patrón y se compararon con cada perfil de los sitios descritos para identificar las perdidas sufridas del suelo. Se pudo diagnosticar la erosión dentro de las siguientes categorías o grados: Nula: cuando no se aprecia diferencia con el perfil patrón. Leve: si el suelo ha perdido al menos el 25% del espesor de su horizonte A. Moderada: cuando la perdida es de 75% o más. Fuerte. Cuando el suelo ha perdido el horizonte A y al menos el 25% del horizonte B. Muy fuerte: cuando el horizonte B se ha perdido hasta en un 75% o más. Los análisis estadísticos se realizaron a partir de una tabla de datos de dimensión 100 por 4, elaborándose las tablas de contingencias de interés. Las variables con sus correspondientes categorías se relacionan a continuación: Grado de erosión (nada, leve, moderada, fuerte y muy fuerte).

Relieve (llano, casi llano, ligeramente ondulado, medianamente ondulado, ondulado, fuertemente ondulado, alomado, montañoso).

Pendiente (menor de 5%, entre 5 y 10, de 10 a 20, de 20 a 30, de 30 a 40 y más de 40%)

Profundidad del suelo (menos de 10 cm, de 10 a 20, de 20 a 40, de 40 a 60 y más de 60 cm). (Ruiz *et a*l, 2005).

Resultados y discusión

Análisis exploratorio a través del análisis de correspondencias simples (ACS).

El ACS está particularmente adaptado para tratar tablas de contingencias, representando los efectivos existentes en las múltiples categorías combinadas de dos variables cualitativas. Al cruzar en una tabla de contingencia el carácter I, con el carácter J (en columnas) podemos representar el número de unidades estadísticas que per-

tenecen simultáneamente a la modalidad i del carácter I y a la modalidad j del carácter J mediante las frecuencias kij (Linares, 2006). Con el fin de estudiar las relaciones entre el conjunto de modalidades del carácter I (relieve, pendiente y profundidad del suelo) y las modalidades de carácter J (grado de erosión), se llevó a cabo un Análisis de Correspondencias Simples con estas parejas de variables cualitativas. Se utilizaron la distancia ji-cuadrado, el método de estandarización de centrar las filas y las columnas y el método de normalización simétrico donde para cada dimensión, las puntuaciones de las filas son la media ponderada de las puntuaciones de columna divididas por el valor propio coincidente y las puntuaciones de columna son las media ponderada de las puntuaciones de fila divididas por el valor propio coincidente. Finalmente, se hace la reducción a dos dimensiones, para obtener las representaciones gráficas respectivas. Para el estudio de la relación del grado de erosión con el relieve se obtienen el Cuadro 1 y la Figura 1. Una reducción a dos dimensiones, tiene una inercia de 0.5855, de la que 0.5483 corresponden a la primera dimensión y 0.0372 a la segunda dimensión. La primera dimensión y más importante señala oposición entre relieves llanos y montañosos. La Figura 1 muestra la cercanía de los puntos que representan las categorías de ambas variables, evidenciándose que en relieve montañoso la erosión es muy fuerte, mientras que en los suelos llanos, ligeramente o medianamente ondulados la erosión es leve o moderada.

Para el estudio del grado de erosión y la pendiente el Figura 2. La representación gráfica muestra un 94% de la variabilidad total. La primera dimensión señala la oposición entre pendientes bajas y altas.

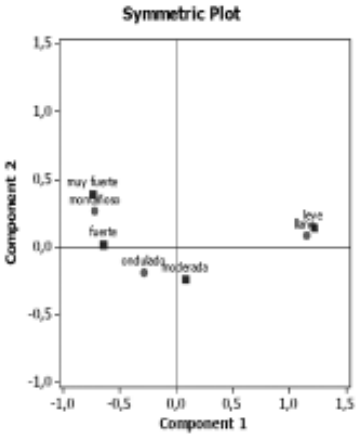

Figura 1. Representación en dos dimensiones del Relieve y el Grado de Erosión

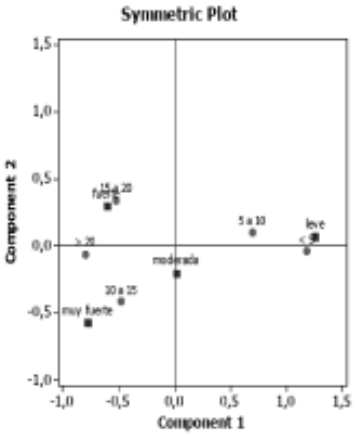

Figura 2. Representación en dos dimensiones de la Pendiente y el Grado de Erosión

Puede apreciarse que los puntos que indican erosión leve o nula están muy cercanos a las pendientes bajas (menor de 10), mientras que, por ejemplo, los puntos erosión «muy fuerte» y pendiente «de 10 a 15» están muy cercanos. De la misma manera ocurre con los puntos que representan la erosión fuerte y la pendiente de 10 a 20. Siguiendo la metodología anterior, el gráfico 3 permite analizar la relación entre el grado de erosión y la profundidad del suelo. La representación en dos dimensiones acumula el 100 % de inercia (0.2461 en la primera dimensión y 0.0159 en la segunda). Los puntos que representan los grados de erosión fuerte y muy fuerte están ubicados muy cercanamente al punto que representa profundidad del suelo menor a 20 cm.

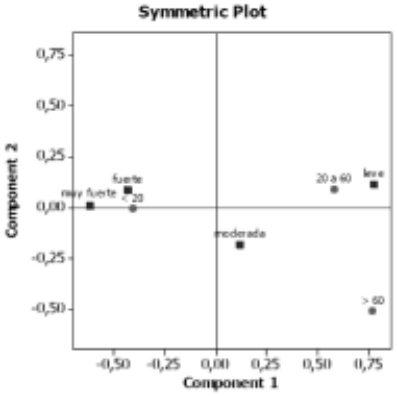

Figura 3. Tabla de correspondencia entre profundidad del suelo y grado de erosión.

El Cuadro 1 resume los resultados. La interpretación de los coeficientes estimados en la RLB depende de la función de enlace, en nuestro caso, logit, del evento de referencia y de los niveles de los factores de referencia. Como puede apreciarse en la tabla por los

Cuadro 1. Regresión Logística Binaria para el grado de erosión versus el relieve, la profundidad y la pendiente

Predictor	Coeficiente	Error Estánda Coeficiente	Z	p	Razón "Odds"
Constante	21.2426	5477.85	0.00	0.997	
Relieve					
ondulado	-39.7172	9630.78	-0.00	0.997	0.00
montañoso	-40.8727.	13877.1	-0.00	0.998	0.00
Profundidad					
De 20-60	41.0708	5255.24	0.01	0.994	6.8680E+17
>60	80.5910	11575.5	0.01	0.994	1.0005E+35
Pendiente					
De 5 a 10	-1.89769	8660.31	-0.00	1.000	0.15
De 10 a 15	-2.07523	11269.4	-0.00	1.000	0.13
De 15 a 30	-2.15418.	11764.9	-0.00	1.000	0.12
>30	-41.8346	1667.9	-0.00	0.998	0.00

valores de los coeficientes estimados y de la razones «odds», todos los factores considerados tienen efecto sobre la respuesta. El estadístico G = 137,989 con 8 grado de libertad muestra un valor de p empírico de 0.00, indicando que existe suficiente evidencia de que al menos uno de los coeficientes es diferente de cero. Obsérvese que, sin embargo, los valores de p empírico de las pruebas Z para cada coeficiente no permiten rechazar la hipótesis nula de que cada uno de los coeficientes es igual a cero, lo que pone de manifiesto problemas de multicolinealidad. Además de esta evidente contradicción entre las pruebas de hipótesis anteriores, obsérvese que los errores estándar de los coeficientes son valores muy elevados y, por tanto, el modelo (aunque confirma las relaciones entre el grado de erosión y las características de los 48 suelos utilizadas como predictores) debe ser utilizado con precaución si se deseara hacer predicciones del grado de erosión de estos suelos.

Conclusiones y recomendaciones

El Análisis de Correspondencias Simple, es una herramientas estadísticas de utilidad a los investigadores de la Ciencia del Suelo, dado que le permite plantear hipótesis de investigación que luego podrán ser corroboradas con otros análisis confirmatorios. Las representaciones gráficas que se obtuvieron, contribuyen a esclarecer las causas que determinan la degradación del suelo en la zona Noroeste de la Sierra Norte de Puebla.

El modelo de Regresión Logística obtenido corroboró que en los suelos de relieve montañoso y en pendientes de más de 30º, la degradación del suelo por erosión es muy fuerte por lo que es indispensable la aplicación integral de medidas encaminadas a la conservación de los suelos.

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EROSIÓN Y MARGINACIÓN EN EL MUNICIPIO DE PAHUATLÁN, PUEBLA, MÉXICO

Rosalía Castelán Vega, Gladys Linares Fleites, Jesús Ruiz, Víctor Tamaríz

Departamento de Investigación en Ciencias Agrícolas, Instituto de Ciencias, Benemérita Universidad Autónoma de Puebla. México. Email: jtamariz@siu.buap.mx.

Resumen

En el medio rural mexicano, al igual que en otros países, se vive una situación compleja: marginación y pobreza extrema en muchas comunidades y una alta degradación de la mayoría de los recursos naturales, sobre todo el recurso suelo. Sin embargo pocos son los estudios que tratan de buscar los principios que vinculan esta problemática y que tratan de establecer las relaciones existentes. En este trabajo el objetivo fue establecer la relación de causalidad entre el gado de marginación y la degradación de los suelos bajo el contexto de erosión, en el municipio de Pahuatlán, Puebla, México, el cual se ubica en la zona montañosa con una población en su mayoría indígena. Para establecer el grado de marginación se extrajeron indicadores del Consejo Nacional de Población (2005) y se aplicó una encuesta de calidad a una muestra de la población. Para el caso de la erosión se estimó mediante el empleo de la metodología establecida por la FAO en 1980. Con el fin de establecer la relación entre estas variables se realizó un análisis estadístico de correspondencia simple. Los resultados obtenidos evidencian un grado de marginación de mediano a muy alto en el municipio, hecho que ha favorecido una alta migración de la población joven del municipio. Por lo que respecta a la erosión según la metodología empleada se clasificó de moderada a muy fuerte, debido principalmente a la alta deforestación y al empleo de técnicas inadecuadas para zonas de montaña. Se realizó el mapa de erosión actual a una escala 1:250,000. El análisis estadístico reflejó y comprobó una alta relación ente el grado de marginación y grado de erosión en el municipio en estudio. Por lo que impera una definición clara de que las políticas públicas y programas de desarrollo y manejo de los recursos naturales, especialmente el suelo, sí se alcanzar la sustentabilidad de la región y superar los niveles de marginación que presentan las comunidades indígenas de la zona.

Palabras clave: Pobreza, marginación, erosión.

Introducción

La población con mayores índices de marginación se concentra principalmente a lo largo de las zonas montañosas, en las cuales, paradójicamente se encuentran áreas ricas en recursos naturales por la diversidad de su ambiente. Sin embargo debido a la falta de recursos económicos los habitantes de estas zonas se han visto obligados a realizar una explotación intensiva de estos recursos. Tal es el caso del municipio de Pahuatlán del Valle, en donde la población presenta grados de marginación alta y muy alta y la agricultura en ladera se ha practicado desde hace décadas, provocando la erosión acelerada de los suelos y la degradación del entorno en muchos sectores de la región (Ruiz *et al*, 2001). Por lo que el objetivo de la presente investigación fue establecer la relación entre el gado de marginación y la degradación de los suelos bajo el contexto de erosión en el municipio de Pahuatlán, Puebla, México.

Materiales y métodos

El municipio de Pahuatlán se localiza en la parte noroeste del estado de Puebla, se asienta sobre una planicie de las laderas del cerro de Ahila. Sus coordenadas geográficas son los paralelos 20º 13' 12" y 20º 21' 98" de latitud norte, y los meridianos 98º 04' 18" y 98º 12' 12" de longitud occidental (Fig. 1). Tiene una superficie de 97 kilómetros cuadrados que lo ubica en el lugar 140 respecto a los demás municipios del estado. Para diagnosticar el grado de erosión de los suelos se seleccionó el perfil más conservado, y se comparó con cada perfil descrito en la zona de estudio, observando las pérdidas que pudieran haber sufrido uno o varios de los horizontes y calcificándolos dentro de las siguientes categorías (FAO, 1980): Nula, leve, moderada, fuerte y muy fuerte.

Figura 1. Localización de la zona de estudio.

Para estimar el grado de marginación por localidad, se extrajeron indicadores del Consejo Nacional de Población del año 2000 y se aplicó una encuesta a una muestra representativa de la población, en la que se establecieron preguntas enfocadas a la calidad de sus servicios de vivienda, drenaje, salud y luz eléctrica, así como indicadores relacionados con la migración y la educación.

Resultados y discusión

Los resultados muestran que el 19% de la superficie del municipio presenta erosión moderada, el 29% ya presenta erosión fuerte y el 52% se encuentra afectado por erosión muy fuerte (figuras 2 y 4). En lo que respecta al grado de marginación, el 16% de la población vive en condiciones de marginación media, el 32% en alta marginación y el 52% con marginación muy alta (Figura 3). Se aplicó un análisis de correspondencia simple en el programa estadístico MINITAB 15, para establecer la relación entre el grado de erosión y el de marginación en el municipio, pudiendo apreciar claramente en el Figura 5 dicha relación, ya que se observa claramente como en el primer eje existe una fuerte asociación entre la erosión muy fuerte y la marginación muy alta, en el segundo eje se asocian la erosión moderada con la marginación media, y en el tercer eje la erosión fuerte con la marginación muy fuerte.

Conclusiones

Debido a la comprobación de la estrecha relación de causalidad entre el grado de marginación y el de erosión en el municipio de estudio, impera que las políticas y programas de desarrollo y manejo de los recursos, especialmente el suelo, la consideren sí se quiere alcanzar la sustentabilidad, y con esto mantener en lo posible el equilibrio ecológico, finamente establecido en los ecosistemas de la región.

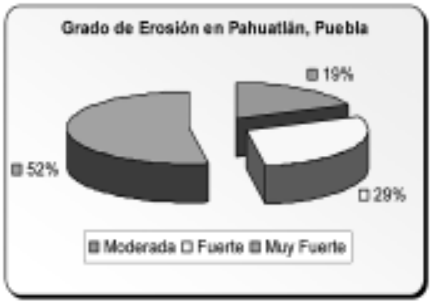

Figura 2. Superficie afectada por el proceso degrado de erosión en el municipio de Pahuatlán, Puebla

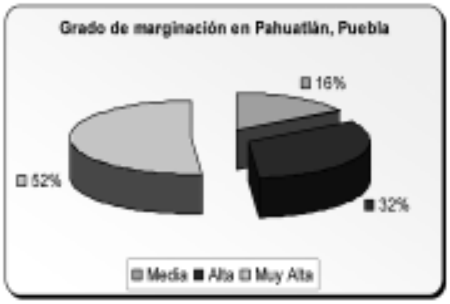

Figura 3. Población afectada según grado de Marginación en el municipio evaluado.

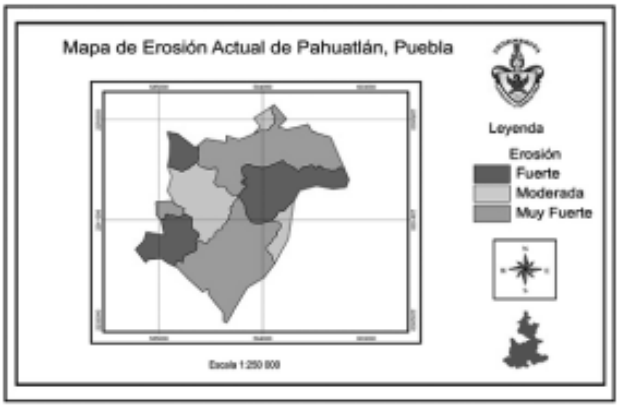

Figura 4. Distribución espacial del grado de erosión en el municipio de Pahuatlán, Puebla.

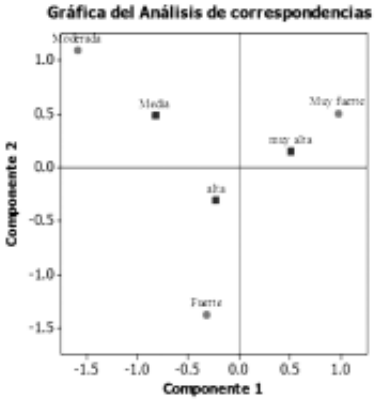

Figura 5. Análisis de correspondencia simple

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EFFECTS OF VEGETATIVE COVER AND RESIDUES MANAGEMENT ON WATER EROSION IN STEEPLANDS OF COLOMBIA

Franco Humberto Obando Moncayo

Departamento de Sistemas de Producción, Universidad de Caldas, Calle 65 No. 26-10, Manizales, Colombia, Tel: 57 68 8781517; Fax: 57 68 8781518; efrancoh.obando@ucaldas.edu.co

Summary

In Colombia it is estimated that 80 percent of agricultural steeplands (= 24 million hectares) are affected by water erosion. Unless suitable farming systems are implemented the harmful effects of erosion will be increased because social pressures and farming encroachment into these ecologically fragile lands. The purpose of the study was to evaluate a weighted crop management factor (Cw) that integrates agronomic conservation practices and cropping systems in terms of the amount of rainfall energy intercepted by the canopy and ground cover. Erosion control trials consisted of Andean raspberry (*Rubus glaucus*) mono-cropping system with conventional hoe tillage and weed management with herbicides, and Andean raspberry interplanting with maize *(Zea mais*), beans (*Phaseolus vulgaris*), and a variety of calabash (*Cucurbita maxima*). A bare soil plot was included as reference treatment. The plots were sited on volcanic ash soils in the high marginal coffee zone of the central Andes of Colombia with slopes ranging between 35 and 67%. An exponential relationship was found between (Cw) and the proportion of canopy and ground cover (C_f). It is concluded that cropping systems and soil management approaches that increase ground cover (residue-based zero tillage and «noble weeds») are effective to control water erosion in steeplands and may lead to the long term sustainability of farming systems. These approaches should be promoted rather than engineering conservation techniques.

Key words: steeplands, conservation agriculture, interplanted crops

Introduction

In Colombia steeplands comprise 27% of the total land area (= 31 million hectares in the Andean region). Historically, these lands have played an important economic and environmental role. They are characterized by high population density and a vast agricultural diversity. However, 80% of agricultural steeplands (= 24 million hectares) are affected by water erosion in some degree (Montenegro

& Olmos 1987). Unless suitable farming systems are implemented the harmful effects of erosion will be increased because social pressures and farming encroachment into these ecologically fragile lands. Technology based on «noble weeds» (Gómez 1990) coupled with no-till technique (stick seeding) along with the interplanting of crops and management of residues have proved to be effective in controlling erosion in coffee-based production systems. Noble weeds are native cover plants that do not compete with crops for water and nutrients because of their shallow root system and close contact with soil; farmers say they are «noble» because do not damage their crops but protect the soil. However, their effectiveness has not been assessed quantitatively. The experimental research described below was to test the hypothesis that the integrated effects of residue-based zero tillage, «noble weeds» and contour interplanted crops will effectively control soil erosion in Colombian steeplands. Thus, a plot study was carried out to evaluate a weighted crop management factor (*Cw*) that integrates agronomic conservation practices and cropping systems in terms of the amount of rainfall energy intercepted by the canopy and surface cover. The research was developed within the framework of the currently growing Andean raspberry (*Rubus glaucus*) based cropping systems in the high marginal coffee zone in the Central Andes of Colombia (HMCZ).

Materials and methods

The field experiment, including land preparation, was carried out over two and a half years (June 2001-December 2003) on La Concha farm (5º12'N, 75º26W, 2100 masl), located in the Neira Municipality of Caldas Department in the Central Cordillera of the Colombian Andes. Prior to setting up the experiment the land had for 15 years been a coniferous (*Pinus patula)* plantation with a native shrub understory. Table 1 shows the physical and chemical properties of the experimental soil determined by standard methods (IGAC, 1990). Mean annual rainfall is about 2000 mm.

Table 1. Main chemical and physical properties of the experimental soil

Organic matter (%)	12	Bulk density ($Mg.m^{-3}$)	0.85
pH	6.2	Sand (%)	64
Phosphorous ($mg. Kg^{-1}$)	27.25	Clay (%)	5
Potassium ($cmol+. Kg^{-1}$)	0.48	Silt (%)	31
Calcium ($cmol+. Kg^{-1}$)	2,80	Total porosity (%)	66
Magnesium ($cmol+. Kg^{-1}$)	2.29	Weighed diameter of water stable aggregates (mm)	2.9
Manganese ($cmol+. Kg^{-1}$)	36.3	Hydraulic conductivity ($cm.h^{-1}$)	21.6
Zinc ($cmol+. Kg^{-1}$)	13.0	Water retention at field capacity, 0.03Mpa ($m^3.m^{-3}$)	51.45
CIC ($cmol+. Kg^{-1}$)	21.5	Water retention at wilting point, 1.5 Mpa ($m^3.m^{-3}$)	28.02

Table 2. Description of erosion control trials

Treatment	Management practice	Slope range(%)
T1	Raspberry mono-cropping and conventional hoe tillage. Weed management with herbicides	37 – 49
T2	Raspberry inter-planted with maize (*Zea mais*) and beans (*Phaseolus vulgaris*), permanent cover, direct drill (zero tillage), selected covers of «noble weeds», management of crop residues	35 – 67
T3	Raspberry with zapallo (*Cucurbita maxima*, a variety of calabash;), permanent cover, direct drill (zero tillage), selected covers of «noble weeds», management of crop residues	41 – 44
T4	Raspberry inter-planted with maize (*Zea mais*), permanent cover, direct drill (zero tillage), selected covers of «noble weeds», management of crop residues	37 – 64
T5	Reference plot: Bare soil and cultivated along slope	48 – 52

An A-frame was used to establish the contour planting lines of the Andean raspberry crop. For maize and beans, zero tillage was applied by using a «matraca» (manual sowing device). For cropped plots noble weeds were encouraged by killing their competitors, by application of a plant specific herbicide with the so-called manual «chemical hoe» (Rivera 2000), with a machete or by manually pulling out of deeply rooted weeds. The rainfall erosivity index (*EI*) was estimated following the guidelines of Foster *et al.* 1981. The crop management factor (*C*) was based on the concept of deviation from the bare reference plot (Yoder *et al.*1997). Factor (*C*) was calculated on a monthly basis as relative ratio of soil loss (*SLR*) under cropped conditions to soil losses under the reference conditions. The relative ratio of soil loss (*SLR*) and the erosivity index (*EI*) were amalgamated into a weighted annual crop management factor (C_w) as

$$Cw = \frac{1}{EI_t} \sum_{i=1}^{n} (SLR * EI_w)_i$$

where SLR_i is the relative soil loss ratio for month i, EI_i is the cumulative *EI* occurring during that month, *n* is the number of month intervals used in the summation, and EI_t is the sum of *EI* for the entire time period. The canopy and contact cover were measured on a monthly basis using a metallic square frame (100 cm x 100 cm) with a 10 cm grid (intersections of wire 3 mm thick every 10 cm) (da Veiga & do Prado 1993). A binary system was used (0 for bare soil and 1 for canopy, residues, «noble weeds» and other nonerodible material in direct contact with the soil) so that contact and canopy cover fraction (C_f) was defined as the summation of resultant intersections matching soil covered divided by 100. Statistic analysis was carried out using SAS versión 7. Analysis of variance was done and the Tukey test was applied with a significance level of 5%. A regression analysis between C_w and the contact and canopy cover fraction (C_f) was carried out.

Results and discussion

Annual soil losses for T1, T2, T3, T4 and T5 respectively were 16,054; 0,475; 0,701; 0,552 and 144,561 $Mg.ha^{-1}.y^{-1}$ (Table 3).

Table 3. Monthly soil losses ($Mg.\ ha^{-1}$) November 2002 to October 2003

Month/year	T1	T2	T3	T4	T5
11/02	1,179	0,099	0,039	0,140	0,462
12/02	0,000	0,000	0,000	0,000	0,581
01/03	0,133	0,055	0,055	0,040	17,616
02/03	0,944	0,010	0,019	0,028	10,363
03/03	2,540	0,019	0,016	0,010	57,725
04/03	5,138	0,187	0,418	0,267	6,290
05/03	0,259	0,019	0,018	0,018	5,748
06/03	0,066	0,005	0,004	0,000	2,613
07/03	0,043	0,006	0,007	0,002	0,304
08/03	0,092	0,046	0,020	0,025	0,724
09/03	0,254	0,000	0,007	0,004	4,960
10/03	5,405	0,030	0,100	0,019	37,176
Total	**16,054b***	**0,475c***	**0,701c***	**0,552c***	**144,561a***

* Means with the same letter are not significantly different at the 95% confidence level using Duncan´s Multiple Range Test. CV= 6%

Soil losses from the reference plot (T5) in March 2003 (57.725 Mg) and October 2003 (37.176 Mg) were 40% and 26% of the total soil losses respectively. On residue-based zero tillage and «noble weeds» treatments (T2, T3 and T4) soil losses were negligible in comparison to T1 and T5 due to the great amount of contact cover, being 77.2%, 76.1% and 84.6% respectively (Table 4). During the measurement period (November 2002 – October 2003) 193 storms occurred giving a total rainfall of 1139 mm; however only 38 storms (20%) caused erosion; as previously mentioned soil losses mostly occurred in the early months of 2003 and in October/03 which match with periods of high rainfall erosivity (Dvorakova 2000). Likewise, *Cw* for T5 was particularly high on March 2003 and October 2003 (Table 5) with values of 0,32 and 0,21 respectively confirming that these two months had the highest rainfall erosivity.

Figure1 shows the exponential relationship between *Cw* and the contact and canopy cover fraction (C_f). At a C_f of about 0,70 the weighted cover factor *Cw*, is 0,10 indicating that a contact and canopy cover of about 70% may be sufficient to control relative soil losses a level of 10%. To control relative soil losses to a negligible level a C_f > 0,9 (canopy and contact cover greater than 90%) is needed. T1, with a C_f value of less than 0,7 (less than 70% of canopy and contact

Table 4. Percentage of surface contact cover and canopy cover and canopy and contact cover fraction, C_f

Type	T1	T2	T3	T4
Residues of coniferous (*Pinus patula),* native shrubs and crops	27.71	44.70	39.89	50.27
Noble weeds	19.12	32.54	36.19	34.30
Interplanted crop	0.00	12.38	8.80	6.37
Raspberry crop	12.12	6.10	8.88	4.59
Total cover (%)	58.95a	95.71a	93.75a	95.52a
Average canopy and contact cover fraction, C_f	0.5895	0.9571	0.9375	0.9552

* Means with the same letter are not significantly different at the 95% confidence using Duncan´s Multiple Range Test. R2 = 93.5%; CV= 6.4%

Table 5. Monthly rainfall, rainfall erosivity and weighted cover factor

Month year	Rainfall (mm)	EI†	weighted cover factor (C_w)				
			T1	T2	T3	T4	T5
11/02	53	59	0,073351	0,006194	0,002465	0,008727	0,028823
12/02	4	0	0,000000	0,000000	0,000000	0,000000	0,000000
01/03	9	23	0,000125	0,000070	0,000046	0,000049	0,011236
02/3	83	225	0,015992	0,000091	0,000259	0,000465	0,109917
03/03	175	654	0,014025	0,000120	0,000093	0,000064	0,319492
04/03	120	124	0,046976	0,001812	0,003967	0,002762	0,060576
05/03	87	108	0,002964	0,000215	0,000188	0,000192	0,052760
06/03	83	86	0,001911	0,000055	0,000239	0,000002	0,042013
07/03	27	17	0,001479	0,000277	0,000146	0,000048	0,008305
08/03	69	83	0,005204	0,002670	0,001154	0,001409	0,040547
09/03	96	239	0,012343	0,000004	0,000113	0,000308	0,116756
10/03	335	429	0,024785	0,000193	0,000600	0,000120	0,209575
Total	1139	2047	0,199154b*	0,011701c	0,009271c	0,014147c	1,000000a

†($Mj.mm.ha^{-1}.h^{-1}.a^{-1}$); means with the same letter are not significantly different at the 95% confidence level using Duncan´s Multiple Range Test. CV= 4.6%.

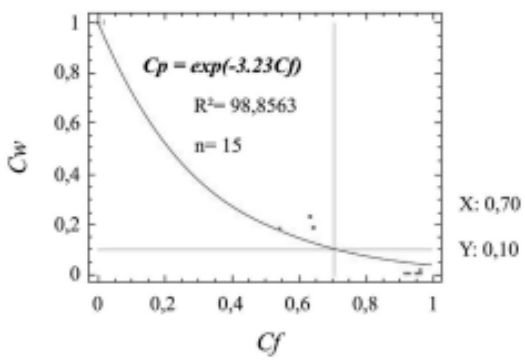

Figure 1. Weighted cover factor (Cw) related to plant contact and canopy fraction cover (Cf)

cover) shows a *Cw* value greater than 0,10 indicating that in the long term conventional monocropping systems with indiscriminate herbicide application and intensive hoeing to control weeds may induce water erosion to significant levels and consequently agricultural unsustainability.

Conclusion

The integration of residue-based zero tillage with the site specific management of «noble weeds», contour cultivation and interplanted crops achieved efficient erosion control during critical periods of high rainfall erosivity. Therefore, these conservation farming systems may lead to the long term sustainability of agricultural steeplands in the Colombian Andes. Such conservation farming systems should be promoted rather than engineering conservation techniques. For modeling or predicting soil erosion on steeplands it is suggested that the weighted crop management factor (*Cw*) should be used.

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NEW LAND TERRACING IN THE MOUNTAINS OF THE PRIORAT VINEYARD REGION, NE SPAIN

María Concepción Ramos, José Antonio Martínez-Casasnovas

Department of Environment and Soil Science. University of Lleida
Alcalde Rovira Roure 191, 25198 Lleida, Spain. fax:34973702613;cramos@macs.udl.es

Summary

The paper presents some terrace designs carried out during the last decades in the mountains of the Priorat vineyard region for new mechanized vineyards. The analysis was carried in a 14.3 ha vineyard plot with elevation ranging from 290 to 478 m, and an average slope of 26.4º. The survey was carried three years after terracing. The terrace design parameters (spacing between terraces: vertical and horizontal intervals, slope of risers, slope of the terrain and width of the bench) were analysed for 20 terraces a across the field. The values were compared with the criteria found in the literature. Another survey to locate and measure soil and mass movements occurred in the study field was also carried out. The riser failures and damages produced by the mass movements were evaluated in the field. Terraces are constructed with higher risers and widths than those expected for the high slopes degrees existing in the area, with the results of landslides after few rainfall events. After 3 years of terracing, the landslides affected 1.72% of the vines, with higher damage down slope (6.86% of the plants in addition to other infrastructures).

Key words: Land terracing, vineyard, schits, mountain region

Introduction

The intensification of agriculture in mountain environments requires land levelling and terracing (Zalidis *et al*., 2002; Borselli *et al*., 2006). This reduces some of the morphology limitations of hillslopes for agriculture, favours the mechanization of tillage operations and reduces labour. However, levelling and terracing are entailing fast and irreversible changes in soil properties and land morphology of still unknown consequences. In this respect, there are some reference works that have reported repercussions of land levelling operations (Lundekvam *et al*., 2003; Faulkner *et al.*, 2003; Borselli *et al*., 2006). Land levelling or terracing are poorly regulated either by specific or environmental laws. Because of that, the design and implementation of those operations usually rely on the field owner or on the person in charge of the machinery. Additional, owners can transform up to 50 ha without an environmental impact assessment declaration. Hence, to a large extent, levelling or terracing escape any control.

The Piorat region, where vines has been cultivated since the 12 century, has expererienced a boom since the late 1980s, based on a new terracing system, which allows mechanization of labours but causing high environmental and landscape impacts. In this paper, the design of some of the land terracing carried out in the area and their impacts area analysed. The design criteria are compared with those proposed for areas with similar slope degree in order to design suitable for a sustainable system.

Materials and methods

The study was conducted in the Priorat region (Priorat QDO) NE Spain (Fig.1). The area is located in a depression formed in the split of the southern part of the Montsant mountain chain. The average slope of the terrain is about 25º. Climate is classified as Mediterranean temperate tending to continental, with an annual average temperature of 14.3ºC (annual average maximum and minimum temperatures of 18.8 ºC and 9.8 ºC, respectively) and an average rainfall about 520 mm mainly distributed in Spring and Autumn. Based on the Soil Taxonomy of the USDA (Soil Survey Staff, 1999), soils are classified as *Lithic Xerorthents*, developed on schist, which give the wines special distinctive characteristics. Soils are slightly acid (pH about 6) and poor in organic matter content in the surface horizon (less than 2%).

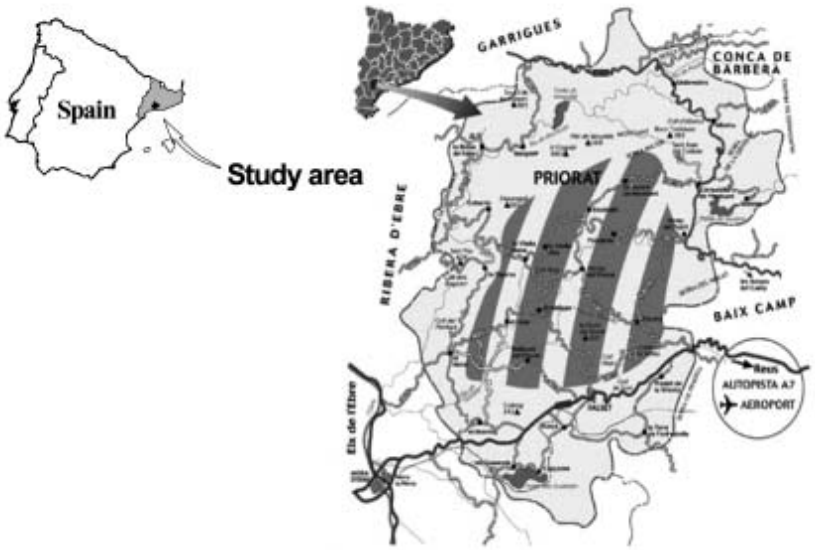

Figure 1. Location of the study area

The analysis of the new terracing system was carried in a new terraced vineyard (UTM 31n Zone T: 322619, 4564575 - 323400, 4563021), which consists of linked bench type. The terrace design parameters (spacing between terraces: vertical and horizontal intervals, slope of risers, slope of the terrain and width of the bench) were analysed for 20 terraces a across the field, using a Geodimeter 422 total station, with ± 0.01 m accuracy. The XYZ data of the points acquired in the field allowed the assessment of the dimensions of the terraces and the slope of the risers. The parameters were compared with the criteria proposed by Sheng (1988), Hunri (1986) and Chan (1981).
In addition, another survey to locate and measure the soil and mass movements occurred in the study field was carried out using a GPS Trimble GeoExplorer XT with differential correction, and an accuracy of less than 1 m. The soil movement dimensions as well as the infrastructures and plants that were affected by the mass movements occurred on the riser were evaluated in the field.

Results and discussion

The field survey carried out to measure terrace design characteristics, shows a great variability in all analysed parameters (vertical and horizontal intervals, bench width, and riser slopes), and they seem not to follow a previous design. The results are summarised in Table 1. Terrace risers have average slopes of 39º (28-56º), which supposes a local slope degree increment of about 33.6%. The average width of the benches is 2.9 m (2.0 - 4.61 m), with slope gradients of 1-3º. Typical terrace lengths (along the contour) measure 65-250 m (average 175 m).

Table 1. Average design parameters of the bench terraces measured in the field.

Local slope before terracing S (º)	Vertical interval VI (m)	Horizontal interval (HI) (m)	Width of the bench Wb (m)	Slope of risers U (º)
29.2 ± 4.9 (18.3 –36.5)	*4.82 ± 3.0 (2.4 –12.9)*	*6.2±3.5 (2.6-16.6)*	*2.94 ± 0.9 (2.37-5.91)*	*39.4 ± 8.7 U=1.21*

Bench width is the design parameter that shows the lowest variability. It is probably the only target that farmers have for the design. An average width of 2,5 m which allows them two vine rows per terrace and narrow tractor trafficability. This width agrees with the suggested by Sheng (1988) for hand made terraces (2.5 to 5 m) but is slightly lower than that for machine built bench terraces (3.5 to 8m). The vertical and horizontal intervals between terraces, however, present high variability, with variations of about 50%. In comparison with published design criteria the terraces are not balanced between the vertical / horizontal intervals and the width of the benches.

Figure. 2. View of new terraces design and failures after their construction

The observed VI and HI were higher than those calculated for reference criteria, and the HI/VI ratio (U) was also higher than that suggested in the literature Fang *et al.* (1981), Hunri (1986), Sheng (1988) and Chan (1981)'s criteria. In hillslopes of the Mediterranean area, similar figures have been found: Lisa *et al* (1998) found terraced vineyards with riser heights ranging between 0.65 and 1.25 m for slopes of 16.7º and up to 2.4 m for slopes of 19.3º.
Sheng (1988) proposed that the ratio between the vertical and horizontal dimensions of the riser should be 0.75-1, but in the present case study this ratio is higher than 1 (1.2 on average).

Conclusions

Using different design criteria proposed for steep slopes it may be observed that in order to maintain the number of terraces, for the slope degree of the terrain and the slope degree of the risers, the width of the benches should be smaller. This would require the reduction of the cultivation surface, implying only one vine row per terrace, which is not accepted by farmers, because the number of plants would be reduced by 50% and because they want to use machinery for most of the labours, and with narrower benches the pass of tractors would not be possible. In addition, this would imply higher cost, near twice, because about 50% of the cost of a new plantation is due to land terracing works. For these reasons vine cultivators prefer to assume some geomorphological risk (riser slides or even terrace collapse, damages in infrastructures, burial of plants, etc.) instead of increasing the expensive man labour works. Therefore, the mechanization of labours and machinery trafficability seem to be the unique design criteria taken into account. Terrace risers are not protected by stone walls or natural vegetation. Soil losses by overland flow are not significant but mass movements can produce the collapse of the risers, particularly in the cases in which there is not a balance between riser length and slope.

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USO DEL SUELO Y TASAS DE EROSION EN MICROCUENCAS DE LA CORDILLERA DE LA COSTA, SUR DE CHILE

Carlos E. Oyarzún, Gustavo Lacrampe, Cristian Frene & Pedro Hervé

Instituto de Geociencias, Facultad de Ciencias, Universidad Austral de Chile. E-mail: coyarzun@uach.cl

Resumen

Estudios recientes en el sur de Chile, han mostrado los efectos negativos de la conversión de bosques nativos por plantaciones exóticas sobre las reservas de agua del suelo, rendimiento hídrico y retención de nitrógeno a nivel de cuencas. El objetivo de este estudio es comparar la exportación de sedimentos y sus relaciones con algunas propiedades hidrológicas del suelo como la infiltración, conductividad hidráulica saturada e índice de continuidad de poros en dos microcuencas, localizadas en la cordillera de la costa del sur de Chile (39° 45' S, 73° 17' O), una con cobertura de bosque nativo y la otra con plantación de *Eucalyptus globulus*. En las microcuencas se instalaron registradores de precipitación, escorrentía y colectores de sedimentos en suspensión y de fondo. Se realizaron mediciones mensuales de las tasas de infiltración y se determinaron las propiedades hidrológicas del suelo, como la conductividad hidráulica saturada, índice de continuidad de poros y la hidrofobia. Los resultados mostraron diferencias significativas en las tasas de infiltración entre las dos coberturas vegetales, ya que en el bosque nativo fluctuaron entre 703,3 ± 380,0 y 76,9 ± 56,7 mm hr^{-1}, en marzo y julio respectivamente, mientras que en la plantación fluctuaron entre 23,0 ± 19,7 y 6,7 ± 5,0 mm hr^{-1} en agosto y abril, respectivamente. La conductividad hidráulica saturada y el índice de continuidad de poros bajo la cobertura de bosque nativo fueron significativamente mayores ($p < 0,05$) que bajo *Eucalyptus*, lo que indicaría una mayor capacidad de conducción de agua del suelo bajo bosque nativo. Las concentraciones de sedimentos en suspensión mostraron grandes variaciones durante el año, en respuesta a las fluctuaciones de las precipitaciones y escorrentía en ambas microcuencas. La tasa anual de exportación de sedimentos en suspensión fue de 307 y 345 kg ha^{-1} $año^{-1}$ en la microcuenca con bosque nativo y *Eucalyptus*, respectivamente.

Introducción

Las propiedades hidrológicas de los suelos que tienen una gran influencia sobre la escorrentía superficial y el transporte de sedimentos

son, entre otros, las tasas de infiltración y permeabilidad (Ward y Trimble 2004). Los usos de suelo asociados con actividades antrópicas, tales como agricultura, pastoreo y manejo forestal pueden afectar negativamente las tasas de infiltración y, de este modo, aumentar la escorrentía superficial acelerando los procesos de erosión (Turnbull *et al*. 2010). La hidrofobia o repelencia al agua que se manifiesta en algunos suelos también dificulta la infiltración del agua (Miyata *et al*. 2010). Los bosques nativos de la cordillera de la costa del centro-sur de Chile, en la denominada Ecorregión Valdiviana (entre los 36° y 48° S), históricamente han sido perturbados por actividades antrópicas debido a la ausencia de prácticas de manejo e incendios. Extensas superficies de bosque han sido eliminadas para su conversión a tierras agrícolas y, en las últimas décadas, a plantaciones exóticas de rápido crecimiento (Lara *et al*. 1996). Algunas estimaciones han indicado que entre 1974 y 1992 alrededor de 200.000 ha de bosques nativos, localizados especialmente en la Cordillera de la Costa, fueron convertidos a plantaciones exóticas de *Pinus radiata* y *Eucalyptus sp.* (Lara *et al*. 1996). Estudios recientes en el sur de Chile, han mostrado los efectos negativos de la conversión de bosques nativos por plantaciones exóticas sobre las reservas de agua del suelo (Oyarzún y Huber 1999), rendimiento hídrico (Lara *et al*. 2009, Little *et al*. 2009) y retención de nitrógeno a nivel de cuencas (Oyarzún *et al*. 2007).

En este trabajo hipotetizamos que los cambios en algunas propiedades hidrológicas del suelo, como la tasa de infiltración, conductividad hidráulica saturada, índice de continuidad de poros y la hidrofobia, como consecuencia de la degradación y desaparición de la vegetación nativa convertida primero a pradera y luego a una plantación exótica, afectarán la exportación de sedimentos en suspensión y de fondo. Por lo tanto, el objetivo del estudio es comparar la exportación de sedimentos y sus relaciones con algunas propiedades hidrológicas del suelo en dos pequeñas cuencas, localizadas en la cordillera de la costa del sur de Chile, una con cobertura de bosque nativo y la otra con una plantación joven de *Eucalyptus globulus* establecida sobre una pradera natural.

Material y métodos

En este estudio seleccionamos dos pequeñas cuencas con geología, clima y suelos similares, localizadas en la vertiente occidental de la Cordillera de la Costa (39 45’ S, 73 17’ O, 250-300 m s.n.m.). En las dos microcuencas el sustrato geológico es un complejo metamórfico, dominado principalmente de esquistos micáceos con lentes de cuarzo intercalados. Los suelos son rojo-arcillosos derivados de cenizas volcánicas antiguas, depositados sobre el complejo metamórfico.

En la microcuenca con bosque nativo, con una superficie de 1,7 ha, la profundidad del suelo es de 65 cm, con una densidad aparente entre 0,47 y 0,84 g cm^{-3} y porosidad entre 68 y 82%. En la microcuenca con plantación de *Eucalyptus* (4,1 ha de superficie) el suelo tiene una profundidad de 80 cm, densidad aparente entre 0,51 y 0,72 g cm^{-3} y porosidad entre 73 y 81%. La microcuenca con bosque nativo posee una formación del Tipo Forestal Siempreverde secundario degradado, donde actualmente hay extracción de árboles para leña. Las especies arbóreas más frecuentes son *Gevuina avellana*, *Amomyrtus luma*, *Amomyrtus meli*, *Myrceugenia planipes*, *Laureliopsis philippiana* y *Dasyphyllum diacanthoides*. La densidad corresponde a 2.330 árb ha^{-1} y el área basal es de 32,8 m^2 ha^{-1}, con una altura promedio de los árboles de 12 m. La otra microcuenca presenta una plantación joven de *Eucalyptus globulus*, establecida en el año 2005 y cubre aproximadamente el 80% de su superficie. La plantación tiene una densidad de 1.267 árb ha^{-1}, área basal de 10,9 m^2 ha^{-1} y la altura promedio de los árboles es de 5,5 m. En la microcuenca cubierta con *Eucalyptus*, a principios de la década de 1970, el bosque nativo secundario nativo que existía fue quemado y el uso del suelo fue convertido a pradera natural para ganadería por aproximadamente 35 años, hasta el establecimiento de la plantación forestal actual.
En la salida de las dos microcuencas se construyeron fluviómetros con V de 60°. Los fluviómetros estaban dotados con registradores DIVER del nivel de agua. Dentro de los fluviómetros, se diseñaron e instalaron colectores automáticos de sedimentos en suspensión. También se diseñaron pequeñas trampas para colectar los sedimentos de fondo. Mensualmente, para el período marzo – octubre 2009, se realizaron mediciones de la tasa de infiltración de los suelos utilizando un infiltrómetro de doble anillo. En laboratorio se determinaron la conductividad hidráulica saturada, índice de continuidad de poros y la hidrofobia del suelo.

Resultados y discusión

La exportación de sedimentos en suspensión y de fondo es mayor en la microcuenca con plantación de *Eucalyptus* con respecto a la de bosque nativo, como consecuencia de las mayores concentraciones de sedimentos en suspensión, especialmente en los meses de invierno (Figura 1). Sin embargo, desde el mes de junio de 2009 las concentraciones de sedimentos en suspensión fueron mayores en la microcuenca con bosque nativo, debido al uso de un camino que atraviesa la cuenca y drena hacia el curso de agua. Las concentraciones promedio anual de sedimentos en suspensión en ambas microcuencas, de 13,6 y 15,6 mg L^{-1} para el bosque nativo y

Eucalyptus, respectivamente, son inferiores al valor de 71 mg L^{-1} reportado para una microcuenca parcialmente forestada con cobertura de bosque nativo, plantación de *Pinus radiata* y pradera cercana a Valdivia (Iroumé 1990). Las tasas de sedimentos exportados por la microcuenca con plantación de bosque nativo (305 kg ha^{-1} $año^{-1}$) y *Eucalyptus* (368 kg ha^{-1} $año^{-1}$) también son menores a los estimados por el mismo autor (900 kg ha^{-1} $año^{-1}$). Las tasas de sedimentos exportados pueden tener fuertes fluctuaciones anuales dependiendo de las características de las precipitaciones (frecuencia, duración, cantidad e intensidad) y de la disponibilidad de sedimentos.

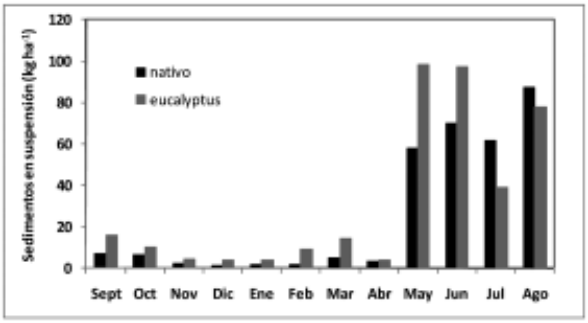

Figura 1: Tasas mensuales de exportación de sedimentos en suspensión en las microcuencas con bosque nativo y plantación de *Eucalyptus*

El uso histórico del suelo, especialmente en el caso de la plantación de *Eucalyptus*, que actualmente todavía refleja las condiciones de transición de pradera a plantación permite explicar las diferencias en las propiedades hidrológicas del suelo con respecto al bosque nativo. Probablemente el efecto residual de la pradera sometida a pastoreo, que se traduce especialmente en bajas tasas de infiltración y una cierta tendencia a la hidrofobia en la estación seca, persistirá todavía por algunos años hasta estabilizarse en la nueva condición de plantación. Los sedimentos en suspensión y de fondo debieran tender a disminuir mientras la plantación esté en desarrollo. Este cambio de uso de pradera a plantación debería tener un efecto marcado sobre los caudales en el corto plazo ya que a medida que la plantación se desarrolle, disminuirán las reservas de agua del suelo y aumentará la evapotranspiración, como ha sido señalado por Oyarzún y Huber (1999), para plantaciones jóvenes de *Eucalyptus* en el sur de Chile.

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PRODUCCIÓN INTEGRADA AGRÍCOLA-GANADERA Y FORESTAL EN SISTEMA DE AGRICULTURA FAMILIAR

Waldo Alejandro Rubén Lara Cabezas

Secretaria de Agricultura Del Estado de São Paulo,
Agencia Paulista de La Tecnologia de lós Agro negocios (APTA), Polo Regional Noroeste Paulista, e-mail: waldolar@apta.sp.gov.br

Introducción

La producción regional del noroeste paulista (São Paulo, Brasil) está basada principalmente en producción de ganado lechero, sobre pastos degradados, compuesta principalmente de arrendatarios de baja renta y escasa diversidad de producción. Es urgente encontrar solución a esta situación criando fuentes diversificadas de renta, con apoyo de la investigación y la extensión al productor familiar. El objetivo principal es efectuar la transformación de la producción convencional de la propiedad familiar en tecnológica, sostenible, trazable y certificable, por innovación tecnológica, con la participación de diversas instituciones de la sociedad civil organizada. Específicamente será implantado el sistema de siembra directa (SD) con la modalidad Integración Agrícola-Ganadera-Forestal (IAGF), siendo evaluada la producción técnica-económica de rotación de cultivos anuales aliado a la plantación de eucalipto durante tres años de cosechas. Tres condiciones de manejo serán testadas: a) con corrección inicial del suelo (alta tecnología), b) con corrección gradual de suelo (tecnología intermediaria) y c) sin corrección (manejo del productor como control), por lo tanto, sobre tres condiciones de capital de inversión inicial.

Materiales y métodos

En la propiedad San Luiz localizada en el km 509 de la autopista Péricles Bellini sentido Cosmorama, municipio de Votuporanga (São Paulo), en un terreno de 10 hectáreas, con pastos degradados hace 15 años fue introducido el sistema IAGF en la cosecha 2009/2010 cultivado con maíz intercalado con pasto *Brachiaria Brizantha* cv. Marandu (entre las terrazas) y eucaliptus (terrazas), com espacio de 0,8 m entre las líneas de plantas el 19/01/2010. Fue utilizado maíz transgénico DKB-390 (Monsanto) en población proyectada para 62.500 semillas por hectárea, tratadas con fungicida e insecticida. El suelo Argissolo (arenoso), presentó pH(CaCl2) 4,5,5 mg dm^{-3} de P (resina), 1,9,9 y 4 mmolc dm^{-3} y 2 mg dm^{-3} de K, Ca, Mg y S-sulfato, respectivamente, valores considerados bajos a muy bajos

para este tipo de suelo en São Paulo (Brasil). Fueron recuperadas las terrazas y destruidos mecánica y químicamente los focos de termitas y hormigueros. El terreno posteriormente fue dividido en tres parcelas de aproximadamente tres hectáreas cada una. Tres tratamientos de manejo fueron establecidos en las parcelas (Cuadro 1) con diseño experimental enteramente al azar. En las parcelas A y B el abono de siembra únicamente para maíz fue 450 kg/ha de 06:19:10 con 6,3% Ca + 6,6% S + 2,2% Mg + 0,1% B + 0,1% Cu + 0,15% Mn + 0,3% Zn. En parcela C fue aplicado 350 kg/ha de 8:28:16 + 0,3% Zn, como es efectuado por el productor. En la etapa de 3 a 4 hojas se aplicó abono NK en las tres parcelas, siendo 345 kg/ha de 20:05:20 con 4,5% S + 0,1% B + 0,05% Cu + 0,3% Zn para la gleba A y

Cuadro 1. Tratamientos de manejo realizado en las glebas (parcelas) de la unidad San Luiz – Votuporanga (SP).

Local slope before terracing S (°)	Vertical interval VI (m)	Horizontal interval (HI) (m)	Width of the bench Wb (m)	Slope of risers U (°)
29.2 ± 4.9 (18.3 –36.5)	*4.82 ± 3.0 (2.4 –12.9)*	*6.2±3.5 (2.6-16.6)*	*2.94 ± 0.9 (2.37-5.91)*	*39.4 ± 8.7 U=1.21*

215 kg/ha de 30:00:20 para las parcelas B y C. Una segunda aplicación de nitrógeno fue efectuada en la forma de sulfato de amonio en la dosis de 200 kg/ha para las tres parcelas con el maíz estando con 5 a 6 hojas expandidas. La siembra del pasto Brachiaria cv. *Marandú* intercalado al maíz fue sembrada con 10 kg/ha de semillas mezclada en una proporción 10:1 con superfosfato triple con la finalidad de relleno. La plantación de eucaliptus fue realizada en el ápice de las terrazas alternando dos variedades E. *urograndis* e E. *citreodora*, en las tres parcelas con una población de 287 plántulas/ha, espaciadas a 2,0 m. Las plántulas fueron pulverizadas con Regent-Fipronil (hormiguicida) en la dosis de 75 mL para 20 L de solución con bomba costal. En la fase de florecimiento del maíz (62 días después de la siembra) fueron colectadas hojas (hoja inferior opuesta a la posición de la espiga) para efectuar evaluación nutricional (Malavolta *et al.,* 1997) y determinada la población efectiva de plantas con espigas. Durante el ciclo de crecimiento de los cultivos se efectuó una evaluación visual registrada por fotografías tomadas e el sitio. Fue realizado día de campo en abril de 2010 con participación de 180 productores de la región noroeste paulista con el objetivo de difundir el sistema de producción, integrando la investigación y la extensión. La cosecha fue efectuada manualmente separándose las espigas limpias sin paja de dos líneas de plantas de cinco metros cada una, con cuatro repeticiones por cada tratamiento. Fueron nuevamente conta-

das las plantas efectivas. En esa oportunidad también fueron colectadas muestras de pasto por el método del cuadrante (0,5 x 0,5 m) lanzado al azar en cada tratamiento, con diez repeticiones por tratamiento, para la determinación de masa verde y seca. Las muestras fueron secadas en estufa con circulación de aire a 65ºC. Las medias de las evaluaciones efectuadas fueron comparadas por el test de t (Student) al nivel de 0,05. Cabe destacar que todos los insumos (semillas, fertilizantes, plaguicidas y las plántulas de eucaliptus) han sido donados por empresas privadas; la maquinaria agrícola, mano de obra y combustible dispuestos por la Patrulla Agrícola del Municipio de Votuporanga (SP). La productora tuvo costos reducidos cediendo el terreno para la instalación de una «vitrina» de validación de tecnología a escala de agricultura familiar. En esta etapa el pasto no fue dispuesto para consumo animal debido al estado incipiente de las plántulas de eucaliptus. Después de la próxima cosecha (2010/2011) durante el otoño/invierno (sin lluvias), el terreno será liberado transformándose en otra fuente de renta. Las condiciones climáticas fueron registradas durante el ciclo de crecimiento de las culturas. Fue realizada la evaluación económica de la producción de granos (Matsunaga *et al*., 1976).

Resultados y discusión

Durante el ciclo del cultivo del maíz hubo una pluviometría acumulada de 390,9 mm, con temperaturas medias máximas e mínimas de 30,8ºC y 18,6ºC. Hubo déficit hídrico si se considera que la cultura requiere por ló menos 412 mm (Coelho *et al.*, 2006) con sequía en períodos críticos de florecimiento y llenado del grano. La evaluación foliar (Cuadro 2) mostró deficiencia de P, B, Cu, Zn y en el limite inferior de suficiencia para Mg en las tres parcelas. La parcela C fue afectada por deficiencia de Ca, Mg y Cu, en relación a las otras parcelas.

Cuadro 2. Nutrientes foliares en maíz bajo tres condiciones de manejo em la unidad San Luis, en la cosecha 2009/2010. Votuporanga (SP).

Manejo glebas [1]	Macronutrientes						Micronutrientes				
	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn
	g/kg						mg/kg				
A	33,9 a	2,4 a	29,7 a	5,2 ab	2,3 a	2,3 a	7,2 a	10,5 ab	123 a	59 a	14,6 a
B	31,4 a	2,3 a	29,6 a	5,7 a	2,2 a	2,4 a	4,3 b	10,9 a	137 a	54 a	13,7 a
C	29,8 a	2,1 a	30,8 a	4,2 b	1,6 b	2,4 a	3,6 b	9,0 b	107 a	48 a	13,0 a
DMS	7,2	0,6	8,0	1,2	0,3	0,4	1,1	1,6	45	64	10,1
CV (%)	7,2	8,0	9,4	7,5	5,0	5,2	6,7	5,1	11,7	37,6	23,1
Ad. [2]	30-40	2,5-4,0	20-40	3,0-5,0	1,7-4,5	1,0-2,0	17-30	10-25	50-250	50-150	30-100

[1]Manejos A, B e C = correcao, gradual y sin correccion, respectivamente
[2] Ad = Valores adecuados medios segun Facelli (2000).

En la Figura 1 en la época de muestreo foliar se destaca el contraste del maíz creciendo sobre el manejo A (izquierda) en relación al manejo C mostrando las hojas inferiores con muerte prematura.

Figura 1. Visión del sistema IAGF instalado en la época de muestreo foliar (izquierda) en la parcela A y muerte prematura de hojas inferiores del maíz en la parcela C (derecha).

La producción de granos en las tres parcelas (Cuadro 3) varió de 3.168 kg/ha (parcela C) a 4.681 kg/ha e la parcela B, siendo negativa la rentabilidad en todos los tratamientos de manejo. Los antecedentes anteriormente presentados, están justificando estos resultados.

Cuadro 3. Costo operacional efectivo (COE) y total (COT), receta bruta (RB), receta líquida (RL), margen bruto (MB) y punto de equilibrio (PN) de la producción de maíz por hectárea, Unidad San Luis, en cada sistema de manejo, cosecha 2009/2010. Votuporanga (SP).

Costo/Beneficio	Sistemas de Manejo					
	Gleba A		Gleba B		Gleba C	
	Valor absoluto [1]	Valor relativo	Valor absoluto	Valor relativo	Valor absoluto	Valor relativo
	US$	%	US$	%	US$	%
	Costo operacional total					
COE						
Operaciones	324,61	22,76	221,11	28,82	226,06	27,75
Insumos	924,96	64,86	490,74	59,52	512,54	62,92
Fletes	170,21	11,94	69,51	12,56	69,33	8,51
Recepción y silo de almacenamiento.	6,31	0,44	9,09	1,10	6,68	0,82
COE total (sin COF) = COT	1.426,10	100,00	790,45	100,00	814,62	100,00
	Rentabilidad					
Producción de granos (sacos/ha) [2]	58,80 B	-	78,02 A	-	52,80 B	-
Precio saco (US$) [3]	8,24	-	8,24	-	8,24	-
RB (US$)	484,43	-	642,78	-	435,00	-
RL (RB-COT, US$)	-941,66	-	-181,76	-	-456,84	-
MB (RL/COT) x 100 (%)	8,24	-	-22,04	-	-46,60	-
PN (COT/precio saco) (sacos/ha)	173,10	-	100,08	-	98,88	-

[1]Dólar comercial (15/07/2010) = R$ 1,76. [2]As medias seguidas de letras desiguales, difieren estadisticamente al nivel de 0,05 por el test de t (Student). DMS = 845, CV (%) = 23,0. [3]Valor saco de maíz (60 kg) para São Paulo consultado em Cooperativa COACAVO.

Con relación al pasto, hubo producción significativa de éste en la parcela A, con valores de 43,5 t/ha de masa verde y 19,8 t/ha de masa seca. En las otras parcelas la producción de masa seca alcanzó valores de 6 t/ha de masa seca, evidenciando competencia entre el pasto y el maíz por nutrientes. Habría sido indicado la aplicación de herbicida para evitar esto.

Conclusiones

Considerando únicamente el cereal y la forrajera, los beneficios acumulados de la parcela A fueron superiores a las otras parcelas, si esta hubiese recibido carga animal para engorde.

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ASSESSING THE EFFECT OF LAND USE ON SOIL REDISTRIBUTION ON MEDITERRANEAN MOUNTAIN SLOPES USING ^{210}Pbex AND ^{137}Cs

L. Gaspar[1], A. Navas[1], D. E. Walling[2], J. Machín[1]

[1] Department of Soil & Water. Estación Experimental de Aula Dei. CSIC. Apdo. 202. 50080 Zaragoza. Spain. anavas@eead.csic.es
[2] Department of Geography, University of Exeter, Amory Building, Rennes Drive, Exeter, EX4 4RJ. U.K.

Summary
The agricultural systems of the Mediterranean region are characterized by long-term cultivation and recent land use change resulting in increased erosion especially in mountain landscapes. In the study reported in this contribution, ^{210}Pbex and ^{137}Cs were used to assess soil redistribution over different timescales. Two slope transects with contrasting land use and orientation were selected, within a subhumid Pre-pyrenean agricultural landscape (NE Spain). The southern transect has a dense forest of Quercus coccifera on a steep slope (22%). The northern transect, has a gentler slope (11%), and was originally cultivated for cereals, but was then abandoned and at present supports a natural sparse shrubland vegetation. The depth distribution of ^{210}Pbex and ^{137}Cs was examined at 5 points along each slope transects. The ^{210}Pbex and ^{137}Cs depth profiles showed maximum concentration at the soil surface and an exponential decline with depth, but slightly higher values of ^{210}Pbex were found in the surface horizons, due to the continuous fallout input of ^{210}Pbex. The mean ^{210}Pbex inventory in the forest transect was 1625 (±393) Bq m^{-2} and 1651 (±526) Bq m^{-2} in the shrub transect. The mean ^{137}Cs inventories were 1544 (±183) Bq m^{-2} and 1581 (±671) Bq m^{-2} in the forest and the shrub transect, respectively. The largest variability was found in the shrub transect for both radioisotopes. In the forest transect, estimates from the ^{137}Cs reference inventory indicates that stability predominates, however, the ^{210}Pbex residuals suggest increased soil redistribution in recent times. For the shrub transect the reduced ^{137}Cs inventories indicate higher soil redistribution, however, estimates from ^{210}Pbex measurements indicate lower deviations, as a result of the recovery of the natural vegetation.
Key words: ^{137}Cs, ^{210}Pbex, soil erosion, land abandonment, Mediterranean environments.

Introduction

In recent decades, agricultural land in mountain areas has, in particular, been affected by land abandonment in Mediterranean landscapes. The process of land abandonment has resulted in increased erosion and this trend has strengthened the need to assess the impact of land use on soil erosion and deposition over different timescales. Isotopic techniques based on the use of fallout radionuclides «FRNs» such as ^{137}Cs and ^{210}Pbex (Walling *et al*., 1995) have been increasingly applied over the past 20 years as a means of obtaining spatially distributed information on erosion and deposition rates. The potential for using caesium-137 to quantify medium-term (c.a 45 years) soil erosion rates under different agro-environmental and natural conditions has been successfully demonstrated in a wide range of environments in different regions of the world (Ritchie and Ritchie, 2008) including Spain (e.g. Navas and Walling, 1992; Navas *et al.,* 2005). Naturally derived ^{210}Pb (half-life 22.2 year), is absorbed by the surface soil and subsequently redistributed across the landscape in a manner similar to ^{137}Cs, offering potential for quantifying soil redistribution rates over a longer timescale than ^{137}Cs (50-100 years). To date ^{210}Pbex has been applied successfully in diverse agricultural landscapes of the world (e.g. Walling *et al*., 2003; Zhang *et al*., 2006; Gaspar and Navas, 2008; Mabit *et al.*, 2009). However, at present its potential as a tracer of soil erosion is less widely recognized than ^{137}Cs, especially in Mediterranean environments. In this study the FRN methodology (^{137}Cs and ^{210}Pbex) has been applied to two slope transects with contrasting land use to derive additional information on the pattern of soil movement, in order to assess the impact of land use on erosion over different timescales.

Materials and methods

Two slope transects with contrasting land use and orientation were selected for this study on slopes of a subhumid (500 mm annual rainfall) agricultural mountain landscape in NE Spain (Figure 1). The forest transect (FT), with a southerly aspect, a 22% slope and altitude ranging from 894 to 860 m has a dense forest vegetation of Quercus *coccifera*. The scrubland transect (ST), with a northerly aspect, has a gentler slope (11%), with altitude ranging from 711 to 690 m and a relict oak forest at the upper part of the slope and sparse shrubland vegetation developed on old abandoned fields. Letptosols and Calcisols are the soil types developed on the Muschelkalk limestones of the forest transect (FT) and on the shrub transect (ST), respectively.

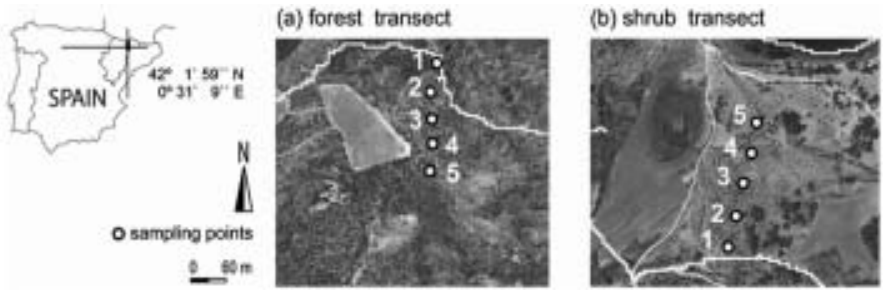

Figure 1. The location of the transects and the sampling sites in (a) FT and (b) ST.

Five sectioned soil cores, separated by 50 m, were collected along each transect using a steel box corer. The soil cores were sectioned into 2 cm depth increments and the sampling depth was 14 cm. Profiles FT2 and FT3 coincided with shallow soils overlying rock outcrops and it was not possible to extend the cores below 10 and 12 cm depth, respectively. The resulting samples were air dried, disaggregated and passed through a 2 mm sieve. For the radionuclide gamma assays 50 g subsamples were transferred into airtight plastic pots and sealed for a period of 30 days prior to assay, in order to achieve equilibrium between ^{226}Ra and its daughter ^{214}Pb.

The ^{137}Cs and ^{210}Pbex activities of a total of sixty-seven samples were measured using a Canberra high resolution, low background, hyperpure germanium coaxial gamma detector coupled to an amplifier and mutichannel analyser. The detector had a relative efficiency of 30% and 1.9 keV resolution (shielded to reduce background) and was calibrated using standard samples with he same geometry as the measured ^{137}Cs and ±12% for ^{210}Pbex (95% level of confidence). The 137Cs gamma emissions were measured at 661.6 keV line, ^{210}Pb at 46.5 keV line and ^{226}Ra at 351.9 keV line of ^{214}Pb (a short-lived daughter of ^{226}Ra). The unsupported ^{210}Pb (^{210}Pbex) concentration was calculated by substracing the ^{226}Ra-supported ^{210}Pb concentration from the total ^{210}Pb concentration.

Results and discussion

The ^{137}Cs and ^{210}Pbex mass activities in the sectioned cores varied greatly and for all depth increments (n=67). The ^{137}Cs mean values are 16.0 (±10.6) Bq kg^{-1} and the ^{210}Pbex mean values are 19.5 (±26.0) Bq kg^{-1}. The mean values of mass activities and inventories for ^{137}Cs and ^{210}Pbex are higher in the FT than in the ST (Table 1).

Table 1. Basic statistics for ^{137}Cs and $^{210}Pbex$ mass activity and inventory in the depth incremental samples.

	^{137}Cs	$^{210}Pb_{ex}$	^{137}Cs	$^{210}Pb_{ex}$	^{137}Cs	$^{210}Pb_{ex}$	^{137}Cs	$^{210}Pb_{ex}$
	Bq kg^{-1}				Bq m^{-2}			
	FT		ST		FT		ST	
n	32	32	35	35	32	32	35	35
mean	20.1	24.9	12.2	14.5	241.3	253.9	225.8	235.9
des vest.	12.3	32.4	7.1	17.3	137.0	274.9	148.7	277.7
min.	4.1	0.0	1.6	0.0	67.0	0.0	18.1	0.0
max.	50.3	126.1	29.2	62.3	568.1	984.3	630.3	1018.8
CV %	61.0	130.0	58.0	119.5	56.8	108.3	65.9	117.7

The inventories of both radiotracers varied along the transects. The $^{210}Pbex$ inventories from the FT (mean 1625 ±393 Bq m^{-2}) ranged between 1033-2079 Bq m^{-2} and were similar to the inventories from the ST (mean 1651 ±526 Bq m^{-2}), that ranged between 740 and 2101 Bq m^{-2}, although they showed a slightly higher variability. The ^{137}Cs inventories were also more variable in the ST 1581 (±671) Bq m^{-2} (range 394-2017 Bq m^{-2}) than in the FT 1544 (±183) Bq m^{-2} (range 1290-1767 Bq m^{-2}).

The ^{137}Cs and $^{210}Pbex$ depth profiles showed maximum concentration at the soil surface and an exponential decline with depth, but slightly higher values of $^{210}Pbex$ were found in the surface horizons, due to the continuing fallout input of $^{210}Pbex$. In the FT the surface mass activities of ^{137}Cs and $^{210}Pbex$ are higher and depth profiles have a more marked depth decay than in the ST (Figure 2). The ^{137}Cs and $^{210}Pbex$ depth profiles are consistent with the land cover and land use associated with the two slope transects.

Over 80% of ^{137}Cs is contained in the top 8 cm of the FT and in the upper 10 cm of the ST, whereas 80% of $^{210}Pbex$ is found within a lesser depth and in the top 6 cm for the FT and for the ST.

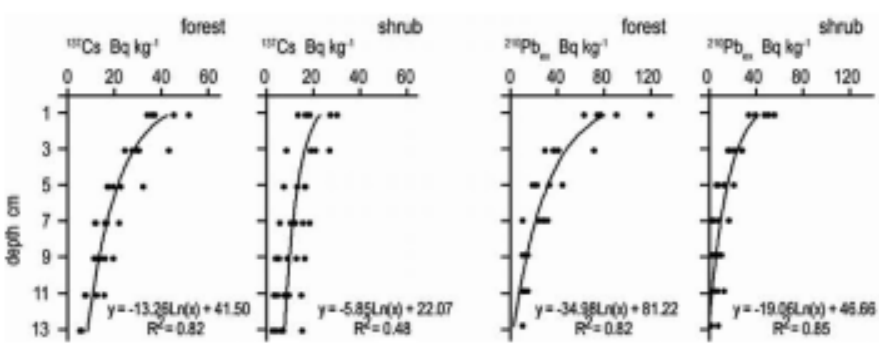

Figure 2. Depth distributions of ^{137}Cs and $^{210}Pbex$ in the forest and shrub transects.

The reference inventory for ^{137}Cs was estimated to be 1570 (± 80) Bq m^{-2} (Soto & Navas, 2008) and that for $^{210}Pbex$ 2020 (± 216) Bq m-2. By comparing the values of the ^{137}Cs and $^{210}Pbex$ inventories obtained for individual sampling points with the equivalent reference inventories for the study site, that were established at stable sites unaffected by erosion or deposition, and calculating the degree of increase or reduction involved, it is possible to derive estimates of the rates of soil loss or deposition associated with each sampling point. For the forest transect (Figure 3), the limited deviation of the measured inventories from the ^{137}Cs reference inventory indicates that stability predominates in three of the five sampling points. However, the $^{210}Pbex$ residuals show higher deviations from the reference inventory with substantial losses in three profiles suggesting increased soil redistribution in recent times. For the shrub transect, a different pattern is observed. The reduced ^{137}Cs inventories relative to the reference value indicate higher soil redistribution, reflecting the impact of the previous intensive agricultural use and subsequent land abandonment. However, estimates derived from $^{210}Pbex$ measurements indicate lower deviations, as a result of the recovery of the natural vegetation.

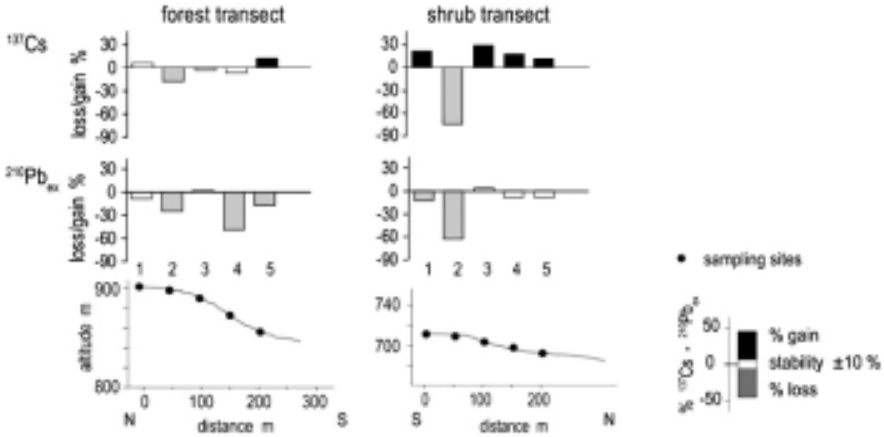

Figure 3 Percentage of 137Cs and 210Pbex gain/loss in the forest and shrub transects.

The variation of the ratio of the percentages of ^{137}Cs and $^{210}Pbex$ gain/ loss to slope is higher for both ^{137}Cs and $^{210}Pbex$ in the shrub transect demonstrating the dominance of land use over slope gradient in soil redistribution at the study site (Figure 4).

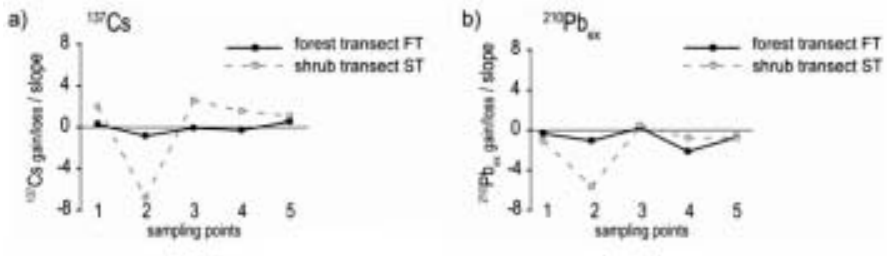

Figure 4 Variation of the ratio of ^{137}Cs and ^{210}Pbex gain/loss to slope in the forest and shrub transects.

Conclusions

The ^{137}Cs and ^{210}Pbex radiotracers provide evidence of different patterns of soil movement for the different timescales and as a function of land use. Although the approach used with both radiotracers is very similar, the constant fallout of ^{210}Pbex suggests that it will be more sensitive to recent soil redistribution. The use of both radiotracers in combination has served to demonstrate the impact of agricultural land use on soil erosion and the influence of the protection of the soil surface by the land cover in restricting soil movement on steeper slopes.

Acknowledgements

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SURFACE ROUGHNESS EFFECTS ON RUNOFF AND SOIL EROSION RATES UNDER SIMULATED RAINFALL

Jan Vermang[a], Alexandre Marco Da Silva[b], Chi-Hua Huang[c], Donald Gabriels[a], Wim M. Cornelis[a], Darrell Norton[c]

[a]Department of Soil Management, Ghent University, Coupure Links 653, B-9000 Gent, Belgium, (t) +32 9 264 60 58, (f) +32 9 264 62 47, Jan.Vermang@Ugent.be
[b]Department of Environmental Engineering, UNESP, Sorocaba, SP, Brazil, amsilva@sorocaba.unesp.br
[c]National Soil Erosion Research Laboratory, USDA-ARS, West Lafayette, IN, USA: Chi-hua.Huang@ars.usda.gov, Darrell.Norton@ars.usda.gov

Summary
Soil surface roughness is identified as one of the controlling factors governing runoff and soil loss. Yet, most studies pay little attention to soil surface roughness. In this study, we analyzed the influence of surface roughness on runoff and soil erosion rates. Bulk samples of a silt loam soil were collected and sieved to 4 aggregate sizes: 0.003-0.012, 0.012-0.02, 0.02-0.045, 0.045-0.1 m. The aggregates were packed in a 0.60 by 1.2 m soil tray, which was set at a slope of 5%. Rainfall simulations using an oscillating nozzle simulator were executed for 90 min at intensity of 50.2 mm h^{-1}. The surface microtopography was digitized by an instantaneous profile laser scanner before and after the rainfall application. From the laser scanner data, a digital elevation model was produced and a roughness factor extracted. The data revealed longer times to runoff with increasing soil surface roughness as surface depressions first had to be filled before runoff could take place. Once channels were interconnected, runoff velocity and runoff amount increased as aggregates were broken down and depressions were filled. Rough surfaces were smoothed throughout the rainfall event, diminishing the effect on runoff. Final wash rates were comparable for all different applications. The simulations reveal that the significance of soil surface roughness effect is the delay in runoff for rougher surfaces rather than the decrease of soil erosion amount.
Key words: rainfall simulations, soil roughness, surface-profile laser scanner

Introduction
Soil surface roughness is identified as one of the controlling factors governing runoff and soil loss (Eltz and Norton, 1997; Darboux *et al*., 2001; Jester and Klik, 2005). Many processes occurring on the soil surface are influenced by roughness, including depression storage,

infiltration, runoff, flow velocity and soil loss (Darboux *et al*., 2001; Römkens *et al*., 2001). Nevertheless, most studies pay little attention to soil surface roughness. In this study, we aim to analyze the influence of random soil surface roughness on runoff and soil erosion rates.

Bulk samples were collected from the 0-0.1 m soil layer from a field in Indiana, USA. This soil is classified as a silt loam according to USDA (Soil Survey Staff, 1999). Prior to air drying, the bulk samples were sieved to 4 aggregate sizes: 0.003-0.012, 0.012-0.02, 0.02-0.045, 0.045-0.1 m. This allowed, after packing the aggregates in soil trays, four different levels of soil surface roughness, i.e., smooth, medium smooth, medium rough and a rough soil surface, in this study. The soil boxes consisted of two compartments each measuring 0.6 by 1.2 m, hence two treatments can be run simultaneously. The bottom of the soil tray was equipped with 8 interconnected tubes in order to measure percolation. The bottom was covered with a porous fabric and a 0.05 m layer of course sand, thus allowing free drainage during rainfall simulations. The sand was covered with another sheet of porous fabric, on top of which a 0.07 m thick layer of aggregates was packed. For the 2 smallest aggregate distributions, the soil pan was packed with the respective aggregates. Nevertheless, for the two larger aggregate size distributions, this would cause very large voids in between the aggregates, thus creating rapid through flow. Therefore, these soil pans were packed differently as described below. First, a thin layer of small aggregates of 0.003 - 0.012 m were added, followed by a layer of the large aggregates. Subsequently, the large voids were filled by adding a next layer of small aggregates. As such, several layers of large aggregates with infills of small aggregates were added until the soil pan was completely filled. Finally, in order to fill the large voids which were less readily reachable, small aggregates of < 0.003 m were added and the filling of voids was facilitated by hammering on the bottom of the soil pan. The soil trays were set at a 5% slope to facilitate runoff.

Rainfall simulations were executed for 90 min at intensity of 50.2 ± 2.1 mm h^{-1} using an oscillating nozzle simulator, consisting of two simulator troughs each equipped with two 80-100 Veejet nozzles (Spraying Systems, Wheaton, IL). The nozzles were spaced 1.07 m within the trough and the troughs are placed 1.37 m apart. A constant pressure of 42 kPa was set at the nozzles. Rainfall intensity was controlled by varying the oscillating frequency of the nozzle. Simulated rainfall was applied to ensure that a steady state runoff was attained. Runoff samples were collected at the downslope edge of the soil pan and infiltration water from the bottom of the soil pan was collected at three minute intervals. Runoff velocity was determined by recording the time for a dye to travel 1 m over the soil surface.

The surface microtopography was digitized before and after the rainfall application by an instantaneous profile laser scanner. The laser scanner consists of two diode lasers and a digital camera mounted on a single rail. The laser projects a bright line on the surface which is digitized by the camera. From the geometry of the laser-camera assembly, the line image is converted to surface heights using a triangulation algorithm (Darboux and Huang, 2003). From the laser scanner data, a digital elevation model was produced in order to extract a roughness factor. Furthermore, aggregate disintegration, sealing and micro-rilling could be followed throughout the course of the rainfall event by analyzing the detailed topographic datasets.
Aggregate stability was determined by sieving after the soil was either slowly or rapidly prewetted as proposed by Le Bissonnais (1996). Bulk density was measured using an excavation approach in which an amount of soil is excavated and weighted and the volume is estimated by filling up the pit with a measured amount of water.

Results and discussion

Because of the specific way of packing the soil in the soil trays, differences in bulk density between the roughness classes did occur (Table 1). This can be explained by the fraction of soil under natural condition present in the soil trays: for large aggregates, a greater portion of the soil is packed in its unspoiled, natural condition. Instead, for small aggregates, a bigger portion of voids between the aggregates decreases its bulk density. As the bulk density for the higher roughness classes is higher, we would expect infiltration rate will decrease more rapidly. Nevertheless, because of the larger depression storage, this did not occur.

Table 1. Bulk density and aggregate size distribution for each roughness class.

Roughness class	Aggregate size distribution (m)	Bulk density ($Mg.m^{-3}$)
Smooth	0.003 – 0.012	1.10 ± 0.05 a
Medium smooth	0.012 – 0.020	1.17 ± 0.06 b
Medium rough	0.020 – 0.045	1.15 ± 0.16 ab
Rough	0.045 – 0.100	1.28 ± 0.04 c

Same letter indicates no significant differences (P = 0.05).

Significant differences exist between the Mean Weighted Diameters (MWD) of the different treatments of Le Bissonnais (1996), fast wetting of the aggregates yielding the lowest MWD (0.56 ± 0.19), slow wetting yielding the highest MWD (1.72 ± 0.24) and shaking after prewetting yielding intermediate MWD (1.44 ± 0.14). This is also reflected by the distribution of the aggregate size fractions shown in Fig. 1. This

indicates the soil is particularly vulnerable for aggregate breakdown under dry conditions as slaking will cause aggregates to be broken down during fast wetting. Since the rainfall simulations were performed on a dry soil, this explains the intensive aggregate breakdown leading to a smoothening of the soil surface and the high soil loss observed. Prewetting the aggregates stabilizes the aggregates, resulting in a high MWD. The results also indicate that the aggregates resist mechanical disturbance relatively well.

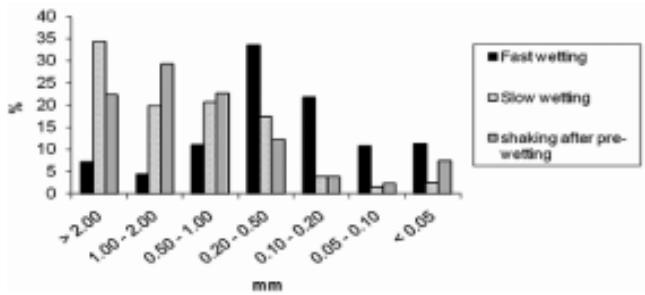

Figure 1. Distribution of aggregate size fractions after treatments proposed by Le Bissonnais (1996).

During the first stage of the rainfall simulations, all rainfall was able to infiltrate. Due to slaking and raindrop impact, aggregates broke down and a seal was formed, causing the infiltration rate to drop. Subsequently, ponding started, hereby filling up the depressions in between the aggregates. Once channels were interconnected, runoff occurred. This process was also observed by several authors, e.g., Darboux *et al.* (2001) and Croft *et al*. (2009). Our results revealed longer times to runoff with higher initial soil surface roughness as larger surface depressions first had to be filled before runoff could take place (Fig. 2). During the rainfall event, runoff rate increased as aggregates were broken down and depressions were filled by deposition of transported sediment, hereby lowering the storage capacity of the surface. As such, rough surfaces were smoothed throughout the rainfall event, diminishing the effect on runoff. Final runoff rates were highest for the smooth soil surface and lowest for the medium rough soil surface. Indeed, final runoff rates were higher again for the rough soil surface as compared to the medium rough soil surface as water is forced by the micro-topography to flow to the depressions rather than infiltrating. Due to depositional crusts in the flow lines, water is less likely to infiltrate and will run off.

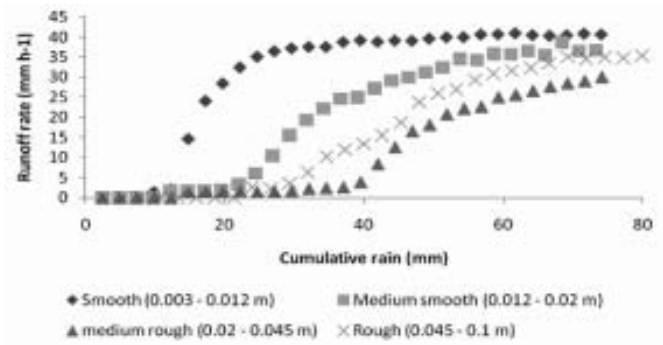

Figure 2. Runoff rate as a function of cumulative rainfall for the four roughness classes.

Our data showed lower runoff velocities with increasing soil surface roughness as water is forced to follow a more tortuous flow path (Fig. 3). Nevertheless, as rough surfaces were smoothed throughout the rainfall event, runoff velocity gradually increased.

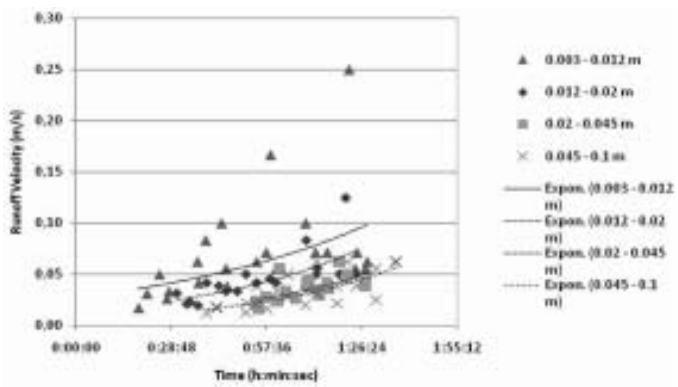

Figure 3. Evolution of runoff velocity as a function of time for the four roughness classes

Final wash rates were comparable for all different applications (Fig. 4). Nevertheless, as final runoff rates were highest for the smooth soil surface and lowest for the medium rough soil surface, this implies sediment concentrations increased with higher soil surface roughness (data not shown). Römkens *et al.* (2001) stated that a higher soil surface roughness can increase soil erosion by flow concentration. Darboux and Huang (2005) also found similar final wash rates but did not found a significant difference in sediment concentrations. As time to runoff is lower for with decreasing soil surface roughness, the total soil loss was highest for the smooth soil and lowest for the medium rough and rough soil.

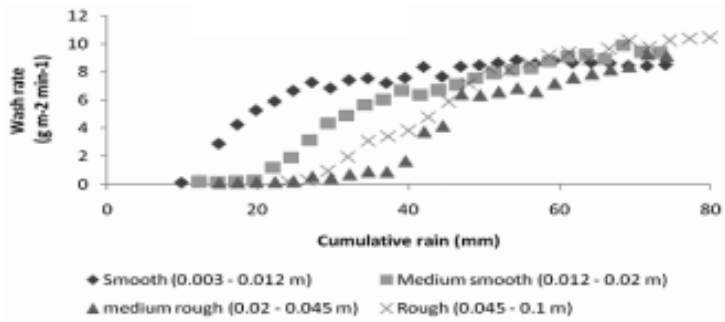

Figure 4. Wash rate as a function of cumulative rainfall for the four roughness classes.

Conclusions

The silt loam soil studied here was vulnerable to slaking which induced a strong aggregate breakdown during the rainfall simulations, resulting in a decay of the soil roughness in all treatments. The final runoff rate was highest for the smooth soil surface and lowest for the medium rough soil surface meanwhile there was no significant difference in final wash rates between the different applications. Therefore, the simulations reveal that the significance effect of soil surface roughness is the delay in runoff for rough surfaces rather than the decrease of soil erosion amount. Similar results were found by Darboux and Huang (2005) who also stressed the delay in runoff initiation as being the primary soil and water conservation benefit of soil surface roughness.

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EVALUACIÓN DE LA DINÁMICA HÍDRICA DIARIA EN FUNCIÓN DE LA HUMEDAD VOLUMÉTRICA EN SUELOS AGROFORESTALES EN EL NW DE ESPAÑA CON EL USO DE SONDAS DE CAPACITANCIA FDR

Roger M. Mestas Valero [(1)], José M. Mirás Avalos [(1)], Juliano Piovezan Pereira [(2)], Antonio Paz González [(1)]

[(1)] Facultad de Ciencias, Universidad de la Coruña - UDC, La Coruña – España
roger.mestas@udc.es
[(2)] Faculdade de Ciências Agrárias FCA - UNESP, Botucatu, SP – Brasil.

Resumen

La variación del contenido de agua en el suelo es una variable esencial en hidrología y tiene una influencia muy importante sobre las interacciones suelo-planta-atmósfera. Frente a esta situación, es muy importante conocer la evolución espacio-temporal del contenido de agua en el suelo con la finalidad de comprender mejor la dinámica y el funcionamiento hidrológico de la misma, y tener mejor control en la administración del recurso hídrico, evitando una posible degradación y contaminación del suelo. El objetivo de este trabajo ha sido evaluar la variación temporal del contenido de agua en la zona de influencia radicular, en función al contenido de humedad volumétrica de suelo, en una región zona agroforestal del NW de España. Las parcelas estudiadas correspondes a un bosque de eucaliptos, cultivo de maíz y praderas. Para estimar el contenido hídrico en el perfil del suelo, se usaron sondas de capacitancía FDR monitorizado mediante un pequeño data logger con una frecuencia horaria. En periodos de días con poca o nula precipitación pluvial se estimaron variaciones del contenido hídrico del suelo (en la zona de influencia radicular), simultáneamente se estimo la humedad volumétrica del suelo, para ser correlacionados mediante una correlación simple. Los promedios de la humedad volumétrica diaria, en los suelos estudiados en este periodo, fueron de 22,77%; 25,29% y 29,45% para las praderas, el maíz y el eucalipto respectivamente. Los promedios de variación diaria de la humedad de suelo fueron de 1,36 mm, 2,95 mm y 0,29 mm para parcelas con praderas, maíz y eucaliptos respectivamente. Los coeficientes de correlación entre la humedad volumétrica diaria y la variación de humedad diaria del suelo fueron de 0,61 para los pastizales, de 0,64 para el maíz y 0,50 para eucaliptos, todos significativos y positivos. Esto nos mostró que el contenido volumétrico de agua del suelo es un factor relevante en las variaciones diarias del contenido hídrico del suelo. Como consecuencia, el control del contenido de agua del

suelo, sería útil en la toma de decisiones relacionadas a la gestión del recurso agua, controlando una degradación del suelo por una mala administración del recurso agua.

Palabras clave: FDR, humedad volumétrica del suelo, zona agroforestal

Introducción

En los últimos años viene dándose mayor importancia a la eficiencia en la administración del agua, enfocándose en una buena distribución, con la finalidad de lograr una adecuada disponibilidad de este recurso. Esta disponibilidad de recursos hídricos viene determinada por el contenido de agua en el suelo.

La importancia del conocimiento del contenido de agua en el suelo está ampliamente reconocida en hidrología. Su influencia en los procesos hidrológicos condiciona fuertemente el funcionamiento de una cuenca, tanto a escala de crecida como a nivel del balance de agua. Sin embargo, a pesar de un gran número de trabajos de campo, los resultados obtenidos son a veces divergentes y hasta contradictorios. Una visión coherente de la variabilidad espacio-temporal de la humedad del suelo, y de los factores que la controlan, no está actualmente disponible. (Famiglietti *et al*., 1998).

Tradicionalmente, los estudios edáficos se han centrado sobre la fracción fina del suelo. En la actualidad son numerosos los estudios que reflejan la importancia de los fragmentos gruesos en el suelo por sus propiedades físicas y químicas (Nichols *et al*., 1984; Poesen & Lavee, 1994).

La disposición de los fragmentos gruesos sobre la superficie y su influencia sobre las propiedades hidráulicas del suelo es motivo de controversia. Numerosos estudios encuentran un incremento de la infiltración a mayor contenido en fragmentos gruesos (Simanton *et al*., 1984; Espejo *et al.,* 1990), mientras que otros autores encuentran una relación negativa entre el contenido de fracción gruesa en superficie y la infiltración (Wilcox *et al*., 1988; Casenave & Valentin, 1992).

Además, el contenido de agua en el suelo se caracteriza por una gran variabilidad espacio-temporal (Grayson *et al*. 1997; Wilson *et al*. 2003; Western *et al*. 2004), que aumenta marcadamente la no linealidad de dichos procesos hidrológicos.

Frente a esta situación, es muy importante conocer la evolución espacio-temporal del contenido de agua en el suelo con la finalidad de comprender mejor su dinámica y funcionamiento hidrológico. De ahí, la relevancia de encontrar métodos eficaces para evaluar la humedad edáfica.

En los últimos años se han desarrollado métodos de medida basados en la relación entre la constante dieléctrica del medio (ka) y la humedad del suelo. El sistema FDR mide la ka del suelo a través de la capacitancia, en consecuencia, estima el contenido de agua en el suelo (Dean *et al*., 1987).
En este contexto, el objetivo del presente estudio se focaliza en la evaluación de las variaciones temporales de la humedad del suelo, en la zona de influencia radicular y en función al contenido de la humedad volumétrica; con la finalidad de establecer futuras relaciones con los procesos hidrológicos y balances hídricos.

Materiales y métodos

El estudio fue realizado en los años 2008 y 2009 en una zona húmeda de la provincia de La Coruña (NW España).
Las parcelas estudiadas corresponden a un bosque de eucalipto (*Eucalyptus globulus L*), ubicado en la cuenca experimental «El Abelar» (área de 10,7 ha), 8º21'15" N, 43º9'10"W. El sustrato geológico es esquisto del complejo de Órdenes. La textura del suelo es básicamente arcilla limosa en toda la cuenca. La media del contenido de materia orgánica es 9,5% y el pH en el agua de 5,2 (Soto *et al,* 2005).
Praderas y cultivo de maíz (*Zea maiZ L*) en el Centro de Investigaciones Agrarias de Mabegondo, situado en una zona costera atlántica, cuyas coordenadas geográficas son 43º14' N, 8º15' W y una altitud de 91 m.s.n.m. con suelo profundo de textura franco limosa desarrollado sobre esquistos de Órdenes.
Los datos meteorológicos se obtuvieron de una estación meteorológica ubicada en el lugar del experimento, propiedad de MeteoGalicia.
El procedimiento para estimar el contenido de agua en el perfil del suelo, se inicio con la instalación en el terreno de las sondas multisensor de capacitancía tipo FDR (Frequency Domain Reflectometry) (Modelo: EnviroScan Solo) el cual monitorizó la humedad del suelo y seguidamente almacenó los datos en un pequeño data logger.
Se estimó la humedad volumétrica (%) para cada día y en cada parcela, seguidamente con los datos del FDR y por diferencia de humedad fue estimada la variación diaria de la humedad del suelo (mm).
Para estimar el contenido de agua en el suelo, en la zona de influencia radicular fueron considerados las profundidades (40 cm en los pastizales, 60 cm en el maíz y 1,40 cm en el eucalipto) y fue monitorizado con una frecuencia horaria.
Para la evaluación de la variación diaria de humedad del suelo, se tomaron en cuenta períodos de días con muy poca o nula precipitación pluvial, simultáneamente se estimó la Humedad Volumétrica del

suelo. El periodo de evaluación de las praderas y el eucalipto fueron durante todo el periodo de estudio, mientras que para el maíz se evaluó durante el periodo del cultivo.
Con datos meteorológicos obtenidos de dos estaciones meteorológicas ubicadas en los lugares del experimento, fueron efectuados cálculos de los valores diarios de la evapotranspiración (ET), utilizándose la metodología propuesta por la FAO mediante la ecuación de Penman-Monteith (Allen *et al.*, 1998)
Los datos de humedad volumétrica diaria en la zona de influencia radicular fueron relacionados con la variación diaria de agua de dicha zona del suelo, mediante una correlación simple.

Resultados y discusión

Los promedios de humedad volumétrica diaria en los suelos estudiados en el periodo del experimento fueron: 22,77% en el ámbito de las praderas, oscilando entre15,10% a 36,07%. En el caso de los cultivos de maíz, el promedio fue de 25,29%, variando desde 19,09% a 33,26% y en el bosque de eucaliptos, tenemos un promedio de 29,45% con un rango de 24,33% a 33,30% (Cuadro 1).
Los promedios de variación diaria de la humedad del suelo (para los días sin lluvia) fueron de 1,36 mm; 2,95 mm y 0,29 mm para las praderas, campos de maíz y bosque de eucaliptos, respectivamente (Cuadro 1).
Los coeficientes de correlación (r) entre la humedad volumétrica diaria y la variación de humedad diaria del suelo fueron de 0,61 para las praderas, de 0,64 para el maíz y 0,50 para eucaliptos, siendo todas las correlaciones significativas y positivas.

Cuadro 1. Datos medios de humedad volumétrica del suelo (HV), media de la variación diaria de humedad del suelo (HS) para el periodo en estudio.

Cultivo	HV diaria (%)	Variación diaria HS (mm)	r	Sig.
Maíz	25,29	1,36	0,64	**
Pradera	22,77	2,95	0,61	**
Eucaliptos	29,45	0,29	0,50	**

Esto indica que el contenido volumétrico de agua del suelo es un factor importante en las variaciones diarias del contenido de agua del suelo, el cual influye en la evapotranspiración, la absorción de agua por las raíces y la infiltración.
Por lo tanto, el control del contenido de agua del suelo, principalmente en las capas superficiales sería útil en la toma de decisiones relacionadas con la gestión del recurso agua, controlando una degradación y contaminación del suelo por una inadecuada administración del recurso hídrico.

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OPTIMIZATION OF A PROPOSAL OF INTEGRATED TERRITORIAL PROTECTION

Podhrázská, J.[1], Dumbrovský, M.[2], Korsun, S.[2], Konecná, J.[1]

[1]Research Institute for Soil and Water Conservation, Dep. For Land Use Planning, Brno, Lidická 25/27 , 60200, Czech Republic tel: 420541126278, fax: 420541126279
e-mail: podhrazska@vumopbrno.cz
[2]Brno University of Technology, Faculty of Civil Engineering, Department of Landscape Water Management, •i•kova 17, 60200 Brno, Czech Republic

Summary

The complex soil-conservation and flood protection of a territory poses a problem which is so complicated, great and costly that it will be suitable and advantageous to use mathematical optimization methods when designing and elaborating more extensive systems of protection in territories exposed to hydrological risks and water erosion. For that reason was developed and tested an optimization computation procedure suitable for practical purposes in an experimental watershed of the 'Nemcický potok' brook in the Moravian Karst. This method is based on the application of the mathematical model OMIPS, which enables to find out with regard to the effective protection of a given territory the most suitable combinations of possible alternatives of territorial organisation, land reallocations, methods of farming, protective anti-flood and soil-conservation measures, hydraulic engineering measures and works including proposals of their optimum dimensions.

This publication recommends methods and procedures for the stabilisation of the landscape water regime and proposals of complex measures reducing harmful effects of surface runoff which causes soil erosion, landscape devastation and flood threats to the territory and to the human population.

Introduction

Methodological guidelines for the proposal and evaluation of efficiency of the system of complex measures for erosion and flood protection are based on methods that can be used above all for engineering and designing activities. The methodological materials were published by Janecek *et al.* (2005), Podhrázská *et al.* (2006), UhlíYová & Mazín (2005) and others. These guidelines apply the results of experiments conducted in research plots and watersheds while procedures suitable for the planning and evaluation of measures in smaller, predominantly agricultural catchment areas are presented. The proposals and

projects of measures are based on hydrological, hydrotechnical and also other calculations and they can use both empirical relationships and simulation models (Dumbrovský *et al*. 2009, Mitasova *et al*. 1999). With regard to soil conservation and flood protection and to the problem of landscape ecological stability, the complex integrated problem of land reallocations is so complicated, great and often costly from the aspect of its implementation that in territories exposed to hydrological risks and water erosion, it will be useful and advantageous to use the tools of mathematical optimization methods when proposing more extensive systems of measures.

An interesting combination of the application of a simulation and optimization model technique in the elaboration of design of a particular water-management system was described by Major *et al.* (1979), a three-model approach to solve water-management systems was used by Onta *et al*. (1991). Benedini (1988) dealt more generally with the design and possible applications of these models. Most likely, an optimization model has not been designed, which would enable to attach territory protection and the measures to eliminate the amount and accumulation of runoff in catchments areas to solving water-management problems.

For that reason there was developed an optimisation computation method that could be used in practice; this method was successfully tested under conditions of an experimental catchment area. This method, which can be used in any agricultural territory, is based on a set of data necessary for the elaboration of proposals of alternatives of measures in all elements of the solved system in the territory under study (at best in a coherent catchment area). It is followed by an optimisation selection from a variety of processed alternatives which appropriately respects all interrelationships and linkages existing among the particular elements of the system and, finally, the analysis of obtained results is done followed by a recommendation of an optimum solution. With regard to the protection of the given studied area this procedure is based on the application of an optimisation mathematical model *OMIPS* (*Optimisation Model of Integrated Protection System*) which enables to find out and select the best combination of possible alternatives of territorial organisation, land reallocations, protective anti-flood, soil-conservation and environmental measures, and hydraulic engineering measures and structures including a proposal of their optimum dimensions.

Material and methods

For any optimization problem at first it is necessary to define either one or several simultaneously working optimality criteria which are then included in the *OMIPS* model in the form of a criterional function. As far as the integrated territorial protection is concerned, it is possible

to select a number of economic, technical (hydraulic engineering, hydrotechnical ameliorations), environmental, social and other criteria. The acquired knowledge of the effects of various criteria, conditions and requirements for the structure and behaviour of a protection system of a concrete territory as well as of the efficiency of individual measures represents an important contribution to debates about negotiations and decision-making on the solution and implementation of such a protective system. The described optimization method may be used when designing and planning an integrated system of territorial protection in any catchment area of 30 to 50 km^2.

The optimization mathematical model is a system of equations, which model a given system behaviour, the variables in the equation describe a system structure and the dimensions of its individual elements. Non-equations found in each model are transformed into equations by means of additional variables in the course of the model solving process. Partial models were created in the modelling and calculation system *GAMS* (*General Algebraic Modelling System*) in its general form (CHARAMZA, 1993) so it can be used to model any integrated territory protection system.

The *OMIPS* model, developed on the basis of mixed discrete programming, is a set of equations in which the variables describe the structure of the modelled system and dimensions of its individual elements while the equations simulate the requirements for its behaviour. The variables simulating the course of activities changing in time describe the dynamic behaviour of an integrated protection system. The model consists of three submodels, namely**:**

I. A submodel of territorial organisation, land reallocations and of a set of soil-conservation measures which reduce erosion effects and surface runoff of precipitation water on the area of a partial locality of the catchment area and, totally, also in the whole catchment area;
II. A submodel of a segment of the stream including possibilities of its regulation and/or revitalisation;
III. A submodel of a water-retention reservoir.

If necessary, submodels can be included in the *OMIPS* model repeatedly (e.g. for partial localities of the catchment area, for particular segments of the stream, for proposed and/or already existing reservoirs) in such a way that they will describe the concrete structure of the catchment area system in the most exact manner possible.

For each optimisation task it is necessary to pre-define at least one optimality criterion; this criterion is thereafter included in the *OMIPS* model in the form of a criterional function. In the case of integrated territorial protection it is possible to define/estimate a number of criteria

of economic and technical (hydraulic engineering, hydrotechnical), environmental, social etc. character. In the selection of several criteria that should work jointly it is necessary to attribute an appropriate weight to each of these criteria with which they will enter so called compromise optimum solution; this weight will influence the effect of the criterion in the result of the solution in competition with the other criteria. The selection of these criteria and the equally important definition of initial conditions and requirements (often of a variant nature) are usually decisively influenced by the competent authority. The optimization procedure of proposing complex measures was tested in the catchment area of the 'Nemcický potok' brook in the protected landscape area of the Moravian Karst. The protective measures involved the building of retention reservoir. The total volume of this reservoir (provided that it is included in the final solution) could range between the minimum, for practice acceptable value of 17,000 m^3 (of which 6,667 m^3 is the constant volume of the permanent water storage) and the maximum, technically realizable volume of 93,000 m^3.
The solution of the *OMIPS* model, developed for this test catchment area, was subjected to the following five optimality criteria**:**

1. Minimization of cumulative runoff from the closure profile of the 'Nemcický potok' brook at a chosen rainfall amount. This criterion is of technical (hydraulic engineering) character, and possibly also of socio-economic character from the aspect of wider effects (it reduces material losses and also fatalities in the flood-stricken population of the downstream situated municipality Sloup).
2. Minimization of the average annual erosion washing away of agricultural soils in fields situated in the catchment area. This criterion is of both economic and environmental character**:** it minimizes devastation of the landscape soil cover and, at the same time, also damage to crops and damage caused by drift soil, which must be removed thereafter.
3. Minimization of the total investment costs necessary for the implementation of proposed biological and forest engineering, ameliorative and hydrotechnical measures. This criterion is of purely economic character.
4. Minimization of the total average annual economic losses incurred in the agriculture and forest sector, which result from the implementation of proposed protective measures in the catchment area. This criterion is of predominantly economic character.
5. Minimization of total material losses incurred in the whole territory under study at a chosen rainfall amount. This criterion is also of predominantly economic character.

Results and discussion

The optimized solution of the *OMIPS* model was run in six variants which respected different initial conditions and required combinations and weights of the aforementioned optimality criteria; this solution should give an answer to the question «*What is the most suitable combination of individual alternatives of territory organisation, land reallocations and protective measures in the catchment area of the* 'Nemcický potok' *brook from the aspect of protection of the studied area and economic impacts of proposed measures?*» The obtained variants revealed significant changes in the structure and behaviour of the integrated system of protection of the territory under study when considering various optimality criteria and different conditions and requirements for the solution to the whole protective system. The most important results of testing the optimization procedure in a concrete catchment area compared to general practical conditions can be summarized as follows**:**

A. The solution of the soil-conservation and flood protection systems for a territory by classical methods using simulation models provides a satisfactory proposal (such solutions are sometimes considered to be optimal; it means that they represent the best of several alternatives of such a proposal calculated by classical methods). However, it is not known how closely such a proposal approaches the real exact optimum. It is quite clear because the pooling of the proposed alternatives of individual elements of an integrated protective system into a final solution results in a high number of their possible combinations. Besides, with the continuous variable parameters of the technical components of a system (e.g. in the case of proposed capacities of retention reservoirs) the number of possible combinations is much higher, and theoretically even indefinite. Mutual comparison of the effects of variants of initial conditions and requirements for the system solved by these methods is unreliable under these circumstances and the decision-making on the implementation of individual proposed variants may be fully irrational.

B. To solve the problem outlined above (see point A) it was decided to develop a procedure which would enable to optimize any solution in the process of the preparation and solution of proposals of integrated systems of soil-conservation and anti-flood protection for a catchment area on the basis of a standard optimization computation method. The advantages of optimized solutions of these problems are above all in:

b. a. the interconnection and maximum interplay of all elements of the system in the process of a computer-aided solution;
c. b. the explicit finalisation of each solution in the framework of pre-defined initial conditions (criteria and principal requirements) always to the absolutely optimal proposal of a protective system which, in cases of the necessity of evaluating the variants of initial conditions, enables to make a reliable mutual comparison of the results of these solutions without any risk of a serious error.

C. The acquired knowledge of the effects of different initial conditions on the structure and behaviour of the system of protection of a given territory and of the efficiency of individual measures is a substantial contribution to the action and decision-making of the quadripartite subjects government – municipalities – economic agents (farmers and foresters) – landscapers (environmentalists, experts in reclamations and water managers) concerned with the solution and implementation of this protective system. This knowledge can also be of great importance for public negotiations and discussions with citizens about the problems of territorial protection.

D. According to the present experience and results, the described optimization procedure may also be used when proposing an integrated system of territorial protection in any catchment area from 30 to 50 km^2 in size. Particularly when solving more complex systems in larger catchment areas with a high number of possible combinations of alternatives of various areal measures in co-action with many alternatives of proposed protective reservoirs, river bed regulations and controlled inundations when it is very difficult to find a suitable solution on the basis of classical simulation models the optimization procedure based on the use of the OMIPS model may be a significant contribution to practice.

Conclusions

The proposed optimization procedure was successfully tested when solving the complex problems of land reallocations in relation to flood protection and soil-conservation, and to the protection of ecological stability of the experimental catchment area of the 'Nemcický potok' brook. It was found out that the main contribution of this procedure consists in the acquisition of knowledge and data concerning the effects of various criteria, initial conditions and requirements for the

structure and behaviour of a system of protection of a concrete territory on the one hand and the efficiency of individual proposed measures on the other. Such knowledge is very important for the decision-making of all those who are concerned with the solution of each concrete system of protection.

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SATISFACCIÓN DEL USUARIO DE LOS PROGRAMAS DE FOMENTO A LA RECUPERACIÓN DE SUELOS DEGRADADOS EN LA REGIÓN DE COQUIMBO, CHILE

Susana Benedetti R. , Marlene González G. , Claudia Delard R.

Instituto Forestal sbenedet@infor.cl; magonzal@infor.cl; cdelard@infor.cl

Resumen

Toda política, programa e instrumento público es periódicamente evaluado por el Ministerio de Hacienda en base a indicadores de desempeño, los que se clasifican en indicadores de Eficiencia, Eficacia, Economía y Calidad. Sin duda, uno de los mejores indicadores para conocer el éxito de la implementación de un programa es el de Calidad, que dice relación con la satisfacción del usuario respecto a la calidad del Servicio, es decir, la capacidad para responder a las necesidades de los usuarios.

A poco tiempo de caducar los dos instrumentos de fomento a la conservación y recuperación de suelos en Chile, «Sistema de Incentivos para la Recuperación de Suelos Degradados, SIRSD», administrado por el Servicio Agrícola y Ganadero (SAG) y el Instituto de Desarrollo Agropecuario (INDAP), y la Ley 19.561 de la Corporación Nacional Forestal, CONAF, en lo referido a su componente de forestación en suelos degradados, y con el objetivo de evaluar su calidad de desempeño a fin de elaborar propuestas para el diseño de nuevas políticas, se realizó en los años 2008 y 2009 una evaluación de dichos instrumentos, a modo de estudio de casos, en la Región de Coquimbo. Para ello se elaboró una encuesta que incluyó desde antecedentes generales del usuario y el predio, evaluación de medios de información de los instrumentos y su operatoria, evaluación de obras implementadas y sus resultados, hasta recomendaciones y sugerencias.

En general, ambos instrumentos son bien evaluados por los usuarios. Sin embargo, se identifican una serie de falencias tanto a la implementación como su operatoria, así como a las obras de recuperación de suelos y los costos de éstas considerados en los reglamentos de dichos instrumentos. Destacan observaciones respecto de los plazos de las distintas fases de implementación de los programas, sistemas de financiamientos y la necesidad de considerar la particularidad de región árida, respecto de flexibilizar los plazos de realización de actividades, pago de créditos y dimensión de obras.

Introducción

A nivel nacional las tasas de erosión y desertificación son importantes, alcanzando niveles graves. Como una medida para frenar su avance y/o revertir su efecto, el Estado ha creado distintos medios de incentivo para la recuperación de estos suelos; entre ellos destacan el «Sistema de Incentivos para la Recuperación de Suelos Degradados (SIRSD)», programa administrado por INDAP y SAG y la Ley 19.561, publicada en mayo de 1998, que modifica el DL 701 en lo referido a su componente de forestación en suelos degradados, a cargo de CONAF.

Particularmente la región de Coquimbo presenta una superficie importante afectada por procesos de erosión en distintos grados; según el Grupo de Investigaciones y Suelos (EIAS), dependiente de la Universidad de Talca, indican que cerca del 85% de su territorio se encuentra bajo proceso de erosión, ya sea en niveles moderado, leve y grave.

Dado este alto grado de pérdida en los suelos, es de suma importancia determinar el nivel de utilización de estos sistemas de incentivo en la región y evaluar cuales son las falencias detectadas desde la perspectiva de los usuarios, de manera de proponer modificaciones que permitan mejoras en los resultados; por ello se planteó el presente estudio, cuyo objetivo es evaluar in situ los proyectos y obras de recuperación de suelos degradados o erosionados implementados por los programas de CONAF y SAG, a través de la aplicación y análisis de encuesta de satisfacción a los usuarios en la región.

Material y método

Para el monitoreo in situ de los programas de recuperación de suelos, se elaboró una encuesta, que incluyó desde antecedentes generales hasta recomendaciones y sugerencias de los usuarios. Fue estructurada en 6 módulos, cada uno de los cuales abarca información descriptiva, de distintos aspectos relacionados con ellos. La descripción de cada uno de ellos se detalla a continuación:

- Módulo A: Antecedentes generales. Permite la identificación del usuario y del predio favorecido con el incentivo.
- Módulo B: Programa de Incentivo a la Recuperación de Suelos. Permite identificar y evaluar medios de difusión de los distintos instrumentos de incentivo y su funcionamiento.
- Módulo C: De las Obras de Recuperación de Suelos. Descripción del tipo de obra y superficie intervenida.
- Módulo D: De los Resultados de las Obras de Recuperación de Suelos. Si ha sido complementario a otras actividades, si han obtenido los resultados esperados, etc.

- Módulo E: Sugerencias y Comentarios. De acuerdo a su experiencia con este tipo de instrumentos, que puede destacar o sugerencias que pudieran aportar en el mejoramiento del instrumento.
- Módulo F: Observaciones. Casilla de uso interno para ser llenada por el encuestador y que da cuenta de información relevante, por ejemplo, participación como dirigente de la comunidad.

La aplicación de la encuesta se llevó a cabo en las provincias de la región de Coquimbo. Se consideró como base los listados de beneficiarios que mantienen SAG y CONAF, actualizados al año 2005 y se complementó con las observaciones en terreno, donde fue posible encontrar obras de recuperación durante la aplicación de la encuesta. Se logró entrevistar a 25 propietarios beneficiados con alguno de los 2 programas establecidos por MINAGRI para la recuperación de suelos, a través de obras de recuperación y/o plantación de especies vegetales.

Resultados y discusión

Evaluación Satisfacción Programa SIRSD – SAG-INDAP

La opinión de los usuarios consultados es variada, y en gran medida depende del objetivo con que las obras de recuperación de suelo fueron establecidas y los resultados esperados por cada uno de ellos. El 89% de los encuestados corresponde a hombres y sólo el 11% restante a mujeres, situación que en gran medida está asociada al dominio de la tierra, y que se evidencia en este y otros programas de fomento a nivel nacional. El 100% de ellos declaró como actividad principal la agricultura y sólo 4 declararon adicionalmente una segunda actividad productiva: ganadería, construcción y artesanía. El rango de edad de los beneficiarios es amplio, 32 a 79 años, sin embargo entre los 41 y 60 años, se concentra el 53% de los beneficiarios (Figura 1).

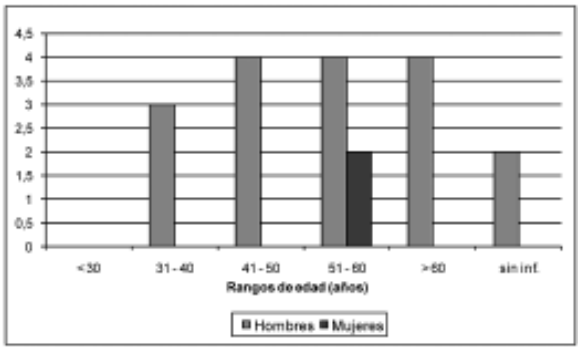

Figura 1. Número de encuestados, según rango de edad.

El total de los encuestados indicó conocer al menos un programa de fomento y/o recuperación de suelos degradados, indicando alguna de las instituciones asociadas: SAG, INDAP, CONAF. Sólo uno de ellos no asoció ninguna institución a estos programas, pero indicó saber de su existencia. Al evaluar los medios de información sobre el instrumento, un 32% indica haberse informado en reuniones de su Comunidad o a través de otros comuneros que lo han utilizado con buenos resultados; 37% se enteró por medio de Operadores o Asesores privados; 10% directamente a través de instituciones dependientes del MINAGRI, 10% por medio de la Municipalidad y 11% a través de otras instituciones (Figura 2).

En relación a la asesoría recibida durante el proceso de postulación, ejecución de las obras y supervisión final (Figura 3), el 100% indica haber contado con apoyo técnico de operadores acreditados, los que fueron seleccionados principalmente por ser parte de la Comunidad, por la experiencia a través de otras asesorías, por recomendación de otras Comunidades o comuneros o por visita directa al propietario o a reuniones de la Comunidad. Fue común encontrar que un mismo Operador asesore a varios integrantes de una Comunidad Agrícola. Es destacable que todos los predios favorecidos por este programa, contaban con la identificación del programa en sus puntos de acceso, lo que facilita su ubicación.

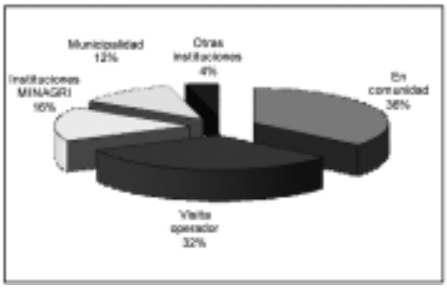

Figura 2. Difusión de SIRSD

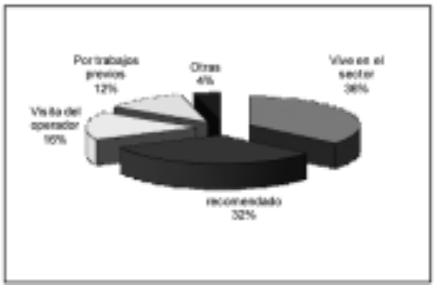

Figura 3. Selección de asesores

Ninguno de los entrevistados calificó como mala la asesoría recibida, sin embargo, 4 de ellos indicaron haber tenido dificultades principalmente relacionadas con la instalación de las obras, periodo en el cual les hubiese gustado haber contado con una supervisión más estrecha, para poder resolver dudas o enfrentar dificultades, principalmente dadas por las condiciones particulares de cada terreno.

Al consultar a los entrevistados cuales fueron los motivos considerados para la participación en estos programas (Figura 6), la mayor parte de ellos indicó más de algún fin, en algunos casos hasta 3, entre los que destacaron control de la erosión o recuperación de suelo

erosionado (29%), como actividad previa a la incorporación de cultivos o plantación (29%), la acumulación de aguas lluvia (21%), o por el dinero entregado como subsidio (18%). Destaca una mención de uso como unidad demostrativa, que corresponde a una unidad donde hubo financiamiento adicional por parte del PNUD.
Existe una gran variedad de estructuras incluidas en estos programas y generalmente se combinan varias de ellas en un mismo sector (Figura 4); sin embargo, se observa que se ha preferido la construcción de zanjas de infiltración (Figura 5). Al preguntar respecto a qué cambios harían para mejorar y optimizar las obras y los resultados, la gran mayoría indicó estar conforme con las características de ellas, pero que sería conveniente aumentar las dimensiones de las microterrazas de manera de aumentar la superficie cultivable, facilitando además las labores con maquinaria.

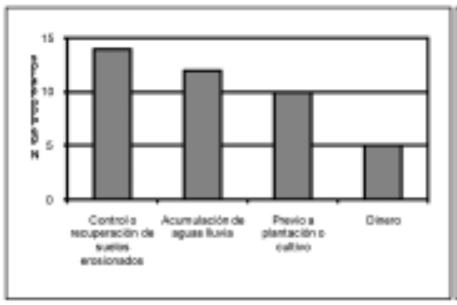

Figura 4. Objetivo de postulación a SIRDS

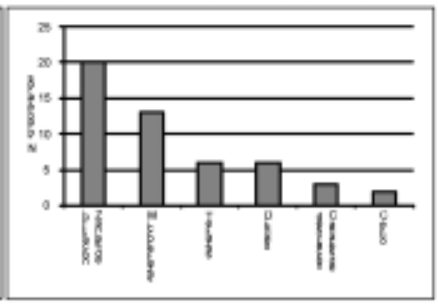

Figura 5. Obras de recuperación utilizadas

Al evaluar la utilización posterior de las obras, el 47% de los casos no se estableció ningún tipo de cultivo, algunos justificado por el período de sequía ocurrido esa temporada o simplemente porque no era el objetivo perseguido. El resto de los propietarios ha establecido plantaciones, principalmente con fines forrajeros utilizando *Acacia saligna* y/o *Atriplex spp*. (21%) o con cultivos agrícolas, principalmente para autoconsumo, papas, porotos, habas, etc.(Figura 7). Destaca en este punto, el establecimiento de frutales, principalmente almendros en 3 unidades, con el apoyo de otro programa de INDAP.

Es importante destacar que quienes han instalado terrazas, aún cuando reconocen que la dedicación de mano de obra durante su instalación es mucho mayor, son quienes están más conformes con los resultados y en definitiva son quienes han notado cambios importantes en su calidad de vida, dado el gran número de cultivos que han podido instalar, principalmente con fines de autoconsumo. Además, algunos de ellos la ha complementado con sistema de riego tecnificado.

Figura 6. Obras instaladas en Choapa

Figura 7. Cultivos asociados a obras

En este mismo sentido, la mayor parte de los encuestados dice no haberse visto enfrentado a ninguna dificultad de importancia durante la ejecución de las obras. Sin embargo, 8 de ellos indicaron lo difícil de cumplir con los plazos estipulados en las condiciones dadas, que coincidió con la falta de lluvia en los años evaluados y que se traduce en un suelo de dureza extrema.

La elección de la estructura a instalar fue definida mayoritariamente por los asesores (58%) y en menor medida por acuerdo entre el propietario y el operador (21%), o en base a los resultados obtenidos por otros propietarios (16%). Esto debería revisarse, ya que en otros programas se ha observado que, mientras mayor es la participación del propietario en todo el proceso, se logra un mayor compromiso durante su instalación y en las tareas posteriores, lo que podría favorecer los resultados de mediano y largo plazo asociados a estos programas.

El 79% de los encuestados indicó que no se realizó ninguna evaluación por parte de los asesores, o de las instituciones encargadas de los programas una vez finalizadas la instalación de las obras, lo que fue mal evaluado por los propietarios, ya que en parte atribuyen a esa situación, la falta de actividades posteriores o de mejor aprovechamiento de las obras de recuperación. Sólo 16% indicó haber recibido supervisión al finalizar la instalación de las obras. Algunos de los propietarios (42%) han realizado tareas posteriores, ya sea a través de otros programas o con sus propios recursos, para complementar las obras instaladas. Destaca la mención de grupos de mantención para el caso de obras instaladas en terrenos comunitarios. Ningún propietario evalúa negativamente los resultados, el 95% de los encuestados los considera buenos. En relación a la estructura u obra de recuperación instalada (Figura 8), el 79% piensa que la elección fue la correcta de acuerdo a las condiciones del terreno, sin embargo, reconocen no conocer todas las estructuras disponibles, lo que refuerza la indicación anterior de favorecer una mayor participación de los propietarios durante el proceso de planificación de las obras.

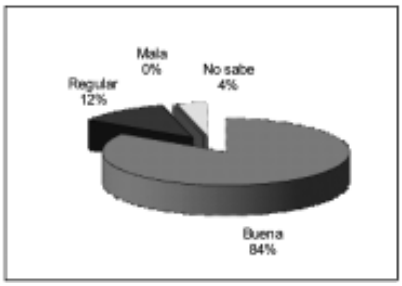

Figura 8. Evaluación de la obra

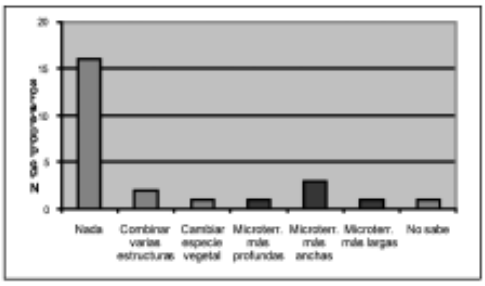

Figura 9. Mejoras propuestas para las obras

Sobre la posibilidad de modificar la obra instalada, de manera de mejorar su efecto sobre el terreno, 58% indicó que no modificaría nada, 26% propuso modificar, profundidad, ancho y/o largo que las microterrazas; 5% propuso combinar varias estructuras, lo que en algunos casos se realiza, sólo un propietario indicó considerar la mantención posterior en el financiamiento (Figura 8). Aun considerando todas las dificultades a las que se han visto enfrentados estos beneficiarios y que manifestaron durante la aplicación de la encuesta, el 100% de ellos volvería a postular a este instrumentos, bajo la modalidad actual, lo que indica que están conformes con su existencia y de la posibilidad de acceso a ellos.

De los comentarios recibidos (Figura 10) destacan: la necesidad de aumentar los montos de subsidio (21%), que fecha de ejecución de obras coincida con periodo de lluvias, asociar estos trabajos a programas de riego (por ejemplo para la construcción de estanques e instalación de riego tecnificado), y contar con financiamiento para tareas posteriores de mantención.

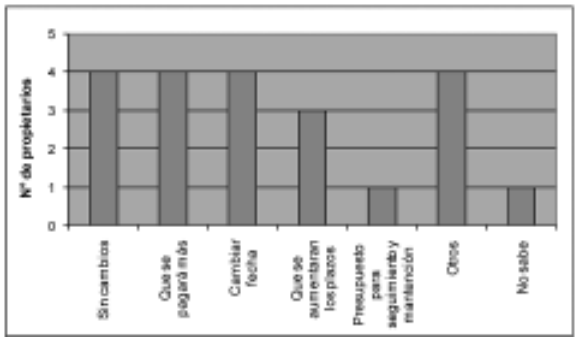

Figura 10. Sugerencias de los beneficiarios

Evaluación Programa Recuperación suelos degradados - CONAF

En este caso, la evaluación se realizó principalmente en las provincias de Choapa y Limarí y en menor grado en Elqui por la menor cantidad de usuarios en esa provincia. El 71% de los encuestados

corresponde a hombres y el 29% a mujeres, situación asociada al dominio de la tierra. El 36% declaró como actividad principal la agricultura y un 18% la ganadería, adicionalmente un 36% declaró como actividad principal la combinación de agricultura y ganadería. El rango de edad de los beneficiarios es amplio pero se concentra en edades superiores a 51 años, con un 68% (Figura 11).

El total de los encuestados indicó conocer este instrumento de fomento, a través de alguna de las instituciones asociadas: SAG, INDAP, CONAF.

En relación a los medios de difusión de este instrumento, un 33% indica haberse informado sobre ellos a través de Operadores o Asesores forestales, un 22% en reuniones de Comunidad y un 22% directamente a través de instituciones dependientes del MINAGRI; el 23% restante se ha informado a través de conocidos y por ser Dirigente campesino (Figura 12).

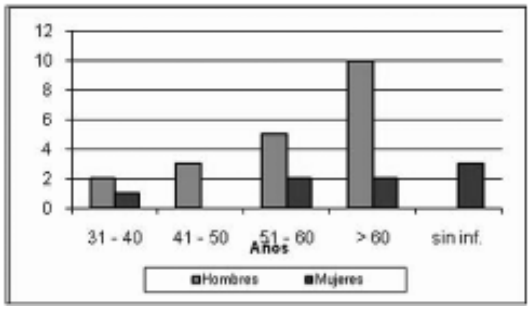

Figura 11. Edad de los beneficiarios del Programa de CONAF.

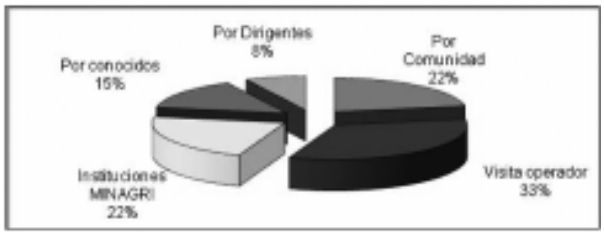

Figura 12. Difusión de programas de recuperación de suelos

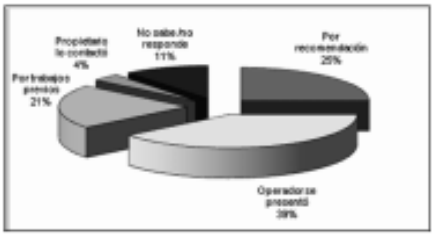

Figura 13. Selección de asesores

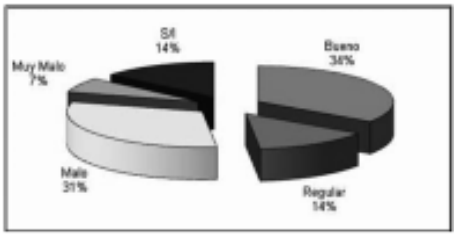

Figura 14. Calificación de los asesores

En relación a la asesoría recibida durante el proceso de postulación, ejecución de las obras y supervisión final, los Asesores fueron seleccionados principalmente por visita directa de ellos a cada propietario o a reuniones de Comunidad, por recomendación de otras Comunidades o comuneros, o por trabajos previos en el área (Figura 13). Sin embargo, la asesoría recibida no fue bien evaluada, sólo un tercio de los beneficiarios la encontró adecuada y casi el 40% la calificó entre mala y muy mala (Figura 14). En varios sectores fue un mismo Operador que trabajó con varios propietarios, motivo por el cual se repiten las opiniones respecto a algunos de ellos. La mayoría de los propietarios indica que hubiesen deseado contar con una supervisión más estrecha, para poder resolver dudas o enfrentar dificultades, y contar con información oportuna y clara.

Las principales dificultades con los Operadores, se refieren a que no va a terreno; no termina trabajo; no hace informe; no es competente; se lleva el Dinero

Respecto de las dificultades en el proceso de postulación se menciona la falta de información (40%), especialmente de los requisitos, obligaciones o responsabilidades por parte del propietario, aspectos legales y montos a bonificar. Se indica también la información sobre resultados de la solicitud de bonificación, la que en la mayoría de las veces no llega a tiempo a los beneficiarios, y que en caso de haber sido rechazada o bonificada parcialmente, genera una deuda al propietario. Otra dificultad recurrente es la que se produce por atrasos en la entrega de los dineros para hacer la instalación de las obras y forestación. Los beneficiarios no disponen de fondos para realizar los trabajos anticipadamente y es frecuente que esto implique realizar las labores en plazos inadecuados a las características de la Región, como precipitaciones escasas y sequias recurrentes, que restringen enormemente los períodos para plantar. Se destaca que un tercio de los encuestados no informa problemas durante el proceso de postulación al Programa (Figura 15)

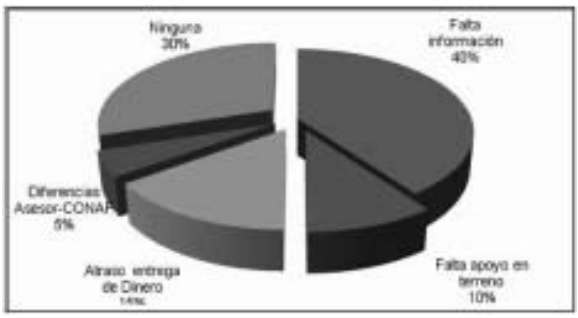

Figura 15. Dificultades durante proceso de postulación

Los motivos indicados por los encuestados para utilizar este instrumento se refieren principalmente a la posibilidad de acumular aguas lluvia (71%) y en segundo lugar al control o recuperación de suelos erosionados (14%) (Figura16).

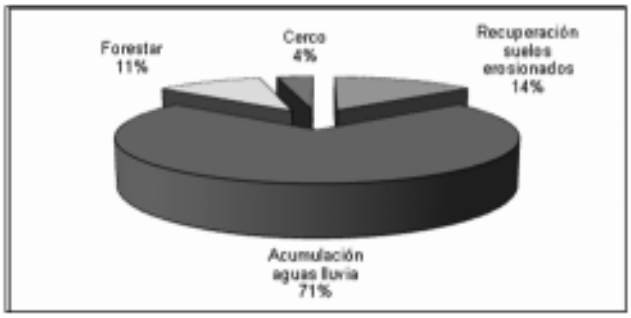

Figura 16. Objetivo de las obras de recuperación de suelos

Respecto de las obras implementadas, en general se combinan varias de ellas en un mismo sector. Los propietarios encuestados indican que se ha preferido la construcción de zanjas de infiltración, seguido por diques de palo y microterrazas (Figura 17). La selección del tipo de obra en su mayoría es realizada por el Operador y/o por el propietario en base a recomendación del asesor (60%). Respecto de las especies asociadas a las obras de recuperación *Acacia saligna* y *Atriplex spp*. han sido las más utilizadas (Figura 18), las que también fueron decididas o recomendadas por el Asesor, en función del requerimiento forrajero por parte de los propietarios (figuras 18 y 19). Respecto de las dificultades para la implementación tanto de las obras como de las plantaciones, si bien un 40% de los beneficiarios indicaron no presentar problemas, se mencionaron dificultades como falta de presencia del Asesor, terreno poco apto, o falta de lluvias, plantas o plantación inadecuadas, y retraso en la recepción de los dineros.

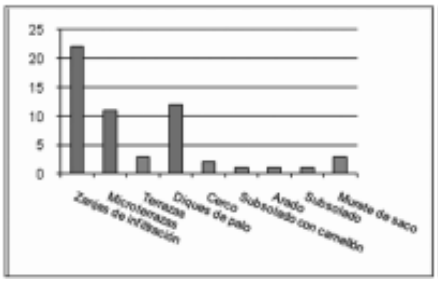

Figura 17.
Obras de recuperación de suelo

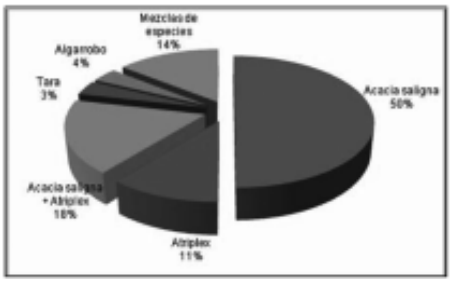

Figura 18.
Principales especies utilizadas

En relación a la obra de recuperación y especie vegetal seleccionada, un 75% de los beneficiarios la consideró adecuada (Figura 20), siendo considerada regular principalmente en situaciones donde el propietario hubiera preferido otra especie. Respecto de los diques de palo, se considera que son de alto costo de implementación en materiales como en mano de obra, y que la bonificación es muy inferior al costo real.

Figura 18.
Zanjas de infiltración

Figura 19.
Plantación de *Acacia saligna*

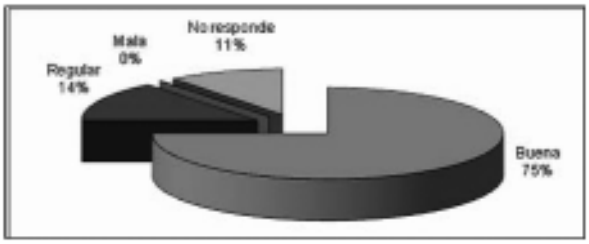

Figura 20. Percepción respecto de la estructura y especie utilizada

Es importante destacar que se reconoce que las obras realizadas cumplen con la función para las cuales fueron implementadas; es decir, permiten una mayor humedad en el suelo lo que se constata con un mayor crecimiento de pasto, alimento para sus animales. La única evaluación realizada a las obras ha consistido en la que realiza CONAF para evaluar prendimiento y posterior bonificación de la plantación. No existe una evaluación hacia los Asesores ni a las instituciones encargadas de los programas una vez finalizadas las actividades de instalación de las obras, lo que fue mal evaluado por los propietarios, ya que en parte atribuyen a esa situación, la falta de actividades posteriores o de mejor aprovechamiento de las obras de recuperación. Algunos de los propietarios (32%) han realizado actividades de mantención como riegos estivales, mantención de cercos, control de conejos y replante, con recursos propios para lograr un

adecuado prendimiento de las plantas y la bonificación asociada. Frente a la consulta de la posibilidad de cambiar algo en la estructura u obra instalada, de manera de mejorar su efecto sobre el terreno, 54% indicó que no modificaría nada, el 46% restante aún cuando indica no saber acerca de modificaciones posibles, cambiaría la especie, aumentaría la cantidad de zanjas, o quisiera una mayor superficie cultivable. Por último, respecto de si los propietarios volverían a utilizar esta herramienta para recuperar suelos, un 81% indica que si, el resto indica que es necesario aclarar diferencias entre Asesor y CONAF y mejorar la oportunidad de información en las distintas etapas del proceso, desde la postulación a la evaluación y bonificación.

Entre las sugerencias (Figura 21) destaca la necesidad de disminuir los tiempos de espera en la entrega del crédito para inicio de las actividades, que los asesores sean de CONAF, se destaca que antiguamente los asesores eran de CONAF y funcionaba adecuadamente. Otro aspecto relevante, es flexibilizar los plazos para realizar las actividades en la Región dada su condición árida. Se propone que sea INDAP el que preste el dinero, ya que el con el BancoEstado no hay flexibilidad, lo que ha generado un gran endeudamiento entre los usuarios. También se propone que CONAF financie directamente. Se menciona también la necesidad imperativa de mayor bonificación para la Región, y considerar además una bonificación para mantención de obras y manejo.

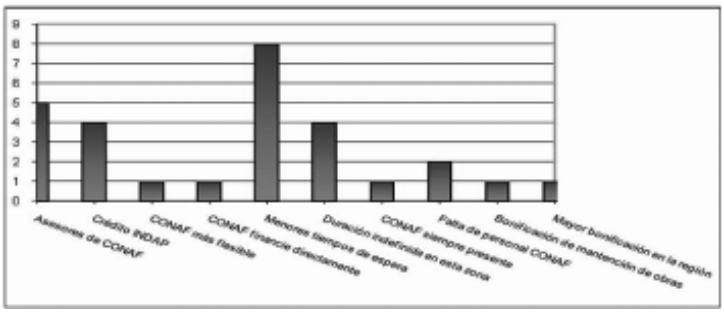

Figura 21. Sugerencias de los beneficiarios

NATURAL CLAY DEPOSITS AS S SOIL CONDITIONER TO THE SANDY SOILS OF SAUDI ARABIA

Abdulrasoul M. Al-Omran,

Soil Science Department, College of Food and Agricultural Sciences, King Saud University, P.O. Box 2460, Riyadh 11451, Saudi Arabia. rasoul@ksu.edu.sa

Summary:
The ecosystems of many regions in Saudi Arabia are impoverished by scarcity of water resources and predominance of marginal calcareous sandy soils. These soils are characterized by low organic matter content, low specific surface area, and low water holding capacity, high infiltration rate, excessive deep percolation losses and high cumulative evaporation, causing inefficient water use for irrigation. These constraints can be partially alleviated through the use of synthetic polymers that act as super absorbent of water to improve water use efficiency and some soil physical properties. The results of our studies in both laboratory and field showed that the polymers improved soil physical properties, but also showed a significant increase in soil pH as a substantial increase in EC. The results showed that the amount of water absorbed with the polymers decreased with increasing salinity of irrigation water. As an alternative for the use of synthetic polymers, natural clay deposits were used as soil conditioner for water management of calcareous sandy soils. The main objective of the study is to investigate the effect of different rates and type of natural clay deposits from Saudi Arabia on relative swelling, infiltration rate, cumulative infiltration and yield of tomato crops. The results indicated that addition of clay deposits rate 4-10% significantly increased relative swelling index and decreased infiltration rate. The advance of wetting front was decrease with the increasing rate of clay deposits. Fields study showed that type of clay deposits significantly affected fruit yields compared with control. The yield increase was 6.4-12.8%.
Key words: natural clay deposits, infiltration rate, sandy soils, synthetic polymers

Introduction

The productivity of calcareous sandy soils are limited by low water holding capacities, high infiltration rates, high evaporation, low fertility levels and low organic content. The use of organic and chemical

amendments could improve the physical properties of these soils. Sewage sludge along with other organic wastes is commonly used as soil amendments. Also, synthetic soil conditioners were used to improve some soil physical properties and its productivity (Al-omran *et al*., 1987; Choudhary *et. al.* 1995; Falatah *et al.*, 1999). These materials can thus increase water supply to growing plants and improve water use efficiency (Al-Harbi *et al.*, 1996). Research on application of different synthetic conditioners showed that their use on a large scale in agricultural land could be unrealistic because of their high cost, insufficient longevity, and drastic reduction in efficiency with salinity (Al-Darby *et al*., 1993; Choudhary *et al*. 1998). There have been studies in some arid and semi-arid areas of the world on the use of natural deposits to alleviate some of the soil constraints to crop production. The use of natural deposits may improve the above constraints and thus increase soil productivity, especially in the areas where these materials are available naturally in abundance and inexpensive. Abou-Gabal *et al.* (1990) found that the addition of local Tafla (dominantly bentonite) to the sandy soils in Egypt improved the soil texture and consequently soil-water plant relationships. Al-Omran *et al.* (2002, 2004) reported a marked decrease in cumulative infiltration, evaporation and depth of wetting front with increasing the rates of bentonite up to 4% in sandy soils. However, further research is needed to determine the effect of natural clay deposits on physical properties of sandy calcareous soils.

Materials and methods

A sample of loamy sandy soil, was collected from the surface layer (0-30 cm) of the Agricultural Experiment and Research Station at Dierab (24 25' N and 46 34' E), 40 Km south west of Riyadh, College of Food and Agriculture Sciences, Saudi Arabia. The soil sample air-dried and passed through a 2-mm sieve. The physical and chemical properties of soil sample were determined according to procedures outlined by Page *et al.* (1982)**.** Two samples of clay deposits; namely CD#22 (gray color, lat. 22 13 53.1 N and Long. 39 13 53.1 E) and CD#23 (red color, Lat. 22 09 09.2 N and Long. 39 20 31.6 E) collected from khyleis area, Jeddah – Madina road, Saudi Arabia were used in the current study. In addition, commercial organic fertilizer (OF) was used. Loamy sand soil mixed with natural conditioners at rates of 0, 1, 2.5, 5 and 10% (on dry weight basis). The conditioners were thoroughly hand mixed with air-dried soil sample. Soil water parameters; such as saturation water content (SWC), field capacity (FC), permanent wilting point (PWP) and plant available water (PAW) were determined according to the methods described by Klute (1986).

Soil water retention curve was performed according to Carter (1993) using pressure plate extractor for tensions of 0.1 to 15 bars (100 to 15300 cm H_2O). Water retention data fitted to van Genuchten model (van Genuchten, 1980) using RETC software (van Genuchten *et al.,* 1991). The soil water retention function, ¸(h) was calculated according to the following formula (van Genuchten, 1980):

$$\theta(h) = \theta_r + \frac{(\theta_s - \theta_r)}{\left[1 + (\alpha h)^n\right]^m}$$

or

$$S_e = \frac{1}{\left[1 + (\alpha h)^n\right]^m} \qquad for\, h < 0$$

$$S_e = 1 \qquad for\, h >= 0$$

where:

$$S_e = \frac{\theta - \theta_r}{\theta_s - \theta_r}$$

h is the pressure head (cm),
θ_r is the residual soil water content ,
θ_s is the saturated soil water content, and
α(cm^{-1}), n and m are empirical parameters (m=1-1/n)

For the infiltration experiment, air-dried (<2.0 mm) sieved soil sample(untreated soil) was packed at 1.6 Mg m^{-3} bulk density in transparent sectioned Lucite cylinders (5 cm internal diameter and 5 cm length). The soil column consists of 8 pieces with length of 40 cm using adhesive strip to construct the column. The column closed at bottom end with piece of cloth held firmly by adhesive strip.The soil column packed with soil to depth of 30 cm every 5 cm to insure a homogeneous of soil in column. The clay natural deposits (CD#22 and CD#23) and organic fertilizer (OF) mixed with the soil at rate of 0, 1, 2.5, 5, and 10% (w/w), and then packed in the upper 0-5 cm of the soil column. A flooding apparatus (Marriot device) designed to maintain a constant head of 3 cm over the soil surface by means of a bubbler tube to allow accurate measurement of infiltration data as a function of time. The observations made during the infiltration experiment included change in the bubbler reading (cumulative infiltration) and the change of visible wetting front advance with time. When the wetting front reached the end of soil column (35 cm depth below the soil surface), infiltration experiment terminated. The soil column sectioned in 5 cm increments and soil water content was determined gravimetrically. Each treatment replicated 3 times.

Evaporation experiment was conducted in 40 cm long transparent sectioned Lucite cylinders (5 cm internal diameter and 5. cm long) The column was packed up to 30 cm with untreated soil and then with 5 cm of treated soil with different rates of natural clay deposits and organic fertilizer as mentioned before(each treatment was replicated three times). The soil packed by tapping every 5 cm increment to give the desired bulk density (1.6 Mg m^{-3}). The soil columns were placed on the bench inside the laboratory (252C). Fifty millimeter of tap water (EC = 0.4 dS m^{-1}) was applied weekly for three wetting /drying cycles. Cumulative evaporation against time was measured daily by weighing each soil column. The soil moisture distribution at the end of the experiment was determined gravimetrically by sectioned the soil column in 5 cm increment. The water conserved in each treatment was determined as follows:

$$water\ conserved\ (\%) = \frac{(cumulative\ applied\ water - cumulative\ evaporation)*100}{cumulative\ applied\ water}$$

Results and discussion

Water retention characteristics: Soil water retention reflects the ability of soil to retain water. Mixing soil with natural conditioners, significantly increased the soil water retention i.e. saturation water content (SWC), field capacity (FC), permanent wilting point(PWP) and available water capacity(AWC), calculated as the difference between FC and PWP. With the statistical viewpoint, the three conditioners significantly increased the water constants of mixed soil, but the CD#22 has a superior effect. At the 10% application rate, the Increments in SWC were 22.75, 15.72 and 11.17% over the control treatment (soil without mixing with natural conditioners) for CD#22, CD#23 and OF, respectively. The corresponding increments for FC were 53.51, 24.34 and 25.27%, for PWP were 53.17, 51.74 and 59.89% and for AWC were 53.59, 17.60 and 17.03%, respectively. The increments more pronounced with PWP. The superiority of CD#22 attributed to more content of clay, especially smectite.

Cumulative infiltration: Cumulative infiltration expressed as depth of equivalent water (D) related to infiltration time (T) shown in Table (5) and Figure (1) for loamy sandy soil amended with clay deposits and organic manure. The results clearly indicate that increasing the application rate of amendments significantly decreased the cumulative infiltration. The decrease in D more pronounced at higher rates. The clay CD#22 was more effective in reducing the cumulative infiltration. The relationship between cumulative infiltrations (D) as a function of time (T) was done by fitting the data to the Kostiakov's equation

(Kostiakov, 1932), Fitting the infiltration data to the above equations gave correlation coefficient (r) ranging between 0.9983 and 0.9999.

Soil moisture profile: The distribution of soil moisture profile with depth for soil treated with natural conditioners illustrated in . The soil moisture profile characterizes by three zones. The *first zone* extend from surface to 5 cm depth which influenced by material and rate of application. The soil water content increased with increasing the rate of application and reaches the saturation content, therefore called *saturation zone*. The *second zone* extends from 5 to 25 cm depth. The soil water content approximately uniform for each treatment and soil water content increased with increasing the application rate. This zone called *transition zone*. The *third zone* is almost dry and there are no differences between materials and rates. The water content is uniform and this zone called *transmission zone*, it is the limit between wetted soil and the initially dry soil.

Intermittent Evaporation: In general, natural conditioners significantly reduced the cumulative evaporation throughout the 3 evaporation cycles. The reduction significantly increased with increasing the application rate, except for the higher rate (10%), which increases the cumulative evaporation under the present conditions. Application of natural conditioners restricts the water movement and increases the water retention by soil, then more water retained in soil surface available for evaporation. The field study concluded that management practices which include subsurface drip irrigation and the subsurface application of natural clay deposits have high potential for improving yield and water use efficiency. Types of clay deposits significantly affected the yield compared with control. The yield increase was 12.8, 8.3 and 6.4 for different clay deposits.

Conclusions

In general, positive effects of different natural clay deposits on improving soil properties encourage farmers to use these natural clay deposits in calcareous sandy soils, especially in regions limited in water resources. The high content of clay in these deposits is desirable to improve water holding capacity of coarse-textured soils. In addition, these soils are poor in organic matter, thus addition of organic fertilizers or organic materials lead to improve the organic matter content of these soils.

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REHABILITATION OF DEGRADED VOLCANIC SOILS OF CHILE AND MEXICO: RESULTS OBTAINED FROM AN INTERNATIONAL AND INTERDISCIPLINARY PROJECT (REVOLSO); (INCO-DEV FRAME PROGRAMME V OF THE EUROPEAN UNION)

[1]G. Werner, [4]A. Báez, [2]M. Bravo, [6]S. Covaleda, [3]J. Espino, [4]J.D. Etchevers, [5]G. Flores, [6]J.F. Gallardo, [8]M. Mazzoncini, [7]M.I. González, [1]M. Haulon, [4]C. Hidalgo, [2]L. Medina, [6]S. Pajares, [8]M. Petri, [9]C. Prat, [10]I. Vidal, [10]E. Zagal, [4]E. Zapata, [6]L. Alonso, [6]M. González, [4]B.M. Gutiérrez, [4]J. Padilla, [3]M.L. Padilla, [8]R. Risalti Y [5]A. Vera.

[1]Justus-Liebig-Universität Giessen (Germany); [2]INIFAP (Uruapan, Mexico); [3]Universidad Autónoma de Chapingo (Texcoco, Mexico); [4]Colegio de Postgraduados (Texcoco, México); [5]Universidad Autónoma de Tlaxcala (México); [6]C.S.I.C. (Salamanca, España); [7]Universidad de Salamanca (España); [8]C.I.R.A.A., Università di Pisa (Italia); [9]I.R.D. (Francia); y [10]Universidad de Concepción (Chillán, Chile). Gerd.Werner@agrar.uni-giessen.de>, JGallard@usal.es, JEtchev@colpos.mx, EZagal@udec.cl.

Abstract

The international and interdisciplinary **REVOLSO** Project («Alternative Agriculture for Sustainable Rehabilitation of Deteriorated Volcanic Soils in Mexico and Chile», # ICA4-CT-2001-10052), belonging to the INCO-DEV Programme of the European Union, aimed the rehabilitation of degraded volcanic soils of Chile and Mexico. Five Latin American and four European scientific organizations were included in this Project that started in January 2002 and ended in July 2006. Experimental works were carried out in selected plots located in the States of Michoacán and Tlaxcala (Mexico), and close to the city of Chillán (Chile). The initial hypothesis was based on the fact that much of soil degradation occurring in the studied areas is caused by the excessive pressure on land resources produced by subsistence agriculture, thus increasing poverty. This vicious circle should be broken avoiding the continuous soil degradation through its recovery by applying new knowledge and alternative agronomic management systems. The goal of the REVOLSO Project was to provide and to test a technological package adapted to the socio-economic circumstances of farmers in both countries, adopting organic soil management or balanced fertilization, diminishing soil tillage, maintaining mulching, and to stop the erosive processes and to increase the productive capacity of these lands by including leguminous rotation and agroforestry. Accordingly, the study presents some important final results obtained by the REVOLSO Project.

Key words: Soil erosion, Tepetates, Soil fertility, Soil organic C.

Introduction

About 25% of the surfaces of the Andean countries in South America (i. e., Chile, Colombia, Ecuador, Peru), Central America, and Mexico are covered with volcanic soils. These physically fertile soils (poor from the point of view of the some macronutrients) have been cultivated inadequately with culture practices that caused severe erosions, decreasing dramatically the yields during the last decades. Due to erosion of superficial layers, hardened subsoil layers called *tepetates* (Mexico), *talpetates* (Nicaragua), *cangahuas* (Ecuador), *trumaos or ñadis* (Chile) appeared at the surface. Small farmers living in these deteriorated regions progressively loose the soils, and migrate toward megacities of Mexico, USA, or Canada.

Taking into account the mentioned problems, the objectives of the REVOLSO Project were listed as following:

- Develop improved technological packages to achieve a sustainable rehabilitation and improvement of deteriorated volcanic soils in Mexico and in Chile, but taking into account the know-how of previous investigations on traditional local practices, principles of organic agriculture, and local experiences in agroforestry.
- Develop a set of measures in order to achieve a sustainable soil management in agriculture and reforestation in order to prevent the erosion of non-deteriorated soils in areas of deteriorated volcanic soils in Mexico and Chile based on results of former research projects, traditional practices, sustainable agriculture, and agroforestry.
- Consolidate and integrate the research results obtained into recommendations for the sustainable rehabilitation of deteriorated volcanic soils and the prevention of the erosion of non-deteriorated volcanic soils.
- Disseminate these recommendations to producers, associations, and governmental institutions of the regions concerned.
- Disseminate the results of the REVOLSO Project internationally by publications in international journals, national and international congresses on agriculture and soil science, and in an International Symposium on Deteriorated Volcanic Soils (ISVO'06) at the end of the lifetime of the project.

Materials and methods

Materials and methods employed were selected by members of the following partners of the REVOLSO-Consortium, according previous experiences:

a) *Justus-Liebig-Universität*, Giessen, Germany (JLU)
b) Institut *de Recherche pour le Développement*, France (IRD)

c) *Colegio de Postgraduados*, Mexico (CPM)
d) *Universidad Autónoma de Chapingo*, Mexico (UACH)
e) *Universidad de Concepción*, Campus Chillán, Chile (UDEC)
f) *Consejo Superior de Investigaciones Científicas*, Spain (CSIC)
g) *Universidad Autónoma de Tlaxcala*, Mexico (UAT)
h) *Instituto Nacional de Investigaciones Forestales y Agropecuarias*, Mexico (INIFAP)
i) *Università di Pisa*, Centro Interdipartimentale Ricerche Agroambientali, Pisa, Italy (CIRAA)

Organisation of the Tasks of the REVOLSO partners: The tasks of REVOLSO, divided into 5 work packages (WP1-WP5), each one of them co-ordinated by members with experience in former projects on their specific research fields, forming joint working groups. Some Latino-American partners provided support, particularly in the accomplishment of empirical research in the individual countries studied.

Partner (a), Justus-Liebig-University of Giessen, Germany (JLU), has been responsible for overall co-ordination of the work plan, profiting existing strengths in international research related to the rehabilitation of deteriorated volcanic soils and his knowledge of local working conditions.

In line with the objectives mentioned earlier, the 5 work-packages divided REVOLSO into specialised activities over the lifetime of the project (4½ years). The first and second work packages (WP1 and WP2) provided the current local agricultural and agroforestry practices and integrate them to innovative alternative cultivation measures in order to work out a more sustainable agricultural technology package. The third and fourth work packages (WP3 and WP4) analysed the impact of the different cultivation practices respectively on the soil fertility and ecology, and on its erosivity and erodibility. The fifth work package (WP5) analysed the social and economical situation of the rural population involved, implementing the role of women and young rural people in marginal regions with deteriorated volcanic soils, and follow up its dissemination and its acceptance of the technical package among the rural community.

Table 1. Arrangements for involvement of the REVOLSO consortium partners in the individual work packages (WPs)

Work Package Nr.	Work Package Title	Cooperation and Name of direct Working Team Partner (Nr.)	Start Month	End Month
1	Cultivation Practices	JLU & UAT	1	55
2	Agroforestry	UDEC, CENAPROS & IRD	1	55
3	Soil Fertility and Ecology	CPM & CSIC	1	55
4	Soil Erosivity and Erodibility	IRD & CENAPROS ; CIRAA & UDEC; JLU & UAT	1	55
5	Social and economical aspects	UACH & CPM	1	55

The REVOLSO consortium used basic methods in agricultural and agroforestry research which are standard on farm investigations for all work packages (WPs) to be applied in Chile and Mexico. For WPs 1-3 and 5 the «traditional» standard methods for laboratories have been used as described in the individual reports or the partners.

Results, deliveries, and achievements

Training and Dissemination:Up to the end of 2006 (end of REVOLSO) 22 MSc and 9 PhD degrees have been obtained by 31 graduated students who elaborated their theses or parts of their theses within the REVOLSO Project. Ten scientists stayed more than 3 months with their partners in Latin America or Europe in order to work together with their team colleagues in their labs and/or teaching and learning methods and discussing results. Members of the REVOLSO consortium and their collaborators presented in total 262 papers: 124 papers in scientific meetings, symposia, national and international conferences, 44 publications on CD or in the internet. Forty two articles in journals have been accepted/submitted, 17 books and/or contributions to books were published (some in print), and 35 other publications are registered by the REVOLSO members. Results are listed in chapter 6 (References: Main results).

Conclusions

The REVOLSO consortium hits the main targets of the Project:

- Rehabilitation and management of the renewable resources; rehabilitation of the environment through sustainable agriculture and agroforestry. The following step should be lead by national public officers through the elaboration of public policies preventing further deteriorations of these important soils and lead specifically to
- Improvement of the quality of life of the small holders by
- Achieve of a sustainable development of their communities.
- disseminating results among the rural community and the follow-up of the implementation of the technology package worked out
- Targets to achieve the sustainable social and economical development of the rural community are important to be drawn. One example of the previous proposition was the result, from a chat between the co-ordinator with the Governor of the State of Tlaxcala, Mexico, the REVOLSO's Tlaxcalan partner *Universidad Autónoma de Tlaxcala* (UAT) convoked the federal and local institutions on July 26, 2006, in order to create a «Permanent Council for the Environmental Protection of the State of Tlaxcala (*Consejo Permanente Para La Protección Ambiental Del Estado*

De Tlaxcala, COPPAET)» which will be organised by a Sub-Committee of Ecology and Environmental Protection within the existing governmental «Planning Committee for the Development of the State of Tlaxcala» (*Comité de Planeación para el Desarrollo del Estado de Tlaxcala).*

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GESTIÓN SOCIAL PARA LA CONSERVACIÓN DE SUELOS FORESTALES EN MÉXICO

Helena Cotler[1], Eduardo Quintanar[2], Sergio Martinez[3], Silke Cram[4]

[1]Instituto Nacional de Ecología, hcotler@ine.gob.mx
[2]Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, eduardo.quintanar@conabio.gob.mx
[3]Posgrado de Ciencias de la Tierra - Universidad Nacional Autónoma de México, sergiomtzt@hotmail.com
[4]Instituto de Geografía - Universidad Nacional Autónoma de México, silkecram@igg.unam.mx

Resumen
La intensa degradación de suelos en México ha originado que en los últimos sexenios, el gobierno federal promueva la conservación de suelo mediante programas de subsidios, haciendo énfasis en las acciones mecánicas (como zanjas, terrazas y presas) (Cotler *et al*. 2007). El análisis social de las obras de conservación, realizadas en cuatro estados del centro de México, se centró en evaluar la respuesta de los usuarios ante el programa de conservación de suelos, analizar la aceptación y la replicabilidad de las obras e identificar los procesos de gestión social que incentivan la conservación de suelos en México. El análisis se realizó mediante entrevistas semi-estructuradas a usuarios en doce ejidos (tipo de propiedad social) en el centro de México. Los principales resultados muestran la debilidad institucional de los ejidos para la planeación de sus bienes comunes, en términos de la posibilidad de establecer reglas claras y sanciones o buscar alternativas que permitan un mejor aprovechamiento de sus recursos. Por otro lado, el aumento de la migración rural-urbana ha motivado un quiebre en la continuidad del conocimiento local.
Palabras claves: conservación de suelos, México, gestión social

Introducción

El suelo cumple con importantes funciones (sostén y sustento de cultivos y vegetación natural, al filtrado y retención de agua, la captura de carbono y el sostén de gran números de microorganismos, entre otros aspectos) de las cuales se derivan servicios ambientales indispensables para el sostenimiento tanto del ecosistema como de la vida humana (Doran y Parkin, 1994). Múltiples investigaciones (Bocco 1991, De Freitas 2000) han determinado que los programas de conservación de suelos deben cumplir con ciertos requisitos para atender sus objetivos, entre los cuales se menciona retomar el cono-

cimiento local de los agricultores y la utilización de prácticas de conservación de suelos fácilmente replicables; ya que se considera un programa de conservación de suelos exitoso aquel cuya continuidad y seguimiento es dado por los mismos agricultores luego de haber internalizado la importancia del problema y sus posibles soluciones.
A pesar de la importancia de las funciones de los suelos, los estudios realizados por SEMARNAT-Colegio de Posgraduados (2002) señalan que 45% de los suelos de México presentan algún tipo de degradación.
En los últimos sexenios, el gobierno federal ha realizado diversos tipos de obras de conservación de suelos mediante múltiples programas de subsidios (Cotler *et al*. 2007). Para los suelos forestales se cuenta con el Programa de Restauración de Suelos de la CONAFOR. La evaluación institucional de este programa especifica el área atendida para la recuperación de suelos a nivel nacional, sin embargo no existe una evaluación sobre la aceptación y replicabilidad de estas acciones entre los usuarios.
A partir del análisis social de las obras de conservación de suelos realizadas en cuatro estados del centro de México se busca (i) evaluar la respuesta de los usuarios ante el programa de conservación de suelo a nivel federal, (ii) analizar la replicabilidad de las obras entre los usuarios, (iii) identificar los procesos de gestión social que incentivarían la conservación de suelos en México.

Materiales y métodos

Los sitios de estudio seleccionados corresponden a aquellos donde se realizaron obras de conservación de suelos, a cargo de la Comisión Nacional Forestal en el 2004. El lapso transcurrido desde que se realizaron las obras (2004) al año de estudio (2009) fue importante para estimar la actitud de la comunidad hacia ellas, su propio análisis y evaluación.
Los sitios estudiados se encuentran en el centro de México: en los Estados de Querétaro, Hidalgo, México y Tlaxcala. Las obras de conservación evaluadas corresponden a aquellas que más comúnmente se realizan: zanjas de infiltración, terrazas individuales, acomodo de material vegetal y reforestación dispuestas sobre las tierras comunes de propiedad social (ejidos), acompañadas de reforestación.
En los 12 sitios analizados se realizaron entrevistas semiestructuradas a los presidentes de los Comisariados Ejidales (máxima autoridad del ejido) a cargo en el momento de realizar las obras así como a las personas que en el momento del trabajo de campo estaban en funciones.

Resultados

En relación a los entrevistados, su edad promedio fue de 50 años, contando con un nivel educativo donde sólo 5 personas terminaron primaria y 1 secundaria. Como reflejo de la situación agraria de México, el 50% de los encuestados mencionaron que su sustento económico más importante proviene de su trabajo en la albañilería o el comercio.

Desde un inicio, los entrevistados reconocen los problemas de degradación de suelos, principalmente en términos de erosión hídrica, y algunos de sus impactos como la escasa profundidad de los suelos, la formación de surcos y cárcavas, y la pérdida de fertilidad; por ello, recalcan la importancia de la conservación de suelos.

A partir de las entrevistas se concluye que de manera general, las obras fueron decididas por los técnicos del gobierno, mientras que los representantes ejidales decidieron el lugar de implementación. Este procedimiento responde a que los ejidatarios mencionan tener poco conocimiento sobre las obras propuestas por el gobierno. El conocimiento de conservación de suelos que han practicado a lo largo de años está centrado en prácticas tales como surcos en contorno, siembra de magueyes y construcción de «petriles» (muros de piedra), ninguna de las cuales está considerada entre las opciones gubernamentales.

La solicitud de apoyos gubernamentales exige ciertas capacidades técnicas que no siempre están presentes entre los ejidatarios, por ello la presencia de un actor externo, como asociaciones civiles constituyen un articulador importante y un puente para evitar la dispersión de apoyos y de programas.

La opinión sobre las obras es variable, sin embargo hay una constante sobre la ausencia de resultados inmediatos, los cuales muchas veces están relacionados con el lento y escaso crecimiento de los árboles plantados. En este punto se diluye la problemática de la erosión del suelo, quedando como solo indicador de éxito la reforestación. Esta visión corrobora la necesidad de una capacitación continua sobre el proceso que conlleva conservar la calidad de los suelos.

En todos los casos, se menciona la necesidad de recibir un subsidio mayor para la construcción de estas obras; igualmente refieren que el mantenimiento y la posibilidad de replicarlas dependen exclusivamente de apoyos económicos que deberían provenir del gobierno. Esta situación puede deberse a los escasos recursos que se obtienen del trabajo del campo que fuerza a los agricultores a buscar otras alternativas.

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EFFECT OF LAND USE AND SLOPE POSITION ON AGRONOMIC PRODUCTIVITY OF SOILS: A GREENHOUSE APPROACH

Hossein Asadi[a*], Behrooz Mehdizadeh[b], Ali Raeisvandi[b], Babak Rabiei[a], Mahmood Shabanpour[a]

[a]Faculty of Agricultural Science, University of Guilan, Rasht 41635-1314, Iran,
[b]Graduated Student, Faculty of Agricultural Science, University of Guilan.
[*]Tel: +98 131 6690388, Fax: +98 131 6690281, Email: asadi@guilan.ac.ir

Abstract
This paper describes greenhouse evaluation of agronomic productivity on soil samples taken from two semiarid regions of Iran. Twelve soil samples were taken from two hillslopes in Kuhin region. Three paired soil samples were collected from up, middle and foot slopes of each hillslope, one sample from dry farm and the other from adjacent rangeland. In Tarhan, as second region, eight soil samples (four pairs) were taken from four slope positions of a dry farm and adjacent rangeland on a hillslope. A factorial experiment of completely randomized design was used to compare the effect of land use, slope position, water stress and fertilizer on yield and yield component of wheat for the soil samples of each region separately. The results of both evaluations showed that all investigated factors have significant effect on wheat yield. Agronomic productivity was higher in the rangeland than the dry farming field and in the foot slope than the up slope for Kuhin soils. In the Tarhan case however, soil samples of dry farm had higher productivity than the adjacent rangeland. There was also some interaction between land use and slope position in both cases. Fertilization increased significantly wheat yield in both cases especially for more degraded soil samples, and the effect of water stress was so huge that could hide the effects of land use and slope position.
Key words; Nutrient, calcium carbonate, water erosion, tillage, manure, overgrazing

Introduction
Soil erosion has been recognized as a major soil degradation process since it adversely affects soil quality by reducing infiltration rates, water-holding capacities, nutrients, organic matter, soil biota and soil depth (Pimentel *et al.* 1995). Consequent results of soil degradation are reduction of soil productivity (Stone *et al.* 1985; Verity and Anderson 1990; Lal 1998) and a significant ecological damage to soil

biodiversity and plant composition. Erosion rate and loss of soil quality depend on many factors including land and crop management, slope steepness and position, and climate condition. Erosion is very severe in the dry farming and range lands of semiarid regions due to high erodibility of the soil, poor vegetation cover and mismanagement. Soil translocation by tillage and water erosion induces changes in the physical and chemical properties of the soil, including soil texture, organic matter content, calcium carbonate contents, nutrients, and bulk density (Kosmas *et al.* 2001; Li and Lindstrom 2001; de Alba *et al.* 2004). In rangelands, grazing and more particularly overgrazing and its attendant effect of depletion of plant cover and litter and trampling of the soil is the most important factor contributing to erosion (Branson *et al.* 1981).

More than 60 percent of farming lands of Iran are consist of dry lands and grains dry farming especially wheat is including of about 4 to 5 million ha. Up-down tillage is the conventional method of cultivation in the most cultivated fields. Rangelands cover about 55% (90 million ha) of the country area. More than 85% of the rangelands are subject to quite heavy, uncontrolled grazing pressure and the production capacities of these lands are gradually decreasing. This study was aimed to evaluate the effects of land use and slope position on soil agronomic productivity on two sets of calcareous soil samples from semiarid regions of Iran in a greenhouse experiment. Yield and yield components of wheat were determined as soil productivity index and the effects of fertilizer and water stress were studied.

Methods

Study regions and soil sampling

Soil samples were taken from two semiarid regions of Iran. Two hillslopes (36º 222 353 N, 49º 352 023 E; altitude: 1454 m and 36º 222 003 N, 49º 362 273 E, altitude: 1350 m) were selected in Kuhin region, Qhazvin province, with the mean annual precipitation and temperature of approximately 325 mm and 12.5 degree Celsius, respectively. Six soil samples (three pairs) of depth of 0-20 cm were collected from up, middle and foot slopes of each hillslope (overall 12 samples), one sample of each pair from dry farming field and the other from adjacent rangeland in the same slope position. The average slope steepness was 20, 15 and 10 percent for upper, middle and foot slope positions, respectively. The second region was Tarhan in Lorestan province, with mean annual precipitation and temperature of 376 mm and 15.8 degree Celsius, respectively, in which a hillslope (33º 302 123 N, 47º 122 183 E, altitude: 1100 m) was selected for soil sampling.

Eight samples (consist of four pairs) of depth of 0-20 cm were collected from four slope position of slopes 24, 31, 27and 22 percent from up to foot slope respectively. As for the first case, one of the soil samples of each pair was collected from dry farming and the other one from adjacent rangeland. Soil samples were obtained after crop harvest in both cases. The samples were air dried and a subsample of weight of about two kilograms was ground, and sieved to pass through a 2 mm sieve for chemical and physical analysis.

Greenhouse experiments

Two separate greenhouse experiments carried out to evaluate agronomic productivity of the soil samples of two regions in two successive years. In the both cases, a factorial experiment of completely randomized design with three replications was used to compare the effect of land use (dry farming and rangeland), slope position, water stress (without and with stress) and fertilizer on yield and yield component of wheat. In the first case (Kuhin soil samples), slope positions were three and fertilizer treatment had two levels (non-fertilization and chemical fertilization). In the second case (Tarhan soil samples), four slope positions were studied and fertilizer treatments were non-fertilization, chemical fertilization and chemical+manure fertilization. Urea, super phosphate triple and potassium sulfate were used in the chemical fertilization pots in the rates of 130, 150 and 250 kg/ha, respectively. Sheep manure (equivalent to 20 ton/ha), urea (60 kg/ha), super phosphate triple (125 kg/ha) and potassium sulfate (20 kg/ha) were used in the chemical+manure fertilization pots. Irrigation was done in the without and with stress treatments in the depletion limits of 50±2.5 and 80±2.5 percent of available water, respectively. Water stress treatment was applied after the end of shooting stage (beginning of earing). A spring wheat cultivar named Atrak planted with density of four plants per pots of weight about 5 kg. In the end of growth period, dry matter, grain yield, grain number and grain weight were determined.

Results

Effect of land use on soil productivity

Land use had a significant effect ($p<0.01$) on agronomic soil productivity in both cases. For the soil samples taken from Kuhin region, yield and yield components of wheat were higher in the rangeland than in the dry farming field. But for the soil samples taken from Tarhan region, yield and yield components of wheat were higher in the dry farming field than in the rangeland (Table 1). These results

clearly show the effect and importance of land and crop management on water erosion and induced soil degradation. Dry farming fields of Kuhin region showed clearly evidence of sheet and rill erosion and the farmers do not usually used to apply manure, but the rangelands had almost good conditions in this region due to normal or even none grazing because of special geographical position and cold weather. On the other hand in Tarhan region, annual using of manure by farmer in one side and very poor condition of the rangeland due to overgrazing on the other side caused the cultivated filed had better condition than the degraded adjacent rangeland.

Table 1. Effect of land use on yield and yield component of wheat. Means values with the same letters within columns of each region are not significantly different at $p < 0.05$.

Land use	Total yield (g/plant)	Grain yield (g/plant)	Number of grain (/plant)	Grain weight (g/1000)
	Soil samples from Kuhin region			
Dray farming	1.223[b]	0.483[b]	19.566[b]	24.73[b]
Rangeland	1.395[a]	0.564[a]	21.819[a]	26.14[a]
	Soil samples from Tarhan region			
Dray farming	1.890[a]	0.700[a]	22.745[a]	29.85[a]
Rangeland	1.632[b]	0.465[b]	19.285[b]	23.51[b]

Effect of slope position on soil productivity

Although slope position had a significant effect ($p<0.01$) on yield and all yield components in the Tarhan region, but in the Kuhin region just total yield ($p<0.01$) and grain weight ($p<0.05$) affected by slope position. For the soil samples of Kuhin region in which slope shape was almost concave, total yield of the foot slope (1.353 g/plant) was significantly higher than the up slope (1.240 g/plant), but this effect was vice versa for grain weight. For Tarhan region in which the hillslope had a complex shape, foot slope had generally higher soil productivity than the up slope (Table 2). The spatial variability in crop yields across a hillslope is often related to the spatial variability in soil properties. Differences in soil formation along a hillslope result in significant differences in soil properties (Brubaker *et al.* 1993). Soil properties and vegetation can also be altered over time under different land uses, management systems and soil erosion. In some cases, the spatial variation in soil properties affecting plant growth has been directly linked to changes induced by soil translocation through tillage (Kosmas *et al.,* 2001; Schumacher *et al*., 1999). In our study, foot slopes had generally higher cation exchange capacity, nutrients (N, P and K) and organic matter and lower calcium carbonate content than the up slope (results not shown).

Effect of fertilization on soil productivity

Results showed that fertilization increases significantly dry matter, grain yield and grain number, but has no effect on grain weight (Table 3) in the case of Kuhin soil samples. The results for Tarhan soil samples showed that there are significant differences among fertilizer treatments regarding to total yield and grain number, but there was no significant difference between chemical and chemical+manure fertilizations regarding to grain yield and grain weight (Table 3). In all cases the non fertilization treatment had lowest yield and chemical+manure fertilization had the highest yield. Our findings correspond with Larney et al (1991) study. Higher yields in the chemical+manure fertilization are due to the chemical, physical and biological effects of manure rather than the single chemical effect of mineral fertilizers.

Table 2. Effect of slope position on yield and yield component of wheat and soil properties in Tarhan region. Means values with the same letters within columns are not significantly different at $p < 0.05$.

Slope position	Total yield (g/plant)	Grain yield (g/plant)	Number of grain (/plant)	Grain weight (g/1000)
Up slope	1.665^{bc}	0.582^{ab}	20.187^{bc}	27.77^{a}
Middle-up	1.687^{bc}	0.532^{b}	$18..610^{c}$	27.18^{ab}
Middle-down	1.837^{ab}	0.602^{a}	22.860^{a}	26.42^{ab}
Foot slope	1.852^{a}	0.615^{a}	22.402^{ab}	25.35^{b}

Table 3. Effect of fertilization on yield and yield component of wheat. Means values with the same letters within columns of each region are not significantly different at $p < 0.05$.

Fertilizer treatment	Total yield (g/plant)	Grain yield (g/plant)	Number of grain (/plant)	Grain weight (g/1000)
Non-fertilization	Soil samples from Kuhin region			
Mineral fertilization	1.080^{b}	0.436^{b}	23.784^{b}	24.93^{a}
	1.538^{a}	0.611^{a}	17.600^{a}	25.94^{a}
	Soil samples from Tarhan region			
Non-fertilization	1.395^{c}	0.457^{b}	17.281^{c}	25.04^{b}
Mineral fertilization	1.797^{b}	0.625^{a}	21.925^{b}	27.19^{a}
Mineral+manure fertilization	2.087^{a}	0.665^{a}	23.812^{a}	27.81^{a}

Effect of water stress on soil productivity

Water stress had a significant effect ($p<0.01$) on agronomic productivity of the soil samples in both cases. All yield and yield components were lower in the water stress treatment than in the without stress treatment (Table 4). This part of the results does not call for any discussion.

Table 4. Effect of water stress on yield and yield component of wheat. Means values with the same letters within columns of each region are not significantly different at $p < 0.05$.

Water treatment	Total yield (g/plant)	Grain yield (g/plant)	Number of grain (/plant)	Grain weight (g/1000)
	Soil samples from Kuhin region			
Without stress	1.441[b]	0.600[b]	23.345[b]	25.70[b]
With stress	1.177[a]	0.447[a]	17.840[a]	25.17[a]
	Soil samples from Tarhan region			
Without stress	2.195[a]	0.835[a]	27.977[a]	29.37[a]
With stress	1.327[b]	0.330[b]	14.052[b]	24.00[b]

Interaction among the treatments

For the Kuhin soil samples the effect of land use×water stress was significant on total and grain yields and grain weight. There was no significant difference between the land uses under water stress (there is no enough space for presenting the data). The results were almost similar in the case of Tarhan region. This means that the real induced impact of soil degradation on soil productivity is hidden in the arid and semiarid regions where water stress is common. There was also a significant interaction between water stress and fertilizer treatments for the Kuhin soils. Fertilization generally increased crop resistant to water stress. But in the case of Tarhan soils, the effect of fertilizer treatments was clearer under full irrigation than under deficient irrigation, though mineral+ manure fertilization could also improved crop growth and yield under water stress. On the case of Tarhan soils, land use×fertilization and water stress×fertilization had also significant effect ($p<0.01$) on all measured yield and yield components. The effect of land use×slope position on grain yield and grain weight ($p<0.01$), slope position×water stress on grain number ($p<0.01$) and slope position×fertilization on grain yield and grain weight ($p<0.01$) and on grain number ($p<0.05$) were significant (results not shown).

Conclusion

Yield and yield components of wheat were measured and compared for soil samples taken from adjacent land uses of two semiarid regions of Iran, and the effect of water stress and fertilizer were studied in two greenhouse experiments. All factors studied including land use, slope position, fertilization and water stress had significant effect on yield and yield component of wheat. Effect of land use was clearly related to land and crop management as it was quiet different in the two regions. Generally, soil quality and productivity were higher in the foot slope than the up slope which could be due to soil particle and nutrient translocation by water erosion. Mineral and organic fertilization increased crop production and crop resistance to water

stress. On the other hand, the effects of land use and slope position were hidden under water stress condition. In the arid and semiarid regions thus soil degradation and productivity reduction may not be detect on their early stages.

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SUSTAINABLE CROP PRODUCTION INTENSIFICATION
- THE ADOPTION OF CONSERVATION AGRICULTURE WORLDWIDE -

Rolf Derpsch[1] ; Theodor Friedrich[2]

[1]International Consultant, C.C. 13223, Shopping del Sol, Asunción, Paraguay
rolf.derpsch@tigo.com.py
[2]FAO, Plant Production and Protection Division (AGP), Viale delle Terme di Caracalla, 00153 Rome, Italy; Tel: +39-0657055694; Theodor.Friedrich@fao.org

Summary

While the world is projected to need a major increase in crop production to feed a population of around 9 billion people in 2050 when compared to 2000[1] it must do so against a challenging backdrop: The decreasing availability of and competition for land and water (including from other land uses such as production of biofuels, urbanization and industrial development); poor soil fertility; access to fertiliser, and improved varieties (developed using conventional and modern plant breeding tools) and quality seeds; and climate change. Previous attempts at managed intensification (such as the Green Revolution of the 1960s and 1970s) have been a qualified success. In some cases it is now recognised that the yield increases achieved – through increased use of fertilisers, high yielding varieties, irrigation, pesticides and intensive tillage - were made at the expense of the environment or in ways which were otherwise unsustainable. Also some smaller-scale farmers were unable to participate or reap the rewards of scale. The International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD, 2009) highlighted the need for policies that value, restore and protect ecosystem services, and addresses the needs of the world's small-scale and family farmers. It emphasized the need for a change in paradigm to encourage increased adoption of sustainable ecological agriculture and food systems. No-tillage systems, such as Conservation Agriculture, hold promise to address these challenges. In this paper the worldwide spread and adoption of No-tillage/Conservation Agriculture is analyzed. In 1973/74 the system was used only on 2.8 million ha worldwide. In 1999 no-tillage, was adopted on about 45 million ha world wide (Derpsch, 2001), growing to 72 million ha in 2003 (Benites, *et al.*, 2003) and to 117 million ha by 2010 (FAO 2010a). Fastest adoption rates have been experienced in South America where some countries are using no-tillage on more than 70% of the total cultivated area. Opposite to countries like the USA where often

[1] On average double in developing countries; 70% increase for the world as a whole.

fields under no-tillage are tilled every now and then, more than two thirds of no-tillage practiced in South America is permanently under this system, in other words once started, the soil is never tilled again. The adoption of no-tillage at present on 117 million ha shows the great adaptability of the system to all kinds of climates, soils and cropping conditions. No-tillage is now being practiced from the artic circle over the tropics to about 50º latitude south, from sea level to 3000 m altitude, from extremely rainy areas with 2500 mm a year to extremely dry conditions with 250 mm a year. The wide recognition as a truly sustainable farming system should ensure the growth of this technology to areas where adoption is still low as soon as the barriers for its adoption have been overcome. The widespread adoption also shows that no-tillage can not any more be considered a temporary fashion, instead the system has established itself as a technology that can no longer be ignored by scientists, universities, extension workers, farmers as well as machine manufacturers and politicians.
Key words: Sustainable crop production, adoption of conservation agriculture, world wide adoption of no-tillage, zero tillage adoption, new paradigms of agricultural production.

Introduction

The per capita availability of agricultural land was 0.43 ha in 1960 and declined to 0.26 ha in 1999. Significant per capita declines are projected in the availability of another essential natural resource for agriculture - water. At the same time, the world must increase its food production by some 70% by 2050 to meet the needs of its growing population projected to reach 9.2 billion then (Bruinsma, 2003).

There is no alternative but to increase agricultural productivity (i.e. crop yield per unit area) and the associated total and individual factor productivities (i.e. biological output per unit of total production input, and output per unit of individual factors of production such as energy, nutrients, water, labour, land and capital) to meet the global food, feed and biofuel demand and to alleviate hunger and poverty. Thus, feeding the world in 2050 and beyond will need further crop production intensification and optimisation. However, until now, agricultural intensification generally has had a negative effect on the quality of many of the essential resources such as the soil, water, land, biodiversity and the ecosystem services which has caused yield and factor productivity growth rates to decline. Another challenge for agriculture is its environmental foot print and climate change. Agriculture is responsible for about 30% of the total greenhouse gas emissions of CO_2, N_2O and CH_4 while being directly affected by the consequences of a changing climate (IPCC, 2007).

The **new paradigm**s of «sustainable production intensification» recognize the need for a productive and remunerative agriculture which at the same time conserves and enhances the natural resource base and environment, and positively contributes to harnessing the environmental services. Sustainable crop production intensification must not only reduce the impact of climate change on crop production but also mitigate the factors that cause climate change by reducing emissions and by contributing to carbon sequestration in soils. Intensification should also enhance biodiversity in crop production systems above and below the ground to improve ecosystem services for better productivity and healthier environment. A set of soil-crop-nutrient-water-landscape system management practices known as Conservation Agriculture (CA) delivers on all of these goals. CA saves on energy and mineral nitrogen use in farming and thus reduces emissions; it enhances biological activity in soils, resulting in long term yield and factor productivity increases. Attention to soil health and good soil system management is critical and this message was highlighted in an international Technical Workshop held at FAO headquarters in July 2008 entitled: «Investing in Sustainable Crop Intensification: The Case for Improving Soil Health» (FAO, 2008). Conservation Agriculture represents a practical concept to achieve improved soil health and better soil-crop-nutrient-water management leading to ecologically and economically sustainable agriculture.

New paradigms of agricultural production

Environmental sustainability is the central paradigm of the 21st Century. Consequently the paradigms of agricultural production need to be changed. In view of the necessity of rising food production by 70% until the year 2050 to feed a world population of more then 9 billion people, it is mandatory that widespread soil degradation is brought to a halt. Conventional, soil degrading production systems, which are the most widely used production systems all over the world, must give way to new methods of cultivating the soil. Erosion of agricultural soil must be banned from the landscape and governments should stop subsidizing systems that leave the soil bare and vulnerable to the destroying action of wind and water. The world can not afford to accept water erosion as an unavoidable process associated to farming on sloping land. Rain and/or wind can not be blamed for the occurrence of erosion on farm land any more. Instead we have to accept that soil erosion is merely a symptom, that for that area and ecosystem unsuited methods of farming are being used. In other words, erosion is caused by soil mismanagement! Not the elements of nature should

be blamed for the occurrence of erosion, but the farmer, through inadequate farming practices, is responsible for soil degradation on the land cultivated. Today there are highly economic, site oriented farming practices that can be used to bring erosion to a halt or at least reduce it to levels below soil formation. Consequently a farmer that allows erosion to occur on the land he/she cultivates should be stopped and eventually penalized or it should be given to better custodians of the soil. Otherwise how could we achieve a 70% food increase while our most valuable resource to reach this, the soil, is degraded by erosion and inadequate farming practices?
If we are serious to stop soil degradation and if sustainable agriculture is really to be achieved, then the paradigms of soil use and management must be changed and new farming practices have to be implemented.

Old Paradigms (conventional, i.e. traditional farming systems)
1) Soil tillage is necessary to produce a crop; 2) Burying of plant residues with tillage implements; 3) Bare soil for weeks and months; 4) Soil heating because of direct solar radiation; 5) Burning crop residues normal; 6) Strong emphasis on soil chemical processes; 7) Chemical pest control, first option; 8) Green manure cover crops and crop rotations are options; 9) Soil erosion is accepted as an unavoidable process associated to farming on sloping land (erosion is caused by excessive rains):

Consequences of old paradigms (soil preparation and bare soil)
Wind and water **erosion** are unavoidable; reduced water infiltration into the soil; less available soil moisture; unavoidable reduction in the soil organic matter content; thus reduction of soil quality; soil carbon is lost as carbon dioxide into the atmosphere contributing to global warming; soil degradation (chemical, physical and biological); reduction of crop productivity; higher use of fertilisers and higher costs of production; survival of the farm family on the farm threatened (lower yields, production without profitability, insufficient monetary income); poverty, rural exodus, increase of slums and marginal populations as well as social conflicts.

Off farm effects of soil erosion associated with old paradigms
Sedimentation of rivers, reservoirs, lakes and micro catchments; reduced water quality; problems in hydroelectric power plants; sedimentation of roads; pollution of above and below water resources with soil nutrients and pesticides; reduced availability of freshwater resources; higher costs for the government and for society due to off farm effects of soil erosion.

Result: Soil resource exploitation. Sustainable land use is not possible (ecologically, socially and economically).

New Paradigms of agricultural production

1) Tillage is **not** necessary for crop production; 2) Crop residues remain on the soil surface as mulch; 3) Permanent soil cover; 4) Reduced soil temperatures; 5)Burning of mulch ruled out; 6) Emphasis on soil biological processes; 7) Biological pest control, first option; 8) Crop rotations and green manure cover crops essential; 9) Soil erosion is merely a symptom, that for that area and ecosystem unsuited methods of farming are being used (erosion is caused by soil mismanagement!).

Consequences of new paradigms
(permanent soil cover and no tillage)

Wind and water erosion near zero; increased water infiltration into the soil; more available soil moisture; maintenance or increase in soil organic matter content (enhancement of soil quality); carbon is sequestered in the soil enhancing its quality and reducing the threat of global warming; soil improvement (chemical, physical and biological); crop productivity increases; reduced use of fertilisers and lower production costs; survival of the farm family on the farm insured through a good profitability and a high and sustainable crop production; basic needs are satisfied, living standard and quality of life of the farm family are increased.

Off farm effects of permanent cover cropping system
(new paradigms)

Reduction of sedimentation of rivers, reservoirs, lakes and micro catchments; enhanced water quality; better groundwater availability; less problems for hydroelectric power plants; less sedimentation of roads; reduction of costs for the government and for society due to elimination of off farm effects of soil erosion.

Result: Rational, site-oriented use of the soil. Sustainable land use ensured (ecologically, socially and economically). Therefore CA/No-tillage technologies need to be spread to achieve sustainable crop production intensification.

Methods of gathering information about adoption

As the understanding of no-tillage (synonymous of zero tillage) often varies it is necessary to have a common understanding of what no-tillage means. Unfortunately, no-tillage is often regarded as a technology where seeds are put into the soil without tillage, not taking

into consideration that this is a completely different system. This adds complexity to no-tillage research because not only one factor, tillage, but a whole set of factors have to be changed. Different seeding equipment to cut through the residues of previous crops is necessary, weed and pest management as well as fertilization and selection of crop varieties need to be adapted to meet the systems requirements. In order to assess the adoption of cropping systems qualifying with the above criteria, a clear farming protocol has to be established and practices which can be identified under such protocol defined. One of the central practices under Conservation Agriculture is no-tillage (synonymous of zero tillage). For the purpose of gathering the information of the area under CA or no-tillage systems for this paper we have asked our informants to apply the definition by Phillips and Young (1973) (with minor modifications), which seems to be the most widely accepted. «No-tillage is defined as a system of planting (seeding) crops into untilled soil by opening a narrow slot, trench or band only of sufficient width and depth to obtain proper seed coverage. No other soil tillage is done». Permanent or continuous no-tillage should be aimed at, rather than not tilling in one season and tilling in the other, or occasionally not tilling the soil. The soil should remain permanently covered with crop residues from previous cash crops or green manure cover crops, and most of these residues will remain undisturbed on the soil surface after seeding. Crop rotation and cover crops are essential elements that need to be applied in the no-till system. More precisely the data collection has been done following the FAO definition of Conservation Agriculture with the respective quantitative specifications (FAO 2010).

CA is a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment. CA is based on enhancing natural biological processes above and below the ground. Interventions such as mechanical soil tillage are reduced to an absolute minimum, and the use of external inputs such as agrochemicals and nutrients of mineral or organic origin are applied at an optimum level and in a way and quantity that does not interfere with, or disrupt, the biological processes. CA is characterized by three principles which are linked to each other (FAO, 2010), namely:

1. Continuous minimum mechanical soil disturbance = No-tillage
2. Permanent organic soil cover = mulching and cover cropping
3. Diversification of crop species grown in sequence or associations = Rotation

Worldwide adoption of No-Till

No-tillage is a fast growing technology. While in 1973/74 the system was used only on 2.8 million ha worldwide the area had grown to 6.2 million ha in1983/84 and to 38 million ha in 1996/97 (Derpsch, 1998).

Table 1: Extent of No-tillage Adoption World Wide (countries with > 100.000 ha)

Country	Area under No-tillage (ha) 2007/2008
USA [1]	26.500.000
Argentina [2]	25.785.000
Brazil [3]	25.502.000
Australia [4]	17.000.000
Canada [5]	13.481.000
Paraguay [6]	2.400.000
China [7]	1.330.000
Kazakhstan [8]	1.300.000
Bolivia [9]	706.000
Uruguay [10]	655.000
Spain [11]	650.000
South Africa [12]	368.000
Venezuela [13]	300.000
France [14]	200.000
Finland [15]	200.000
Chile [16]	180.000
New Zealand [17]	162.000
Colombia [18]	102.000
Ukraine [19]	100.000
Total	**116.921.000**

Source: Derpsch, R. and Friedrich, T., 2010 Extracted from: http://www.fao.org/ag/ca/6c.html Information provided by: 1) CTIC, 2007; 2) AAPRESID, 2010; 3) FEBRAPDP, 2005/06; 4) Australian Bureau of Statistics, 2009; 5) Dr. Doug McKell, Soil Conserv. Council of Canada, 2006; 6) MAG & CAPECO, 2008; 7) Li Hongwen, 2008; 8) Mekhlis Suleimenov, 2007; 9) ANAPO, Bolivia, 2007; 10)) Miguel Carballal AUSID, 2007; 11) Emilio González-Sánchez, AEAC/SV, 2008; 12) Richard Fowler, 2008; 13) Rafael E. Perez, 2004; 14) APAD, 2008; 15) Timo Rouhianinen, FINCA, 2008; 16) Carlos Crovetto, 2008; 17) John Baker, 2008; 18) Fabio Leiva, 2008; 19) Estimate by the authors.

In 1999 data was presented at the 10th ISCO Conference in West Lafayette, Indiana, showing a world wide adoption of the no-tillage technology of 45 million ha (Derpsch, 2001). As shown by Benites, et al (2003) at the ISTRO Conference in Brisbane, Australia (2003) the area had grown to 72 million ha. In the last 11 years the no-till technology has expanded at an average rate of more than 6 million ha per year from 45 to 117 million ha showing the increased interest of farmers in this technology (Table 1).

In South America the growth of the area under no-tillage has been especially rapid. The MERCOSUR countries (Argentina, Brazil, Paraguay and Uruguay) are using the system on more than 70% of the total cultivated area. It should be pointed out that more than two thirds

of no-tillage practiced in MERCOSUR is permanently under this system, in other words once started, the soil is never tilled again.
When analyzing the data on no-till implementation one has to take into consideration that only a few countries in the world conduct regular surveys on CA/No-till adoption. The data presented in this paper is mainly based on estimates made by farmer organizations, agro industry, well informed individuals, etc. The authors have been careful to only include data that seems well founded and reliable. Table 1 shows an overview of CA/No-till adoption in those countries that have more than 100.000 ha of the technology being practiced by farmers, and table 2 shows the area under no-tillage and the percent of adoption by continent.

Table 2. Area under No-tillage by continent

Continent	Area (hectares) total	Percent of
South America	55.630.000	47.6
North America	39.981.000	34.1
Australia & New Zealand	17.162.000	14.7
Asia	2.630.000	2.2
Europe	1.150.000	1.0
Africa	368.000	0.3
World total	**116.921.000**	**100%**

At present it is estimated that no-tillage is practiced on about 117 million hectares world wide. As table 2 shows 47.6% of the technology is practiced in South America, 34.1% is practiced in the United States and Canada, 14.7% in Australia and New Zealand and 3.5% in the rest of the world including Europe, Asia and Africa. The latter are the developing continents in terms of CA/No-till adoption. Despite good and long lasting research in these continents showing positive results for no-tillage, this technology has experienced only small rates of adoption.

Development of No-Tillage in South America

Argentina: Already in the early 1970's Argentina started its first research and farm experiences with no-till. Several farmers started with the system and then gave up because of the lack of adequate herbicides and machinery which together with lack of know how, constituted the main constraint for early adopters. A milestone in the development and spread of no-till in Argentina was the foundation in 1989 of AAPRESID, the Argentinean Association of No-till Farmers based in Rosario. Since 1992 AAPRESID is organizing no-till

conferences in August of every year (simultaneous translation into English), which have been visited by more than 1000 farmers at the beginning and nowadays exceed 2000 farmers. Since the founding of AAPRESID also Argentina experienced an exponential growth of the system.

Argentina experienced a paradigm shift with the advent of the no-tillage technology and the idea that tillage was necessary to grow crops was finally discarded. In Argentina the concept of «arable» soils has been abandoned after recognizing that soils that cannot be ploughed do can be seeded. According to AAPRESID (2010) in 2007/08 there were 25.8 million ha of no-tillage being practiced in this country (http://www.aapresid.org.ar). With more than 25 million ha under no-tillage Argentina is among the most successful countries in terms of no-till adoption. The first group of farmers started using no-till in 1977/78 after exchanging ideas with Carlos Crovetto, one of the most renowned no-till experts from Chile, as well as with Dr. Shirely Phillips and Dr. Grant Thomas from the US. At the beginning growth was slow because of lack of experience, knowledge on how to do it, machines and limitations on the availability of herbicides. It took 15 years until 1992/93 when about one million ha under no-tillage were reached. Since then adoption increased year by year thanks to the intensive activities of AAPRESID so that in 2008/09 about 79% of all cropland in Argentina was under no-tillage. The main advantages of the system according to AAPRESID (2010), is that it is possible to produce without degrading the soil and that soil physical, chemical and biological properties are improved.

One of the main factors that made the rapid growth of no-tillage possible in Argentina was the fact that machine manufacturers quickly responded to the increasing demand in no-till seeders. Among the many big and small no-till seeders manufacturers in Argentina there are at least 15 that are in conditions to export their equipment. No-tillage in Argentina is almost exclusively performed with disc seeders.

Table 3. Area under no-tillage in Argentina (AAPRESID, 2010)

Year	Area (million hectares)
1993/94	1.81
1995/96	2.97
1997/98	5.00
1999/00	9.25
2001/02	15.10
2003/04	18.26
2005/06	19.72
2006/07	22.71
2007/08	25.78

Similar to other countries in South America, farmers in Argentina prefer to do permanent no-tillage once they have started with the system. More then 70% of all no-tillage practiced in Argentina is permanently not tilled. At the beginning cover crops were not an issue for no-till farmers in this country because it was believed that these crops would take too much moisture out of the soil. This has changed in recent years when research could show, that water use efficiency can be enhanced when using appropriate cover crops. A milestone in no-tillage in Argentina was reached on 7 May 2010 when G. Cabrini with the help of AAPRESID became the first farmer to certify his no-till production system in this country. The protocol is based on principles and criteria developed from international initiatives that focus on sustainability.

Brazil: First no-tillage experiments in Brazil were started in April 1971 at the IPEAME Research Institute (later EMBRAPA), in Londrina, Paraná, by the first author of this paper. The next year Herbert Bartz, the first farmer to try the technology in Latin America, was already introducing the system on his farm. From there it took Brazil almost 20 years to reach the first million ha of no-tillage being applied by farmers, but after this milestone the technology has experienced an exponential growth.
The Brazilian Federation of No-till Farmers (FEBRAPDP, 2009) informs that in the season 2005/06 there were 25.5 million ha of no-tillage being practiced in this country. (http://www.febrapdp.org.br) Brazil continues to be one of the leading countries in the world in terms of adoption and understanding of the no-tillage System. The first farmer to use the technology in Brazil started in 1972, ten years after the first farmer in the US was applying no-tillage. In Brazil about 70% of no-tillage is practiced permanently, this means that once started most farmers never till the soil again. While about 90% of farmers in the US practice rotational tillage (several years no-tillage and then they till again) this is the case only with a minority of farmers in Brazil. Most Brazilian farmers and technicians believe that those farmers using rotational tillage will never get to reap the full benefits of the no-tillage system as described in the evolution of a continuous no-till System (Derpsch, 2005). Another aspect where Brazilian farmers are ahead of their peers in the US is in the use of GMCC (green manure cover crops). GMCC are used on millions of ha in Brazil and many farmers are convinced that they are a must in a sound no-tillage system. FEBRAPD is now concerned about improving the quality of no-tillage and is aiming at certifying the quality of the system to farmers in order to qualify for carbon credits in the future.

Table 4. Area under no-tillage in Brazil (FEBRAPDP, 2009)

Year	Area (million hectares)
1993/94	3.0
1995/96	5.5
1997/98	11.3
1999/00	14.3
2001/02	18.7
2003/04	21.8
2005/06	25.5

Full set of data from 1972 to 2006 under Area de Plantio Direto at http://www.febrapdp.org.br/port/plantiodireto.html

The production of specialized no-till equipment in Brazil from as early as 1975/76 made a quick and steady growth of no-tillage possible in this country. Today Brazilian no-till seeding machines are exported all over the world. Brazilian machine manufacturers are not only engaged in producing equipment for motorized mechanization but produce also equipment for animal traction and manual operation. This equipment has been highly appreciated in many developing countries. FAO has played a mayor role in distributing Brazilian no-till equipment for small farmers throughout the world. The development of this industry in Brazil was possible because there are about 100.000 small farmers using no-till farming systems in this country needing specialized machines. On medium and large farms in Brazil no-tillage is almost exclusively performed with disc seeders.

Paraguay: Because of lack of appropriate machines, herbicides and know how early adopters in Paraguay experienced the same drawbacks as their counterparts in Argentina and Brazil. Akinobu Fukami, a Japanese immigrant and president of the Colonia Yguazú cooperative, was the first farmer to successfully apply the technology in Paraguay in 1983. With the support of JICA all farmers of this cooperative were using no-tillage 10 years later. Until 1992 there were only 20.000 ha of no-tillage being practiced by farmers in Paraguay. From 1993 on, with the support of a GTZ project and the Ministry of Agriculture, no-tillage expanded massively throughout the country. Whole landscapes have been transformed to country sides where tillage practices have disappeared almost completely.

In tractor mechanized farming systems it is estimated that about 90% of all cropping area is under no-tillage, reaching about 2.4 million ha in 2008, as informed by the Ministry of Agriculture and Livestock (MAG) and the grain exporting chamber of Paraguay (CAPECO). Most farmers apply permanent no-tillage systems. But also in small farmer production

systems with animal traction or manual no-till systems no-tillage practices have increased. It is estimated that about 22.000 small farmers apply no-tillage at least on part of their farms covering about 30.000 ha. The increased interest in small farmer no-till systems has been a result of efforts of the Ministry of Agriculture together with GTZ (German Technical Assistance) and KfW (Kreditanstalt für Wiederaufbau) from Germany that provides grants for buying no-till equipment. Small farmers have been able to successfully grow crops that initially where thought not to be appropriate for no-tillage as for instance cassava (Manihot utilissima). Planting cassava under no-tillage in combination with cover crops has resulted in substantial yield increases (often doubling yields) compared to conventional farming systems. Reduction of drudgery (tillage, weed control) and the resulting improvement in the quality of life because of a dignified work are among the main reasons for increased adoption under small farmers.

Bolivia: The farmer Dr. Jean Landivar started no-tillage on his 2000 ha farm in the lowlands of Santa Cruz in 1986, after having visited Brazil and Argentina. His main crops are sorghum, maize and also some soybeans. Research started at about the same time but without positive results. In 1996/97 Bolivia reported 102.000 ha under no-tillage in the lowlands of Santa Cruz, in the east of the country, mainly with soybeans but also maize, rice and some cotton. Since then no-tillage practices have been increasingly adopted in Bolivia.
Main crop under no-tillage in this country is now soybeans. According to ANAPO (The soybean and wheat producers association of Bolivia) soybeans under no-tillage have increased from around 240.000 ha (39% adoption) in the year 2000 to 706.000 ha (72% adoption) in the year 2007. The occurrence of wind erosion in conventional tillage systems has been one of the major driving forces for adoption. Also the increased water use efficiency under no-tillage is appreciated by farmers in a region with low and erratic rainfalls.

Uruguay: About 82% of cropland, that is 655.000 ha was under no-till systems in the 2006/07 growing season according to the Uruguayan No-till Farmers Association (AUSID). This is a great progress compared to the 2000/01 season when only 119.000 ha of no-tillage were reported, corresponding to 32% adoption. These numbers have been provided by DIEA, (The Statistics Department of the Ministry of Agriculture, Livestock and Fisheries), and reflect the trend also seen in the other MERCOSUR countries (Brazil, Argentina, Paraguay and Uruguay). Another interesting fact is that in Uruguay (according to DIEA), 65% of crops are seeded on rented land for which contracts

are renewed every year. This hinders the planning of medium term crop rotation and investment strategies. In Uruguay the integration of agriculture and livestock is very popular and no-tillage fits very well into the requirements of this production system. Pastures are grown for several years until they show signs of degradation. Then crops are grown for several years according to the needs of the farmers and the market situation. Uruguay also belongs to the countries that have engaged predominantly in permanent no-tillage practices.

Venezuela: Despite repeated efforts to obtain information about the area under no-till in Venezuela it has not been possible to obtain updated data on the progress in the adoption of this technique. Therefore the same numbers are used as in 2005 when no-tillage was applied on 300.000 ha (Derpsch, 2005).

Chile: As early as 1978 no-till pioneer Carlos Crovetto started using no-tillage on his farm near Concepción, Southern Chile and has been using it continuously for 32 years until now. On land with 15 to 18% slope he has virtually eliminated erosion by eliminating tillage and leaving crop residues on the soil surface. Already in 1997, «after 19 years of continuous no-tillage, Carlos Crovetto had added one inch of topsoil, boosted the organic matter content from 1.7 to 10.6% in the first 5 cm of soil, improved the bulk density from 1.7 to 1.4 g/cm^3, increased the soil water-holding capacity by more than 100%, increased the phosphate content from 7 to 100 ppm and potash from 200 to 360 ppm in the top 5 cm of soil, improved the soil's cation exchange capacity from 11 to 26 milli-equivalents per 100 g of soil and raised the soil's pH level from 6 to 7" (No-till Farmer, 1997).
Carlos Crovetto who is also author of several books about no-tillage, informs that there are about 180.000 ha of no-tillage being practiced in Chile, which is about 30% of the cropped area in rainfed farming systems. Unfortunately there is a relatively large amount of no-till farmers that have not yet understood the importance of soil cover in this system and burn their cereal residues regularly putting the sustainability of the system at risk. Official research institutions have taken little interest in this technology and have not been willing to study the long term detrimental effect of burning on soil health and yield.

Colombia: In this country the area under no-tillage has virtually remained static and no increase in the area under this system has been reported. This has little to do with the merits of this system but more with the political situation of this country and the insecurity in rural areas. According to Fabio Leiva (personal communication, 2008) there are about 100.000 ha under no-tillage in Colombia.

Mexico: The estimated area under no-tillage in Mexico in 2001 was 650.000 ha. However, this estimate was based on the number of no-till drills sold which was multiplied by the average farm size. This method showed to be wrong as it greatly overestimated the area under no-till. A study by CIMMYT showed that the real area is about 50.000 ha.

Development of No-Tillage in North America

United States: Already in the late 1940's first no-tillage experiments were reported in the United States. In 1951, K.C Barrons, J.H. Davidson and C.D. Fitzgerald of the Dow Chemical Co., reported on the successful application of no-tillage techniques (Phillips and Phillips, 1984). Since than the US has been the leading nation in terms of area with no-till adoption. Already in 1996/97 the no-tillage technology was used on 19.4 million ha in this country (Hebblethwaite, 1997), representing about 50% of worlds total at that time.

The US has been among the few countries that conducted regular surveys on the area under no-tillage and other forms of Conservation Tillage. Unfortunately these surveys were discontinued in 2004. The data is published at the CTIC homepage www.conservationinformation.org and shows that by 2004 the area under no-till was 25.3 million ha The surveys were based on the actual area under no-tillage found in the different regions in different years, but it did not consider the number of years a farmer had been not tilling the soil. It was estimated that only about 10 to 12% of the area under no-tillage in the USA was permanently under this system (CTIC, 2005). An amendment to the 2004 figures was done in 2007 which is shown in http://www.conservationinformation.org/?action=members_crm (CTIC, 2007). The CTIC CRM data collection shows the 2007 Amendment to the National Crop Residue Management Survey Summary which is based on 374 counties in 8 states. Here no-tillage appears with 65,48 million acres which is equivalent to 26.493.000 ha. The Amendment also shows that no-till acres have increased from 23.2% to 25.5% of total cropland acres. Although the percentage of adoption has increased the numbers still reveal that the majority of farmers in this country are still using conventional or reduced tillage practices. Despite the fact that the growth of the area under no-tillage in the US was not dramatic, a continuous and steady growth could be observed in the last decade.

Canada: Because of heavy erosion problems in the 1930's and the subsequent focus un conservation tillage Canada has had a similar development as the United States. However, after the year 2000 more importance was given to a systems approach, not only focusing on reduced or zero tillage and chemical fallows, but including factors

Table. 5: Area under no-tillage in the United States (CTIC, 2005/07)

Year	Area (million hectares)
1994	15.7
1996	17.3
1998	19.3
2000	21.1
2002	22.4
2004	25.3
2007	26.5

More detailed information under CRM data collectionhttp://www.conservationinformation.org/?action=members_crm

like soil cover and crop rotations. As a consequence between 1999 and 2004 the amount of wheat grown in Canada went down by 6.4 %, while the oil crops increased by 48.7 % and pulses by 452.7 %. At the same time the use of fallow went down by 58.7 % (Yuxia Li and Chi Chang, 2007). These developments are parallel to the recent increase in the application of Conservation Agriculture in Canada since the year 2000. Canada is actively promoting CA adoption in other countries, such as in China.

An agricultural census is conducted in Canada every 4 years, the last one being performed in 2006. This Census also includes adoption of no-tillage practices. The regions with highest percentage of adoption of no-tillage are Saskatchewan (60.1%), Alberta (47.8%), Ontario (31.2%), Manitoba (21.3%) and British Columbia (19.0%). According to the Soil Conservation Council of Canada no-tillage was practiced on 13.48 million ha in Canada in 2006 and on average the technology is used on 46.1% of the cropped area (Doug McKell, personal communication 2008). The Soil Conservation Council of Canada informs that in the year 2000 no-tillage was used on 8.8 million ha. This shows an average increase of 780.000 ha per year of no-till adoption in Canada throughout this period. According to Doug McKell the majority of the conventionally tilled land is in the hands of the older and/or smaller farmers who will likely not change their practices. Thus the change in adoption will take place when the land changes hands. The majority of no-tillage in Canada is performed with airseeders that are equipped with hoe-type openers.

Development of No-Tillage in Australia and New Zealand

Australia: According to the Australian Bureau of Statistics (2009), no-tillage is now practiced on 17 million ha in this country. Overall

large increases in no-till adoption have been experienced since 2003 with high levels of growers using no-till to establish crops in 2008. Reduced soil disturbance through no-till and conservation farming methods have led to large increases in profitability, sustainability and environmental impact in the Australian cropping belt (Llewellyn, *et al.*, 2009). The proportion of growers using at least some no-till is now peaking at levels around 90% in many regions. In regions with relatively low adoption 5 years ago, there have been very rapid increases in adoption, particularly in the period 2003-2006 (Llewellyn, *et al.*, 2009). The adoption of no-till by farmers in Australia varies from 24% in northern New South Wales, to 42% in South Australia and 86% in Western Australia. During 2008 the percent of the area under no-tillage was expected to grow to 88% in Western Australia and to 70% in South Australia (Flower *et al.*, 2008). Because of the water, time and fuel savings with this technology, as well as the other advantages of the system, no-tillage is expected to continue growing in this country, especially in those States with lower rates of adoption. In northern New South Wales the area under no-tillage is expected to increase from 24% in the year 2000 to 36% in 2010. Overall adoption of no-till in Queensland was approximately 50% with some areas as high as 75% (Flower *et al.*, 2008).

No-tillage is expected to continue growing in this country because of the water, time and fuel savings with this technology, as well as the other advantages of the system. In Australia most farmers use airseeders equipped with narrow knife point openers, although some farmers use disc openers which in the last years seem to gain popularity. Also the use of cover crops is getting popular among no-till farmers. Combining cropping with livestock (generally sheep) is a common practice throughout the country. This often leads to insufficient crop residues left on the soil surface at seeding but more recently the importance of soil cover is increasingly recognized in Australian no-till. Another complementary technology used in Australia on no-tillage farms is controlled traffic farming to avoid soil compaction.

New Zealand: Renovating pastures with no-tillage made New Zealand famous as one of the first countries to implement the technology in practical farming. In the early 1960's also annual crops were seeded with the no-tillage system. In the year 1995 only about 4% of the cropped area was under no-tillage and was virtually confined to pastures. According to John Baker (personal communication, 2008) there are about 160.000 ha under no-tillage in New Zealand, which corresponds to about 25% of all cropland hectares and includes

pasture, forage crops as well as arable crops. Because in this country many farmers use double cropping systems, the total number of hectares seeded each year in no-tillage amounts to around 250.000 ha. But to avoid double counting of hectares under no-tillage, for the purpose of this publication only the real area under no-tillage is counted. The same as in South America the growth of the area under no-tillage has taken place without subsidies or outside incentives.

Development of No-Tillage in Asia

China: To understand the difficulty to gather information about the spread of no-till in China one has to know that an average farmer has only about 0.08 ha of farm land and on average there are 3 to 5 persons in each family. This fact does not make it easy to estimate the area under no-tillage in this country and has to be taken into consideration when putting together numbers on tillage practices. But one thing is certain, the area under Conservation Agriculture has greatly increased in the last years in China. Conservation Agriculture is generally termed conservation tillage and includes mulch tillage and no-tillage. Conservation tillage is a term used for land that is not ploughed and where more than 30% cover with plant residues are left on the soil surface. No-tillage makes about 50% of conservation tillage in China and they allow for low disturbance subsoiling or ripping in their no-tillage fields. According to the head of the Conservation Tillage Research Centre, CTRC (Li Hongwen, personal communication, 2008) who has been committed by the Ministry of Agriculture to do a survey on conservation tillage practices every year, conservation tillage is practiced on about 3 million ha (He, 2010). As no-tillage makes about 50% of conservation tillage he informs that there are 1.33 million ha under no-tillage being practiced in China. The data for no-tillage is conjectured according to CTRC's knowledge and reports from different provinces and is based on talking to farmers and local administrative organizations.

The rapid growth of no-tillage in China was only possible because of the development of no-till seeding equipment industry for small farmers. China is now producing many types of no-till seeders for smaller tractors (Gao, 2007) and has difficulties to cover the high demand. Soil erosion by wind and water as well as scarce water, low levels of organic matter and declining productivity has been among the main driving forces for a quick adoption of no-tillage in this country. Paradoxically another factor has been limited labour availability because an increasing amount of young farmers have left for jobs in the cities leaving the older farmers behind. It should also be pointed out that government policy favours adoption of no-till technologies in

China, as has been stated in the 2004 «No. 1 document of the China Government» as well as the 2006/10 five year plan for agriculture stating clear goals for upscaling conservation tillage (Li 2010).

Kazakhstan: In this country no-till adoption has been promoted for some time by CIMMYT and FAO which introduced no-tillage systems in a Conservation Agriculture project from 2002 to 2004. CA has had an explosive development in recent years as a result of farmers interest, facilitating government policies and an active input supply sector. According to Mekhlis Suleimenov (personal communication 2008) no-till adoption started from 2004 on in the north Provinces (North-Kazakhstan, Kostanai and Akmola), were the highest adoption rates have been registered. A survey in this country showed a total area of adoption in Kazakhstan of 600.000 ha in 2007 and 1.3 million ha in 2008. With this Kazakhstan places itself under the ten countries with the biggest area under no-tillage in the world. The total area not using the plough any longer has even increased more. The official reports by the Ministry of Agriculture count about twice the area reported in this paper, including also technologies with high soil disturbance.

Indo-Gangetic-Plains: In 2005 about 1.9 million ha were reported under no-tillage in the Indo-Gangetic-Plains which include four countries in South Asia, India, Pakistan, Nepal and Bangladesh. As was found out later this refers only to the wheat crop in a double cropping system with rice. For rice virtually all farmers plough the land or use intensive tillage practices. As this can not be, in our view, termed no-tillage, we are not including it in our overview. According to Raj Gupta (personal communication, 2008), the area of no-tillage wheat in that region has increased to about 5 million ha with still very few farmers practicing permanent no-tillage systems.

India: Also in India the rice - wheat double cropping system is very popular among farmers and no-tillage practices have been adopted primarily for the wheat crop. The main reason is that tillage takes too much time resulting in delayed seeding of the wheat crop after rice. It is well established that for each day of delayed sowing beyond the optimum date wheat yields are reduced by 1 to 1.5%. This timely planting of wheat after rice is critical and that is the reason for the quick uptake of no-tillage wheat. The Rice – Wheat consortium for Indo-Gangetic-Plains, an initiative of CGIAR that involves several National Agricultural Research Centres has been promoting no-tillage and it is mainly their efforts that have resulted in the massive uptake of no-tillage wheat in the region. The uptake of the technology was

rapid in the north-western states which are relatively better endowed with respect to irrigation, mechanization and where the size of holdings is relatively large (3 – 4 ha) compared to the eastern region which is less mechanized and where the average land holding is small (1 ha) (Inder Pal Abrol, personal communication, 2008). The massive uptake of no-tillage was accompanied by local no-till seeders manufacturers that have been able to supply the local market. Some estimates on the area under no-till that have been undertaken in the region have been based on the sales of no-till drills and the average coverage per drill. As seen in other countries (e.g., Mexico) this method greatly overestimates the area under no-tillage because the drills are also used in reduced and some times even in conventionally tilled fields. For this reason one has to be cautious when alleged areas under no-tillage are mentioned based on the number of sold drills.

North Korea: The Democratic People's Republic of Korea (DPRK) has been supported by FAO for introducing Conservation Agriculture/ No-till through a TCP project since 2002. The FAO project showed that «no-tillage is a technically viable, sustainable and economic alternative to current crop production practices. After some years the scientific community, the ministry of agriculture and the farmers directly involved in the FAO project have been fully convinced of the economic benefits of crop rotation, no-tillage and straw mulching, which increased yields and reduced inputs. The project demonstrated the value of these CA practices for weed control, soil moisture retention and improvement of soil conditions for crop development» (FAO, 2007). During this period, Korean farmers adopted no-tillage techniques also for rice growing with great success as well as for potatoes, integrating both crops into CA crop rotations with permanent no-tillage. Starting on 3 cooperative farms CA is now practiced on about 30 cooperative farms on an area of about 3,000 ha the limitation being the availability of no-tillage equipment. In Sukchon County, which has been declared CA-model County by the Ministry of Agriculture, the no-tillage rice area in 2008 was 70% of the total rice area (personal communication from the Sukchon County Farm Management Committee).

Turkey: This country has engaged only recently in experimenting in no-tillage techniques (generally referred to as direct seeding or conservation tillage) mainly at the research level by universities and research institutes. Results have been positive for no-tillage compared to minimum and conventional tillage systems in terms of time and energy consumption. Yields of no-tillage have been comparable to

other tillage and seeding practices. But research results have not yet reached the farmers. The main reasons for this are: (Engin Çakir, personal communication 2009).

- **There is not enough information available in this field,**
- **There is lack of know how on how to do no-tillage,**
- **Some farmers tried no-till but abandoned because of reduced yields,**
- **There is no government support for conservation agriculture technologies,**
- **Crop rotation is almost impossible due to low income of the farmers,**
- **Small sizes of farms (average 6,1 ha) make it difficult to buy a specialized machine,**
- **No-tillage machines are not available in the market to try.**

These problems are common to many developing countries and have to be solved first before any attempt should be made to diffuse no-tillage technologies. Turkey could benefit from the results of no-tillage technologies being applied by GTZ projects under similar conditions in Syria and Lebanon.

Development of No-Tillage in Europe including Russia

Because of the slow uptake of the no-till technology Europe is considered to be the developing continent regarding Conservation Agriculture adoption (Basch, 2005). Only Africa has a smaller area under Conservation Agriculture/No-till than Europe. «European and national administrations are still not fully convinced that the concept of Conservation Agriculture is the most promising one to meet the requirements of an environmentally friendly farming, capable to meet the needs of the farmers to lower production costs and increase farm income, and to meet the consumer demands for enough and affordable quality food with a minimum impact on natural, non-renewable resources. The reliance of Conservation Agriculture on the use of herbicides and the alleged increased input of herbicides and other chemicals for disease and pest control are the main constraints for the full acceptance of Conservation Agriculture as sustainable crop production concept» (Basch, 2005).

Spain: While in South America the no-tillage technology was researched already in the early 1970's, no-tillage research in Spain started only in 1982. On the clay soils of southern Spain no-tillage was found to be advantageous in terms of energy consumption and moisture conservation, as compared to both, conventional or minimum tillage techniques (Giráldez and González, 1994).

Several factors including the contribution of engaged farmers and importing no-till seeding machines from South America has resulted in a quick adoption of the technology. From 1999 to 2008 only Semeato, a Brazilian no-till seeders manufacturer has exported almost a 1000 no-till seeders to Spain (Marcelo Rossato, personal communication 2010). Spain now is the leading country in terms of no-till adoption in Europe. According to AEAC/SV (Spanish Conservation Agriculture Association – Suelos Vivos), no-tillage of annual crops is practiced on 650.000 ha in Spain. Main crops under no-tillage are wheat, barley and much less maize and sunflowers. Besides annual crops grown in the no-tillage system in Spain many olive plantations and fruit orchards have turned to no-till systems. AEAC/SV reports 893.000 ha of no-tillage being practiced in perennial trees in most cases in combination with cover crops. Main tree crops in no-tillage in combination with cover crops are olives and much less apple, orange and almond plantations. Because this report is only based on no-till systems on annual crops we are not including no-tillage practices in tree crops in our global estimates. In total it is reported that Conservation Agriculture is applied on about 10% of arable land in Spain.

France: According to Boisgontier *et al*., (1994) INRA and ITCF started long-term experiments with different minimum tillage techniques including no-tillage in 1970 mainly with cereals. The authors concluded, that a comprehensive range of technical and economic data are now available in France in relation to where minimum tillage can be developed and how it can be implemented. France is among the more advanced countries in Europe in terms of Conservation Agriculture/No-till adoption. APAD (The French No-till Farmers Association) estimates that no-tillage is practiced on about 200.000 ha in this country. Some farmers have developed superior no-till systems with green manure cover crops and crop rotation which are working very well. The 2008 IAD International Conference on Sustainable Agriculture under the High Patronage of Mr. Nicolas Sarkozy and the following launching of the IAD Charter for Sustainable Agriculture is expected to show results in terms of greater acceptance of CA/No-till practices at all levels and especially at the political level. A greater acceptance of CA/No-till at political level is needed in the EU in order to increase farmer acceptance.

Finland: Among European countries Finland experienced one of the fastest adoption rates of the no-tillage technology. According to the Finnish Conservation Agriculture Association (FINCA) in less than

ten years no-tillage grew from some hundred hectares to 200.000 ha in 2008. This way Finland managed to advance to one of Europe's leading no-till countries. The reason for this rapid adoption was that those farmers that believed in the no-till system and made it work communicated their experiences to their peers. The extension service and research organizations as well as agribusiness took interest in this development only later. FINCA has played a mayor role in spreading no-tillage in Finland. One manufacturer of no-till seeders in Finland took interest in no-tillage very early and claims to have sold almost a thousand no-till seeding machines until 2007, having about 50% of the market share in this country. About ten no-till seeders manufacturers from around the world have been able to place their no-till machines in the Finnish market and four of them are made in Finland. Another interesting fact about no-tillage in Finland is that no-tillage is practiced successfully from the far South of the country up to the Artic Circle in the North. (66º N).

Ukraine: Estimates on the adoption of no-tillage vary greatly in this country depending on the source of information. They go from less then 30.000 ha to more than a million ha. Official government statistics on no-tillage state an adoption of 250,000 ha. Unfortunately, no-tillage systems as understood by the authors of this paper (see definition above), has not progressed as much as some people wish. According to Agrosoyuz (a big cooperative farm in Dnipropetrovsk) there are about 1.1 million ha of Direct Seeding technology being practiced in Ukraine. Direct Seeding here is a technique were a specially designed machine seeds directly after the harvest of the previous crop into undisturbed soil. This type of machine, which is very widely used in Ukraine, does a virtually complete disturbance of the soil surface in the whole width of the seeding machine because they use wide tines and often duckfoot openers. For this reason this form of seeding can not be termed no-tillage and can only be classified as reduced tillage or mulch tillage. Agrosoyuz has organized several no-till conferences in Dnipropetrovsk inviting many renowned international speakers and since then understanding has been growing that only low disturbance systems bring additional benefits, justifying the focussing on no-tillage. As there seems to be a substantial amount of low disturbance no-tillage being practiced in Ukraine the authors of this paper, after carefully balancing information, estimated the area under no-tillage provisionally at 100.000 ha.

Switzerland: Remarkable progress has been made in this country in terms of research, development and adoption of no-tillage practices. Research performed in Switzerland over more than ten years has

shown equal or better yields under no-tillage in a variety of crop rotations. No-till tends to be more and more accepted in Switzerland. This is because conventional tillage (and also reduced tillage practices as chisel ploughing), expose the soil to erosion under the topography prevailing in this country. According to Swiss No-till http://www.No-till.ch no-tillage is applied on about 12.500 ha in Switzerland and this corresponds to about 3.5% of arable land in this country. The Swiss No-till website offers very useful information on no-tillage in French and German. The No-Till ABC offers straight answers from practitioners to frequently asked questions by farmers.

Germany: Already in 1966 Bäumer (1970) started research into no-tillage technologies in this country. Intensive and long term research in Germany by Bäumer, Czeratzki, Kahnt and later Teebrügge and Böhrensen, concluded that no-tillage is a viable cultivation system. According to Tebrügge and Böhrnsen, (1997) no-tillage is a very profitable cultivation system compared to conventional tillage because of the lower machinery costs and lower operating costs. No-tillage decreases the purchase costs, the tractor power requirement, the fuel consumption, the amount of required labour as well as the variable and fixed costs. Since the same crop yields can be achieved by no-tillage compared to plough tillage, on average the profit will increase. Despite these facts adoption in Germany is still very low.
Well informed scientists, farmers and experts with a thorough understanding of no-till as practiced in most parts of the world coincide, that probably still today there are no more than about 5000 ha of this technology being practiced by farmers in Germany. At the same time one can recognize that there are outstanding farmers practicing no-tillage in this country like for instance Thomas Sander who farms in Oberwinkel, Saxony and receives many visitors every year**. http://www.infofarm.de/sn/BetriebSander/index.html** The quality of his no-tillage operation with crop rotations and cover crops has earned his farm the Environmental Award of the State of Saxony 2006. With boosting fertilizer and fuel prices, erosion problems in some regions and regular droughts in others, the interest in no-tillage is growing steadily and adoption is increasing. Some farmers like Alfons Bunk from Rottenburg, Suabia are using continuous no-till for more than 12 years successfully.

Russia: Despite all the efforts made to get at least some information on the area under no-tillage in Russia it was not possible to get realistic numbers for this country. We need to recognize that in this huge

country it is difficult to get reliable data on the area under no-till. On the other hand those people that have closer contact with Russia will know that several machine manufacturers have exported no-till machines to Russia in significant numbers. With the National Foundation for development of Conservation Agriculture (NFDCA) Russia also has an organization promoting Conservation Agriculture and with this is part of the European Conservation Agriculture Federation (ECAF). For this reason there should be a considerable area under no-tillage being practiced in this country. We hope to be able to get reliable estimates on the area under no-tillage in Russia in future.

Development of No-Tillage in Africa

No-tillage has been in a state of intensive promotion for the last decade in Africa. Reported levels are still low, even where some massive large scale adoption is taking place. Adoption in Africa is in the early stages of building capacities and setting up structures for up scaling (FAO 2008a).

South Africa: Data presented at the III World Congress on Conservation Agriculture in Nairobi in 2005 showed an area of 300.000 ha under no-tillage in South Africa (Derpsch, 2005). According to Richard Fowler (personal communication, 2008) the area has grown to about 368.000 ha in this country. Although research and practical results have identified that CA techniques can be applied with beneficial outcomes, this obviously has not been communicated in an appropriate form to farmers and technicians. South Africa needs to make bigger efforts to promote and spread no-tillage systems to overcome erosion problems and limited rainfall in many regions. The authors of this paper believe that this country presents excellent conditions for applying no-tillage technologies, e.g., adequate infrastructure, the presence of no-till clubs and government programs to promote Conservation Agriculture adoption, which need to be better exploited.

Southern and Eastern Africa: Many African Countries, particularly in Southern and Eastern Africa have been exposed to no-tillage systems and CA for the last decade and some of them have included this into their government policies. A number of emergency rehabilitation projects promoted CA in several countries, such as Zambia, Zimbabwe and Swaziland. Conservation Agriculture activities and promotion programmes exist especially in Kenya, Tanzania, Zambia, Zimbabwe, Lesotho, Swaziland, Mozambique and Malawi and CA has also been incorporated into the regional agricultural policies by NEPAD (New

Partnership for Africa's Development) and more recently by AGRA (Alliance for a Green Revolution in Africa). So far the area in ha is still small, since most of the promotion is among small farmers, but there is a steadily growing movement involving already far more than 100.000 small scale farmers in the region. A network coordinated by FAO with qualified informants in different countries of Africa has gathered initial information about the application of no-tillage in some countries with following preliminary results: Ghana 30.000 ha; Kenya 15.000 ha; Morocco 4.000 ha; Mozambique 9.000 ha; Sudan 10.000 ha; Tanzania 6.000 ha; Zambia 40.000 ha; Zimbabwe 7.500 ha.

Northern Africa: No-tillage systems have been promoted particularly in Morocco and Tunisia. In Morocco 4.000 ha of no-tillage have been reported. In Tunisia the promotion and development was farmer centred and the area under no-tillage increased from 27 ha on 10 farms in 1999 to nearly 6000 ha on 78 farms in 2007 (Baccouri,2008).

Results and discussion

The rapid expansion of the area under no-tillage / zero tillage from 2.8 million ha in 1973/74 to 45 million ha in 1999 and then to 117 million ha in 2010 shows the increasing interest that this technology is having among farmers. The superiority of this system in relation to unsustainable intensive tillage practices; time and fuel savings as well as higher economic returns are the driving forces for this development. In almost every country there are at least some activities in no-tillage, be it in research or in farmer adoption. No-tillage has expanded to soils and climates earlier thought inadequate for practicing the technology successfully. No-tillage is now being practiced by farmers from the artic circle (e.g. Finland) over the tropics (e.g. Kenya, Uganda), to about 50º latitude South (e.g. Malvinas/Falkland Islands). From sea level in several countries of the world to 3000 m altitude (e.g. Bolivia, Colombia), from extremely dry conditions with 250 mm precipitation a year (e.g. Western Australia), to extremely rainy areas with 2000 mm a year (e.g. Brazil) or 3000 mm a year (e.g. Chile). No-tillage is practiced on all kind of farm sizes from half hectare (e.g. China, Zambia) to hundreds of ha in many countries of the world, to thousands of ha in countries like Australia, Brazil, USA or Kazakhstan. It is practiced on soils that vary from 90% sand (e.g. Australia), to 80% clay (e.g. Brazil's Oxisols and Alfisols). Soils with high clay content in Brazil are extremely sticky but this has not been a hindrance to no-till adoption when appropriate equipment was available. Soils which are extremely sensitive to crusting do not present this problem under no-tillage because the mulch cover avoids the formation of crusts. No-tillage has even allowed expansion of

agriculture to marginal soils in terms of rainfall or fertility (e.g. Australia, Argentina). All crops can be grown adequately in the no-tillage system and to the authors knowledge there has not yet been found a single crop that would not grow under this system, including root crops. The wide range of conditions where the no-tillage system is working successfully all around the world, its economic, social and environmental advantages as well as the recognition as a truly sustainable farming system should ensure the expansion of this technology to areas where adoption is still low as soon as the barriers for its adoption have been overcome.

It is estimated that at present no-tillage is practiced on about 117 million hectares world wide. 47.6% of the technology is practiced in South America, 34.1% is practiced in the United States and Canada, 14.7% in Australia and New Zealand and 3.5% in the rest of the world including Europe, Asia and Africa. The latter are the developing continents in terms of CA/No-till adoption. Despite good and long lasting research in these continents showing positive results for no-tillage, this technology has experienced only small rates of adoption.

Concluding remarks

Environmental sustainability is the central paradigm of the 21st Century. Consequently the paradigms of agricultural production need to be changed. We also should keep in mind that «the age-old practice of turning the soil before planting a new crop is a leading cause of farmland degradation. Tillage is a root cause of agricultural land degradation - one of the most serious environmental problems world wide – which poses a threat to food production and rural livelihoods» (Huggins and Reganold, 2008).

With increasing awareness that sustainability of agricultural production is a must if sustainable development at national and global level is to be achieved, Conservation Agriculture/No-tillage systems will continue to grow world wide. But for sustained growth to take place the main barriers to no-till adoption need to be overcome.

- Mindset (tradition, prejudice)
- Knowledge on how to do it (know how)[2]
- Availability of adequate machines
- Availability of adequate herbicides
- Adequate policies to promote adoption

These barriers must be overcome by politicians, public administrators, farmers, researchers, extension agents and university professors. With adequate policies to promote Conservation Agriculture/No-till, it is

[2] No-tillage requires a learning effort on the part of the farmer to be successful

possible to obtain what is called the triple bottom line, economic, social and environmental sustainability, while at the same time improving soil health and increasing production. Farmers, researchers and extensionists need also to reflect on the benefits of no-till farming systems.

Benefits of no-till farming systems according to AAPRESID (2008):

- 96% less erosion
- 66% reduction in fuel consumption
- Reduced CO_2 emissions
- Enhanced water quality
- Higher biological activity
- Increased soil fertility
- Enhanced production stability and yields
- Incorporation of new areas into production
- Lower production costs

Recognizing the multiple benefits of no-tillage over reduced and conventional farming systems should foster research and development efforts in order to overcome the bottlenecks of the system and help extensionists in diffusing the technology so that farmers can have a sound basis for practical application.

The many benefits of no-tillage and the wide recognition as a truly sustainable farming system should ensure the growth of this technology to areas where adoption is still small as soon as the barriers for its adoption have been overcome.

The widespread adoption of no-tillage shows, that this way of farming can not any longer be considered a temporary fashion. Instead, this farming system has established itself as a technology that can no longer be ignored by politicians, scientists, universities, extension workers, farmers as well as machine manufacturers and other agriculture related industries.

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WEPP MODEL APPLICATIONS FOR EVALUATIONS OF BEST MANAGEMENT PRACTICES

D.C. Flanagan[1], W.J. Elliot[2], J.R. Frankenberger[3], C. Huang[4]

[1]USDA-Agricultural Research Service, National Soil Erosion Research Laboratory, 275 S. Russell Street, West Lafayette, Indiana, USA, 47907. Phone: +01 765-494-8673, FAX: +01 765-494-5948, email: Dennis.Flanagan@ars.usda.gov
[2]USDA-Forest Service, Rocky Mountain Research Station, 1221 S. Main St., Moscow, ID, USA. 83843. Phone: +01 208-883-2338, FAX: +01 208-883-2318, email: welliot@fs.fed.us
[3]USDA-Agricultural Research Service, National Soil Erosion Research Laboratory, 275 S. Russell Street, West Lafayette, Indiana, USA, 47907. Phone: +01 765-494-8673, FAX: +01 765-494-5948, email: Jim.Frankenberger@ars.usda.gov
[4]USDA-Agricultural Research Service, National Soil Erosion Research Laboratory, 275 S. Russell Street, West Lafayette, Indiana, USA, 47907. Phone: +01 765-494-8673,FAX: +01 765-494-5948, email: Chi-hua.Huang@ars.usda.gov

Summary

The Water Erosion Prediction Project (WEPP) model is a process-based erosion prediction technology for application to small watersheds and hillslope profiles, under agricultural, forested, rangeland, and other land management conditions. Developed by the United States Department of Agriculture (USDA) over the past 25 years, WEPP simulates many of the physical processes that are important when estimating runoff, soil erosion, and sediment delivery at a location having unique climate, topography, soils, and plants/tillage/management. A variety of user interfaces and databases make the model very easy to apply and use, particularly within the United States. The USDA Agricultural Research Service (ARS) has developed a stand-alone Windows WEPP system, as well as internet web-based hillslope and GIS watershed interfaces. GeoWEPP is an ArcGIS extension for performing model applications with a user's own detailed geospatial topographic, soils, and land management data. The USDA Forest Service (FS) also has a variety of custom online web-based interfaces for WEPP model applications targeted to specific problems, such as forest road design, effects of timber harvest operations, and identification of areas most important for remediation after wildfires. This presentation provides information on the current WEPP model and interfaces, and demonstrates the model's application at a field site. Existing conditions (climate, soils, slope, cropping/management) were used to provide baseline runoff and erosion estimates, and then the impacts of various alternative conservation practices were explored, including modified crop rotations, use of conservation tillage, strip cropping, and buffer strips. For the example in this paper for a 50-m long 6% slope eroding hillslope profile

in southern Indiana, use of a system leaving substantial residue and/or vegetative cover on the soil is needed to successfully reduce soil loss below a tolerable level.

Introduction

Soil erosion by wind and water detachment and transport processes continues to be a serious threat to productive soils throughout the world. When raindrops, flowing water, and/or wind removes topsoil, it also detrimentally impacts a number of soil properties. Soil organic matter content, nutrient levels, and water holding capacity can all decrease. Sediment in water is the largest pollutant of streams and lakes by volume, and deposition of this sediment can clog harbors and waterways – resulting in high dredging costs to maintain navigability. Pollutants transported with sediment and runoff water (nitrogen, phosphorus, pesticides, pathogens) can also cause large off-site water quality problems, including eutrophication and hypoxia.

Farmers and land managers need the ability to estimate soil loss for their current agricultural practices, as well as investigate how the use of alternative land management systems may be able to help them reduce the risk of erosion that can threaten their soil and its productivity. Empirically-based soil erosion prediction technology, such as the Universal Soil Loss Equation (USLE), has been used for many years to estimate the amount of long-term average annual soil loss. However, USLE is limited by its simple equation structure, is difficult to extend beyond the experimental database used in creating the equation subfactors, and cannot predict a variety of other important and related processes, such as runoff, sediment deposition, or sediment delivery.

Over the past 25 years, new generation water erosion prediction technology that is based upon mathematical representation of the important physical processes occurring has been developed by the U.S. Dept. of Agriculture (USDA). The Water Erosion Prediction Project (WEPP) model simulates processes of surface and subsurface hydrology, plant growth, water balance, residue decomposition, soil disturbance and consolidation, interrill and rill detachment, sediment transport, and sediment deposition. In addition to simulation of soil detachment, transport and deposition on hillslope profiles (at a scale of application similar to USLE), WEPP can also be applied to small watersheds composed of multiple hillslope areas connected to channels and impoundments, to allow for field- and farm-scale based analyses, up to areas of about 260 ha in size. Advanced GIS tools are under development to increase this up to 20 km^2 or more.

Materials and methods

The WEPP erosion prediction system is composed of a scientific model, coded in the Fortran programming language, some large databases for climate, soils and management, and a variety of user interface programs. WEPP can be applied in either a single storm mode, or in a continuous simulation mode, depending upon the type of user and model application. Climate input to WEPP is typically generated synthetic weather when the model is being applied in a continuous simulation mode to estimate long-term average annual runoff and soil loss rates, as well as conduct probability risk analysis. Observed weather data containing breakpoint precipitation information from recording raingauges can also be used as input.

During a continuous simulation, the scientific model determines the status of the soil water content down through the soil profile layers, and if a rain storm occurs on a day, will estimate infiltration of water into the soil through the event using a Green-Ampt Mein-Laurson procedure adjusted for unsteady rainfall (Flanagan and Nearing, 1995). If rainfall rate exceeds infiltration rate, and all soil surface depressions are filled, then runoff will be predicted to occur. Surface runoff rate is estimated using a solution to the kinematic wave equation, or an approximation to it to obtain the peak runoff rate. Peak runoff rate allows computation of the flow shear stress, which in turn is used in the sediment transport and rill detachment equations. Interrill detachment is a function of effective rainfall intensity and interrill runoff rate, as well as several other factors, including slope,

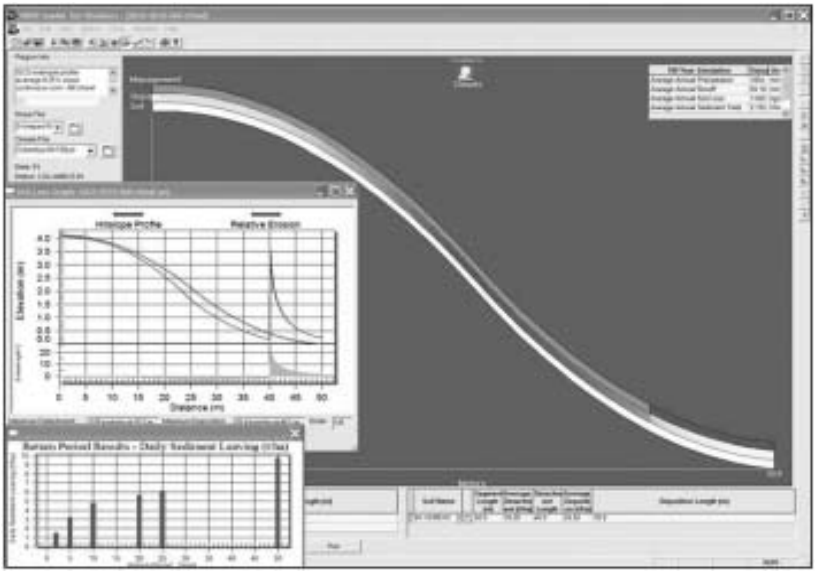

Figure 1. Screen capture of results of a 100-yr WEPP model simulation utilizing the WEPP Windows interface for a complex hillslope profile with a crop on the upper region and a grass buffer on the toe.

roughness, particle size, and adjusted interrill erodibility. Rill detachment occurs when flow shear stress exerted on the soil exceeds critical shear stress, and sediment load is below sediment transport capacity. An excess flow shear stress equation is used, with an adjusted rill erodibility multiplied by the difference between the flow shear stress and the adjusted critical shear stress. The change in sediment load down a slope with distance is the sum of the interrill sediment delivery rate to the rills and the rill detachment or deposition rate (Flanagan & Nearing, 1995).

The WEPP science model is run from a set of flat ASCII input files (slope, soil, climate, management, irrigation, run information (I/O), watershed structure, channel parameters, impoundment parameters), and generates a set of flat ASCII output files, based upon the values in the input run information file. In hillslope simulations, the main model output file can provide very detailed storm-by-storm information on runoff and soil loss, monthly, annual, or average annual results. Other text output files provide information on soil, plant, and water output, crop yield, winter hydrology, event-by-event runoff and sediment line summaries, and soil and plant parameter information through time. Return period information on rainfall, runoff and sediment loss can be determined from long simulations, and displayed in tabular and graphical form (Figure 1). The Windows interface program facilitates easy creation and modification of model input files and reading/viewing of output files. Graphical viewing of soil loss spatially down a slope profile is available, as is viewing of over 100 model parameters and outputs through time. Simple watershed simulations can also be conducted with this interface, but for more complex applications, use of other programs that access and utilize geospatial topographic, soils, and land-use data are more appropriate. (WEPP url: http://www.ars.usda.gov/Research/docs.htm?docid=10621)

GeoWEPP (Renschler, 2003) is a geospatial interface to the WEPP Windows software components. It is available as an ArcView 3.x or ArcGIS 9.x extension, that allows a user to use their own specific digital elevation model (DEM), land-use, and soils information for a location of interest.

More recent model interface work has focused on web-based interfaces, both for simple hillslope simulations as well as more complex watershed erosion assessments. The USDA Forest Service has an extensive set of web-based WEPP interfaces, custom designed to address erosion applications for forest road design, harvesting regions, and areas having experienced wildfires (http://forest.moscowfsl.wsu.edu/fswepp/). ARS also has several web-based interfaces for applications to cropland situations, and which utilize the existing national databases for the model (http://milford.nserl.purdue.edu). One of these interfaces is a prototype web-

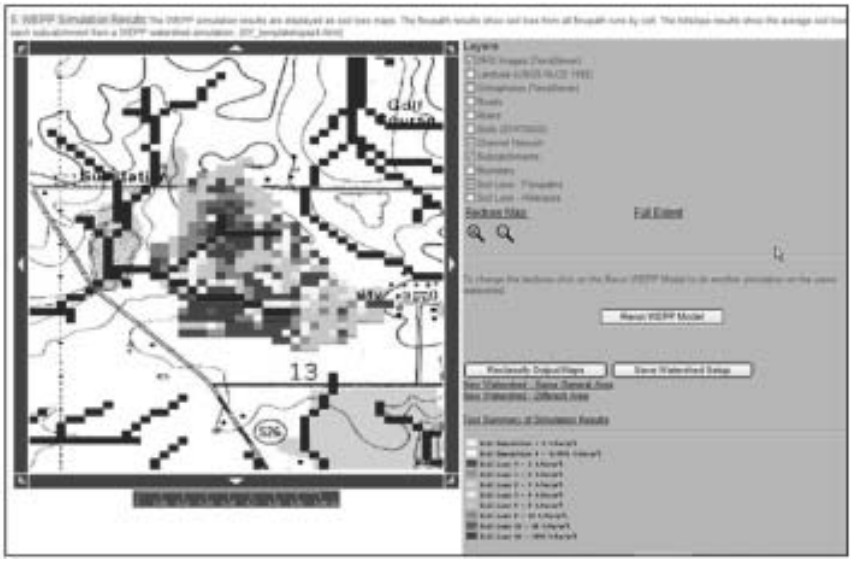

Figure 2. Screen capture of results of a 10-yr WEPP model simulation utilizing the web-based WEPP GIS interface for a small field watershed. Spatial soil loss values are shown in shades of red (above T) and green (below T), and yellow indicates deposition.

based WEPP GIS system, that allows a watershed application of the model to any location within the United States and utilizes nationally available USGS topographic DEMs and other information. Figure 2 shows a screen capture of results from a watershed simulation using this interface.

For the exercise in this paper, hillslope simulations using the WEPP Windows interface (v2010.1) were conducted for a field site located in south central Indiana, near the city of Columbus. An S-shaped profile (Figure 1) with an average slope of ~6% on a Pekin silt loam soil was simulated, using soil information from the WEPP database and a CLIGEN-generated climate input file for that location. The T-value for the soil is 9 Mg ha^{-1}, and the conventional cropping system is a rotation of corn and soybeans with fall moldboard plowing. Various alternative WEPP model simulations were conducted here.

Results and discussion

Table 1 shows the results of the WEPP model simulations for this example slope profile. The existing conventional system under fall moldboard plowing has an extremely high soil loss rate of 51.1 and sediment loss of 47.5 Mg ha^{-1}, which is more than 5 times the tolerable soil loss value (T) of 9 Mg ha^{-1}. Placing a permanent grass buffer strip on the last 10 m of the profile will reduce off-site sediment loss to 11 Mg ha^{-1}, however this is still greater than T, and soil above the buffer is still eroding at an

excessive rate. Switching to a continuous corn rotation with a buffer strip will reduce sediment loss rate below T, but again the upslope erosion is still too high. Even switching to a strip-cropping system with five 10-m long strips and a long rotation including alfalfa was not able to reduce

Table 1. WEPP model 100-yr simulation results for example profile.

	Average Annual		
	Runoff	Soil Loss*	Sediment Loss
Cropping/Management System	(mm)	(Mg ha^{-1})	
Fall moldboard plow corn-soybeans rotation	173	***51.1***	***47.5***
Fall plow corn-soybeans with 10-m grass buffer	146	***52.6***	***11.2***
Fall moldboard plow continuous corn	161	***28.3***	***28.0***
Fall plow cont. corn with 10-m grass buffer	140	***28.8***	7.0
Fall chisel plow continuous corn	163	***18.7***	***18.7***
Fall chisel cont. corn with 10-m grass buffer	142	***18.7***	4.8
Fall chisel plow corn-soybeans rotation	177	***40.6***	***37.3***
Fall chisel plow corn – no-till soybeans	188	***26.0***	***23.6***
Conv. till – corn,soybeans, wheat, alfalfa(4-yr)	168	***17.6***	***16.7***
Conv. till – c-s-w-a-a-a-a with 10-m grass buffer	145	***18.6***	4.5
Strip(5)crop – staggered c-s-w-a-a-a-a –conv.	150	***15.2***	***12.8***
Strip(5)crop – staggered c-s-w-a-a-a-a -chisel	147	***11.2***	***9.8***
No-till continuous corn	196	2.0	2.0
No-till corn-soybeans rotation	206	4.4	4.4
No-till corn-soy with 2-m grass buffer	191	3.6	2.6
No-till corn-soy with 10-m grass buffer strip	168	4.1	2.2
Continuous alfalfa, replant every 5 years	162	7.4	6.9
Permanent grass vegetation	155	0.8	0.7
Permanent forest vegetation	190	1.0	0.9

* Soil loss on detaching area of profile only (above toe-slope and grass strip).
Values highlighted in ***black* exceed T. The T-value for this soil (Pekin silt loam) is 9 Mg ha^{-1}.

the soil loss values enough under either conventional or conservation tillage. Some type of tillage system that leaves high amount of residues (no-till), or a permanent vegetation such as forest, grass or alfalfa are needed to reduce soil erosion to rates below T.

Conclusions

The WEPP model is a powerful tool that can be used to assess the impacts of various land management practices on runoff, soil loss, and sediment yield. Easy-to-use interfaces and large databases are available for application of the model. For a specific location with unique climate, soil, and slope profile shape, WEPP can help determine what conservation practices and crop rotations will best help conserve soil resources. The exercise in this paper illustrates the variety of management practices that can be evaluated, and in this case, the great importance of maintaining high soil surface cover.

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EFFECT OF SOIL CONDITIONERS AND GEOGRIDES ON RUNOFF AND SEDIMENT LOSS IN STEEP SLOPES, USING RAINFALL SIMULATOR

H. Rouhipour[1], A. Akbarzadeh[2] And H.G. Refahi[3]

[1]Research Institute of Forests and Rangelands, P.O. Box 13185-116 Iran. Tehran. Email: rouhi@rifr-ac.ir
[2,3]Department of Soil science, College of Agriculture and Natural Resources, University of Tehran, Karaj, Iran.

Summary

This experiment examines the influence of soil conditioners both synthetic material and natural amendment and geogrides on stabilization of steep slopes in order to control erosion and sediment loss Laboratory experiments were carried out using rainfall simulator and small flume facilities. 216 series of experiments were conducted on one soil sample taken from a marl hill located on the downstream part of Zanjan river catchment, Zanjan province of Iran. Soil sample was a heavy clay soil texture.. For all experiments approximately 100 Kg of soil sample was packed in the 1x1x 0.1 meter flume's tray and leveled manually. For each experiment, 3 slopes ranging between 5 to 20 percent. Treatments were five types of geogrids(made from polypropylene materials) with regular grid network of square apertures having diameters of 5.5, 3, 1.5, 1 and 0.5 cm, and soil conditioners (gypsum and PAM). Soil surface with and with out treatments in flume were subjected to 3 simulated rainstorm intensity of 25, 50 and 75 mm h^{-1}, in 4 different slopes of 15, 20 ,25 and 30 percent. Runoff water, percolation water, sediment yield, shear strength of soil surface and splash of soil particles were measured for each run collected for 60 minutes. The results showed that all treatments had significant effect on reducing sediment loss compared to the control wit out any treatments. Furthermore, results showed that geogids with apertures of 1.5 and 0.5 cm diameter were the most effective treatments in controlling sediment loss and runoff. It was found that application of 30 $Mgha^{-1}$gypsum reduced 92% sediment loss compared to control treatment. Furthermore amending soil surface with soil conditioners did not reduce runoff significantly compared to control treatment at steep slopes.

Key words: Soil conditioners, geogrid materials, simulated rainfall, runoff and sediment yield.

Introduction

Numerous studies have shown that dissipation of raindrop energy by any means, natural or artificial, leads to reduce erosion. In particular Ziegler and Sutherland (1998) claimed that some of erosion control materials (natural and synthetic) are able to reduce runoff and sediment significantly compared to control.

Agassi (1997) used 5 types of geo membranes to reduce runoff and erosion on 50% slope under laboratory and field conditions. The membranes dissipated the drops impact and reduced runoff significantly compared with the control. There was no significant difference among the membranes regarding their effect on the runoff. Another way of increasing the stability of soil structure is by the use of soil conditioners, which improve the physical properties of soils, and these include synthetic polymers and natural material like gypsum (Ben-Hur, 2006).

Polyacrylamide (PAM) is one of the synthetic polymers with the ability to enhance soil stabilization. This polymer is able to reduce soil detachment, maintain the soil structure and increase infiltration rate early in the rain events. In 1990s has shown that PAM is an effective polymer in reducing erosion in furrow irrigation on fine silt/clay soils (Lado *et al*., 2004.).

Another group of soil conditioners are the cementations-based binders such as gypsum. Calcium ions are effective at improving soil structure and increasing water infiltration. In addition, calcium and sulfur are important micronutrients for plants. (Alcordo and Rechcigl, 1995). Tang *et al*., (2006) reported that because of economical advantages of gypsum, application of PAM along with gypsum can be recommended for increasing their efficiency in increasing aggregate stability and reducing runoff and sediment yield.

The present study was therefore, carried out with objective to test the effect of soil conditioners and geogids materials on stabilization of sloping soil bed using rainfall simulator and small flume facilities.

Methods and materials

The site of sampling was in a village in Zanjan province of Iran, located on downstream side of Zanjanrood river. Sampling was conducted on 15 cm of the soil surface from one of the sloping lands of this region. Experimental treatments were consisted of soil without cover and amendments (control), and soil with geogrid covering and amendments. For each experiment approximately 100 kg of soil was packed in the 1×1×0.1 m tilting flume tray (adjustable between 0 and 50% slope) and leveled manually and then saturated for 24 hours.

Before each run geogrid was installed on soil surface with U shape steel pins to provide complete contact with the soil surface.

For amendments treatments dry granular anionic PAM copolymer with a molecular weight of about 5 Mg mole/L was used. Before application of PAM this polymer was dissolved in water and then was sprayed on the soil surface with 3 solution concentration of 25, 50 and 75 kg ha^{-1}. Also 10, 20 and 30 Mg ha^{-1} dry powder of natural inorganic gypsum was mixed with upper 5 mm of the soil surface (Figure 1b). Also, combination of 25 kg ha^{-1} PAM + 10 Mg ha^{-1} gypsum, 50 kg ha^{-1} PAM + 20 Mg ha^{-1} gypsum and 75 kg ha^{-1} PAM + 30 Mg ha^{-1} gypsum was investigated in this study.

.A rainfall simulator with oscillating nozzle was used in the studies. Mean drop size of produced rainfall was 1.5 mm diameter with a kinetic energy of 15.1 Jmm m^{-2}.

Runoff and percolated water, sediment yield, shear strength of soil surface and splash of soil particles were measured for each run. Runoff was collected in different time interval for 60 minutes after runoff initiation. Weight and volume of runoff samples were recorded. Sediment concentrations were determined gravimetrically using the evaporation method from collected runoff samples in different times (Brakensiek *et al*., 1979). Splash of soil particles was collected and measured for each run after drying the samples in the oven.

Water stable aggregate (WSA) and mean weight diameter of soil particles (MWD) before and after treatment with soil binders were determined using wet sieving method. Soil shear strength was measured with Tore vane.

Results and discussion

As an example of the effect of geogrids on reducing sediment oncentration is presented in Fig. 1. As shown in this figure at 30% slope and three rainstorm intensities, with decreasing the aperture of geogrid network, sediment concentration is reduced due to more covering area of soil bed with geogrid. The same trend was found for other three slopes investigated.

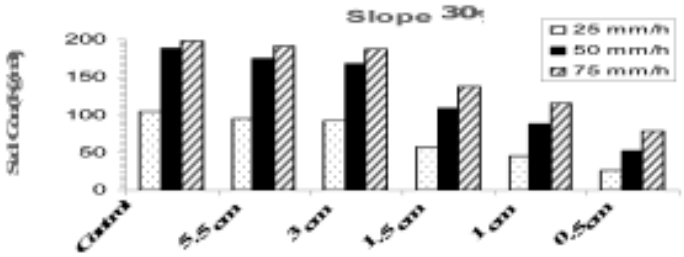

Figure 1. Changes in sediment concentration with geogrid aperture of different diameters at 30% slope and three simulated rainstorm intensities.

The results of the experiment in terms of soil conditioner indicated that application of 10, 20 and 30 Mg ha^{-1} inorganic gypsum on clay soil at different slops and rain intensities reduced sediment loss by 11 - 44 , 48 -64, and 85 - 92% respectively compared with the control. The high efficiency of 30 Mg ha^{-1} gypsum in reducing sediment loss was presumably due to improving soil aggregate stability.

Application of PAM up to 50 kg ha^{-1} had no significant effect on soil bed in reducing sediment concentration at 30% slope under rain intensities of 50 and 75 mm h^{-1}. Whereas, the effect of same amount of PAM was relatively high at 15, 20 and 25% slopes under different rain intensities.

Application of 75 kg ha^{-1} PAM associate with 30 Mg ha^{-1} gypsum reduced soil loss to non-detectable levels as compared with control (~ 99 %). Therefore, with the role of soil binders in flocculation of clay particles and improvement of soil physical properties, reduction in sediment concentration to a small level is not impossible. Because of the economic advantages of gypsum, application of polyacrylamide along with gypsum can be recommended for increasing their efficiency.

Conclusions

It was concluded that despite the effectiveness of synthetic polymers such as PAM in reduction of sediment loss and modifying aggregate stability, are not recommended because of cost and difficulties in their application. It was found that application of gypsum alone reduced soil erosion by approximately 92% as compared with the control. Thus easily application of gypsum together with its low cost make it a suitable soil amendment for erosion control in steep slope having marl formation. application of gypsum with PAM resulted in significant improvements over PAM applied alone. Further research is needed to refine the appropriate rates of PAM application for a variety of slope, soil, and climatic conditions.

It was also shown that geogrid or geotestile with apertures of 1.5, 1 and 0.5 cm diameter were the most effective treatments in sediment reduction compared with the control. Hence, it can be concluded that minimum ground cover for 1.5 cm aperture is 36% to be sufficient for significant reduction in soil loss.

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LONG-TERM SOIL MICROBIAL COMMUNITY AND ENZYME ACTIVITY RESPONSES TO AN INTEGRATED CROPPING-LIVESTOCK SYSTEM IN A SEMI-ARID REGION

V. Acosta-Martínez[a], C.W. Bell[b], B.E.L. Morris[c], J. Zak[b], and V.G. Allen[d]

USDA-ARS, 3810 4th St., Lubbock TX 79415 [a]; Department of Biological Sciences, Texas Tech University, Lubbock TX, 79409 [b]; Department of Botany & Microbiology, The University of Oklahoma,770 Van Vleet Oval, Norman OK 73019 [c]; Department of Plant and Soil Science, Texas Tech University, Lubbock TX, 79409 [d]

Summary

This study is part of a larger long-term project to develop and evaluate integrated crop and livestock systems in order to reduce dependence on underground water sources by optimizing cotton (Gossypium hirsutum) production in the Texas High Plains of U.S. Microbial communities and activities were evaluated (between years 7 – 10) in a clay loam soil (Fine, mixed, thermic Torrertic Paleustolls) under continuous cotton compared to an integrated cropping-livestock system. In the integrated system, steers grazed in sequence a perennial warm-season grass 'WW-B. Dahl' old world bluestem (*Bothriochloa bladhii*) paddock, and then rye (*Secale cereale* L.) and wheat (*Triticum aestivum* L.) grown in two paddocks (stages) of a rotation with cotton. Our previous studies after 5 years showed greater microbial biomass C (MBC) in perennial pasture (193 mg kg^{-1} soil) and the rotation when sampled under rye or cotton (average of 237 mg kg^{-1} soil) compared to continuous cotton (124 mg kg^{-1} soil) at 0-5 cm. After 7 years, MBC became significantly higher in the rotation independent of the crop compared to continuous cotton in this study. At the end of 10 yrs, total C was higher in both the rotation and pasture of the integrated cropping-livestock system (average across grazing treatments: 17.3 g kg^{-1} soil) compared to continuous cotton (11.4 g C kg^{-1} soil). Soil MBC and several enzyme activities (EAs) were higher under non-grazed areas compared to grazed areas within the integrated cropping-livestock system in some samplings. Microbial community structure of pasture soil showed higher FAME indicators for G- (i.e., a17:0 and cy19:0) and actinomycetes (i.e., 10Me17:0) under grazed areas compared to non-grazed areas, but overall, pasture showed higher fungal populations compared to continuous cotton. The rotation showed intermediate sum of bacterial FAME indicators among systems (continuous cotton > rotation >pasture) and a tendency for numerically higher fungi:bacterial ratios compared to continuous cotton.

Introduction

Efforts to sustain cotton production in the Texas High Plains region of U.S. have focused on integrating small grain crop rotations with cotton and pasture for livestock production systems in order to reduce irrigation needs relative to typical continuous cotton-monoculture (TWAC, 2007; Allen *et al.,* 2005; 2008). In 1997, a long-term research site was established in the Texas High Plains in order to compare a monoculture cotton-cropping system with an alternative system that integrated cotton and livestock production, in which cattle sequentially grazed a 2-paddock cotton and small grain crop-rotation and a perennial pasture paddock throughout the year while maintaining cotton production during summer. This type of cattle-grazing is a common practice in the livestock production industry sector, which views the rotation and pasture as a single integrated cropping-livestock system because of the interaction of the sequential cattle grazing between pasture and crop-rotation paddocks over time. Non-grazed zones were also established within each paddock area to evaluate long-term soil responses to the effects of grazing within the integrated cropping-livestock system. In order to evaluate potential soil quality enhancements between these contrasting agriculture management practices, the size, composition and activity of soil microbial communities must be considered. Soil microbial communities, as the primary source of soil enzymes, mediate critical nutrient cycling functions such as decomposition, nutrient mineralization, C sequestration and soil organic matter transformation (Tabatabai, 1994; Sotomayor-Ramirez *et al*., 2009). Therefore, this study evaluated the soil microbial community structure (microbial functional groups and abundances) and function (enzyme activity) as affected by an integrated cropping-livestock system including long-term soil responses to grazing (between 7- 10 yrs).

Material and methods

The research site was located (1997-2008) at the Texas Tech University field laboratory in Lubbock County in the Texas High Plains (101? 47' west longitude; 33? 45' north latitude; 993 m elevation). Mean annual precipitation is 465 mm. The continuous cotton and integrated cropping-livestock systems were replicated three times in a randomized block design (12.75 ha). Both systems were irrigated with an underground drip irrigation system with tapes located on 1-m centers and buried about 0.36 m deep. Each replicate of the integrated cropping-livestock system comprised 4 ha divided into three-paddocks (Fig. 1). Approximately 53.6% (2.14 ha) of the area consisted of a perennial warm-season grass 'WW-B.-Dahl' old world bluestem [*Bothriochloa bladhii* (Retz) S.T. Blake] paddock. The remaining 46.4% of the system was divided equally into 2-paddocks for two stages of a small grain forage-cotton rotation (0.93

ha each). Livestock production was maintained throughout the whole year as Angus and Angus-cross beef steers (*Bos taurus*) sequentially grazed the pasture and the forages available in the (two stages) rotation while cotton was produced in one of the two stages of the rotation in summer. Within each paddock, caged grazing exclusions (4.8 m x 4.8 m) were established at the beginning of this system and remain intact in the same location during the study. Forage within the caged areas were managed as a hay crop.

Soil samples were taken in summer 2004 (June), fall 2006 (Nov) and summer 2007 (July) from each field-replicate of the systems and from grazed and non-grazed cage areas within the integrated cropping-livestock system. Selected soil properties were determined as described in Table 1. The MBC was determined by the chloroform-fumigation-extraction method (Vance *et al*. 1987). FAME analysis was conducted following the MIDI (Microbial ID, Inc., Newark, DE, USA) protocol for soil analyses (Acosta-Martínez *et al*., 2004). Several EAs were assayed as described in Tabatabai (1994) or Parham and Deng (2000).

The data were analyzed as a randomized block design model in SAS (version 9.1) for each sampling to determine system effects (continuous cotton vs. integrated cropping-livestock system under non-grazed areas) and grazing effects within the integrated cropping-livestock system. Principal Component Analyses (PCAs) were performed using the PCORD program (version 5) with FAME indicators of bacterial and fungal populations in order to compare the soil microbial community between the systems. PCAs were also performed in the PCORD program for ten soil enzymes activities to compare the soil metabolic capacity or diversity between the systems.

Results and discussion

After 5 years, Acosta-Martínez *et al*. (2004) found higher MBC and EAs, and shifts in microbial community structure to higher fungal abundances under pasture when compared to continuous cotton; although this trend was not consistent within the crop-rotation paddocks, which only displayed similar patterns while under specific crops. In our study, long-term evaluation of the integrated cropping-livestock system (between 7- 10 yrs) revealed higher soil MBC in the pasture and rotation (regardless of the crop) compared to continuous cotton (Fig. 2). Increased soil MBC has been linked to increased soil quality and C sequestration under agriculture systems focusing on minimizing fallow periods while increasing soil organic matter levels by planting perennial grasses or small grain crops (Acosta-Martinez *et al.*, 2004; Sotomayor *et al*., 2009). Our findings indicate that consistent increases in soil MBC occur more slowly (>5 years) in the rotation within this

integrated cropping-livestock system compared to cotton monoculture. This may suggest that the summer fallow periods limited microbial biomass at earlier stages of this study despite the higher residues incorporation and root secretions when wheat and/or rye are integrated into cotton rotations. In addition, it seems that cotton produces far less residue than other major crops.

Higher bacterial populations than fungal populations were found under continuous cotton (Fig. 3) due to low biomass return with monoculture and soil disturbance with conventional tillage, which is known to disrupt fungal hyphae (Calderón *et al*., 2001). The rotation showed intermediate bacterial abundances among treatment s (continuous cotton > rotation >pasture) along with slightly higher fungal to bacterial ratios probably due to the inclusion of other crops in cotton rotations and the elimination of tillage. The fact that fungal populations were still not significantly different between the rotation and continuous cotton may suggest that soil community structure shifts may require >10 yrs due to the fallow periods used in this rotation for this region.

Overall, higher EAs in the integrated cropping-livestock system (Figure 4) were positively correlated with higher fungal abundances when compared to continuous cotton (Parham and Deng, 2000; Acosta-Martínez *et al*., 2004). Lower MBC and EAs (i.e., β-glucosaminidase and alkaline phosphatase) under grazed areas compared to the non-grazed areas within the integrated cropping-livestock system may suggest some reductions in plant biomass, soil nutrients and soil moisture for microbial communities. In general, despite the lower activities of certain enzymes observed under grazed soil compared to the non-grazed soil, the integration of livestock and cropping production as a system provides an overall increase in the metabolic capacity of soil compared to the continuous cotton system.

Conclusions

This study complements previous research activities evaluating the sustainability of an integrated cropping-livestock system for a semiarid region with limited water availability for agricultural activities. The detected increases in MBC and EAs of C, N, P and S cycling under this integrated cropping-livestock system may suggest that it provides viable alternatives for improving soil quality and metabolic function in this semiarid region to current practices such as cotton monocultures.

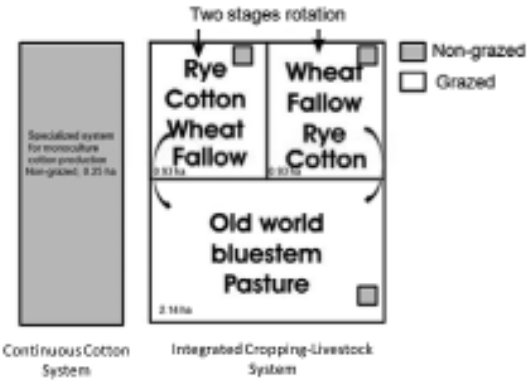

Figure 1. Drawing representation of the continuous cotton system and integrated cropping-livestock system compared at the Texas Tech University field research site. In the integrated system, livestock grazed in sequence a pasture grass paddock and small grains grown in two paddocks with different stages of the same rotation, except for non-grazed zones within each paddock excluded

Table 1. Selected soil properties (0-5 cm) under the integrated cropping-livestock system compared to continuous cotton.

Soil property	Integrated cropping-livestock system						Continuous Cotton
	Perennial Pasture		Rye-Cotton-Wheat-Fallow[a]		Wheat-Fallow-Rye-Cotton		
	Grazed	Non-grazed	Grazed	Non-grazed	Grazed	Non-grazed	
	Summer 2004						
Total C ($g\ kg^{-1}$ soil)	13.34b[b]	13.92ab	16.34a	13.15b	12.57bc	13.73ab	11.82c
Total N ($g\ kg^{-1}$ soil)	--	--	--	--	--	--	--
pH	7.43a	7.67a	7.47a	7.52a	7.53a	7.48a	7.70a
Moisture (%)	17.5c	16.7c	17.8c	25.1a	12.6d	16.3c	19.9b
	Fall 2006						
Total C ($g\ kg^{-1}$ soil)	15.27b	18.95a	15.27b	17.21ab	17.21ab	16.82ab	10.83c
Total N ($g\ kg^{-1}$ soil)	1.48a	1.81a	1.46a	1.81a	1.72a	1.69a	1.09b
pH	7.53a	7.55a	7.48a	7.23a	7.39a	7.39a	7.69a
Moisture (%)	14.3ab	16.3a	10.4ab	13.5ab	10.7ab	16.4a	9.1b
	Summer 2007						
Total C ($g\ kg^{-1}$ soil)	16.24ab	17.7ab	14.89b	17.40ab	19.53a	18.17ab	11.41c
Total N ($g\ kg^{-1}$ soil)	1.30b	1.46ab	1.55ab	1.71a	1.68a	1.58ab	1.07c
pH	7.47a	7.46a	7.18a	7.20a	7.34a	7.42a	7.68a
Moisture (%)	14.2bc	13.9c	17.4a	19.6a	16.6ab	17.3ab	16.8ab

[a]Soil samples were collected under different crops in the rotation in summer 2004 or 2007 (Wheat-Fallow-Rye-Cotton or Rye-Cotton-Wheat-Fallon) vs fall 2006 (Wheat-Fallow-Rye-Cotton or Rye-Cotton-Wheat-Fallow)
[b]Different letter indicate significant differences among cropping systems each year from LSD's at $P < 0.05$.

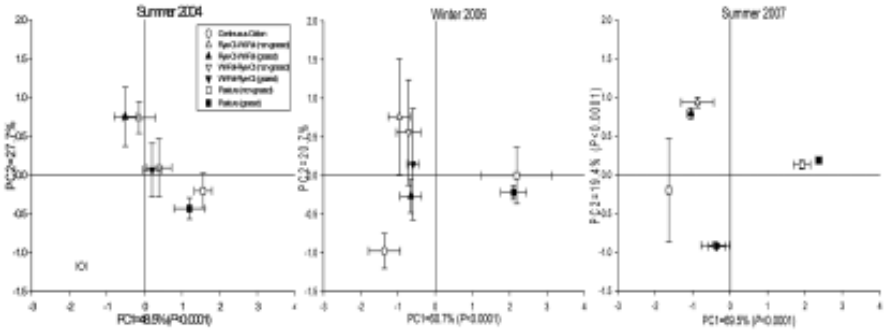

Figure 2. MBC as affected by the system (integrated crop-livestock system vs. continuous cotton) and grazing treatment (grazed vs. non-grazed areas) at 0-5 cm. Different letter indicates significant treatment differences (LSD) at *P* < 0.05. MBC values are expressed as mean ± S.E.

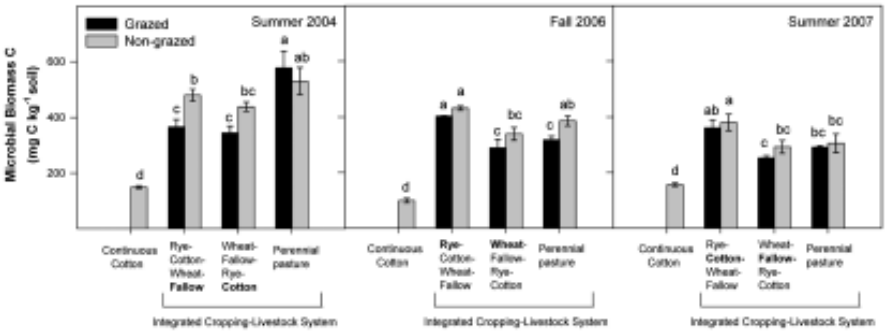

Figure 3. PCA plots to compare the soil microbial community structure using FAMEs under an integrated cropping-livestock system (grazed and non-grazed areas) and continuous cotton at 0-5 cm depth for different sampling times. A total of 14 FAMEs were used representing fungal indicators (18:1?9c, 16:1?5c, 18:2?6c and 18:3??c) and bacterial indicators for G+ (*a*15:0, *i*15:0, *a*17:0, and *i*17:0), G– (cy17:0, cy19:0, *i*13:0 3OH, and *i*17:0 3OH) and actinomycetes (10Me16:0, 10Me17:0). Data shown are means for each system ± SE.

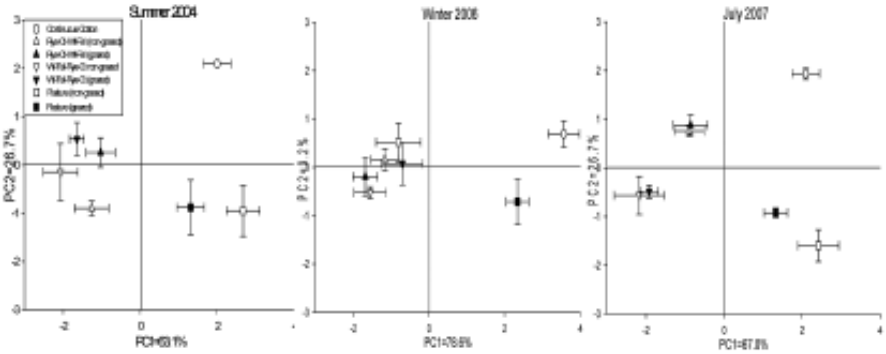

Figure 4. PCA plots to compare the soil metabolic capacity or diversity using several enzyme activities under an integrated cropping-livestock system (grazed and non-grazed areas) and continuous cotton at 0-5 cm depth for different sampling times. The enzyme activities are involved in C-cycling (β-Glucosidase, α-Galactosidase, and β-Glucosaminidase), N-cycling (β-Glucosaminidase, Amidase, Urease, and L-Asparaginase), P-cycling (Acid Phosphatase, Alkaline Phosphatase, and Phosphodiesterase) and S-cycling (Arylsulfatase).

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EFECTO DEL CAMBIO DE USO DE UN TYPIC DURUDAND SOBRE LA FUNCION Y RESILIENCIA FUNCIONAL DEL SISTEMA POROSO

José Dörner[(1)], Dorota Dec[(1)], Felipe Zúñiga[(1)], Pablo Sandoval[(1)], Rainer Horn[(2)]

[(1)] Instituto de Ingeniería Agraria y Suelos, Facultad de Ciencias Agrarias, Universidad Austral de Chile. josedorner@uach.cl
[(2)] Institute of Plant Nutrition and Soil Science, Christian Albrechts University zu Kiel, Germany. rhorn@soils.uni-kiel.de

Resumen
Un Andisol de la serie Los Lagos (Typic Durudand) fue utilizado para estudiar el efecto del cambio de uso de suelo sobre la función y resiliencia funcional de sus poros. Muestras disturbadas y no disturbadas de suelo fueron recolectadas a 5 y 20cm de profundidad en un suelo bajo renoval de bosque nativo (BN), una pradera de 30 años de uso sin realizar labores (P30) y otro utilizado para cultivo (C). Con las muestras se determinaron características del suelo como textura, carbono orgánico y otras más específicas como la distribución de poros, permeabilidad de aire, curvas de consolidación y contracción. El cambio de uso de suelo provocó una disminución del volumen de poros responsables de la aireación, alterando además la continuidad entre los poros lo que se reflejó en una reducción importante en la permeabilidad de aire en C con respecto a BN y P30. La resiliencia estructural del suelo también se ve afectada des pues del cambio de uso de suelo, particularmente después de la consolidación lo que está estrechamente relacionado con el carbono orgánico. Tanto el estrés mecánico como el hidráulico alteran la estructura del suelo, sin embargo, mientras el primero produce una reducción de la conductividad de aire por compactación, el segundo la incrementa producto de la formación de grietas.
Palabras clave: Cambio de uso de suelo, función poros, resiliencia

Introducción

El suelo es un medio trifásico que cumple una serie de funciones en la biosfera como p.ej. es regulador en los ciclos biogeoquímicos siendo también un almacén de agua, aire y nutrientes para las plantas. Las funciones que cumple el suelo dependen en gran medida de la estructura y su estabilidad. Por lo tanto, cambios estructurales generados por estreses mecánicos (compactación) e hidráulicos (ciclos de mojado y secado), que usualmente ocurren con el cambio de uso de suelo, producen alteraciones que afectan p.ej. la capacidad del suelo para almacenar y transmitir agua y aire (Dörner *et al*. 2009).

Los suelos volcánicos del sur de Chile constituyen cerca del 60% de los suelos arables en el país (Besoain, 1985). Además, presentan características particulares que los diferencian de otros suelos del mundo (p.ej. densidad aparente < 0.9 Mg m^{-3}) y se encuentran bajo un amplio rango de usos. Esto permite evaluar cómo un cambio en su uso afecta sus propiedades estructurales usando como referencia los sistemas menos intervenidos. Este trabajo busca presentar cómo el cambio de uso de suelo afecta sus propiedades estructurales particularmente la función de los poros y a la capacidad que estos tienen de recuperarse después de eventos de estrés mecánico e hidráulico.

Material y métodos

Un Andisol de la Serie Los Lagos (Typic Durudand) fue utilizado para estudiar el efecto del cambio de uso de suelo sobre la función y resiliencia funcional de sus poros. Para ello, muestras no disturbadas y disturbadas de suelo fueron recolectadas a 5 y 20 cm de profundidad en un suelo bajo renoval de bosque nativo (BN), una pradera de 30 años de uso sin realizar labores de suelo (P30) y otro utilizado para cultivo (C). El suelo disturbado fue utilizado para determinar: textura, densidad real, contenidos de carbono orgánico y alofán. El suelo no disturbado fue recolectado en cilindros metálicos para determinar la curva de retención de agua, de contracción y la permeabilidad de aire (220cm^3, n: 7) como así también la curva de consolidación (110 cm^3, n: 4). A partir de las curvas de consolidación y contracción se calculó el coeficiente de extensibilidad lineal (COEL). Las metodologías y las ecuaciones utilizadas se presentan detalladamente en Dörner y Horn (2006) y Dörner *et al*. (2009).

Resultados y discusión

Efecto del cambio de uso de suelo sobre la porosidad y su función

Se observan ligeras diferencias en la textura de los sitios estudiados (Cuadro 1) que, sin embargo, corresponden a la definición del perfil de la serie Los Lagos (IREN – CORFO, 1978). En todos los sitios se determinó que mientras $_s$, el material más grueso y el monto de alofán aumentan en profundidad, la arcilla disminuye. Los cambios texturales afectan principalmente a la porosidad más fina del suelo. Un cambio de uso de suelo significó una reducción en el COS de 20% entre el BN y los otros sitios a 5cm de profundidad. Las labores de suelo realizadas hace más de 30 años en P30 y anualmente en C, como también el gran número de raíces observadas en la estrata de 20 a 50 cm de profundidad, se manifiestan en un mayor COS en los sitios intervenidos en comparación al BN. Mientras el cambio BN a P30 no se ve reflejado en una reducción significativa del volumen poroso, esto sí se observa entre BN y C. Labores

de cultivo realizadas en los primeros 25 cm de suelo destruyen la estructura lo que se manifiesta en una pérdida de poros, particularmente los más gruesos responsables de la aireación y drenaje del suelo. Usualmente, la redistribución de los poros en Andisoles como consecuencia de una compactación significa perder poros de aireación y ganar poros de almacenamiento de agua (Dörner *et al.*, 2009).

Cuadro 1: Características físicas del suelo estudiado

Uso	Prof	Arena	Limo	Arcilla	Alofán	COS	ρ_s	PT	PDR	PDL	PAU	PAI
[-]	[cm]	----------[g/kg]----------					Mg m^{-3}	----------%----------				
BN	5	354	531	115	70	93.9	2.05	67.3a	9.2a	8.3ab	22.7a	27.2c
	20	546	350	105	118	47.6	2.36	72.1a	17.7a	16.9a	21.7b	15.9a
P30	5	377	493	130	94	73.1	2.24	66.0a	4.5b	6.7b	23.0a	31.8b
	20	410	470	120	110	68.4	2.36	69.1b	8.7b	16.8a	24.8b	18.8b
C	5	366	512	123	80	75.4	2.24	63.2b	3.5b	10.2a	15.3b	34.2a
	20	480	407	113	105	80.0	2.30	64.9c	3.5c	10.2b	29.0a	22.3c

Arena: 2000–630??m, Limo: 630–2 ?m, Arcilla: <2 ?m; COS: Carbono orgánico suelo, $_s$: Densidad real, PT: Porosidad total, PDR: Poros drenaje rápido (>50 ?m; Capacidad de aire suelo), PDL: Poros drenaje lento (50–10 ?m), PAU: Poros agua útil (10–0,2 ?m), PAI (<0,2 ?m). Letras distintas a igual profundidad pero diferente uso indican diferencias estadísticamente significativas (test de Tukey, p< 0.05).

Junto con la importancia de los poros para almacenar agua y aire es fundamental conocer la capacidad del suelo para transmitirlos. La Figura 1 presenta la permeabilidad de aire en función de los poros saturados con aire. En general se puede apreciar que: *i*) k_a aumenta con el incremento en e_a, *ii*) los valores de k_a de BN y P30 son mayores a los observados en C. Llama la atención que a pesar que P30 y C presentan la misma capacidad de aire (PDR) a 5 cm de profundidad, k_a en P30 es casi un orden de magnitud mayor a lo observado en C. Esto ratifica lo presentado por otros autores (Ball *et al*. 1988; Dörner y Horn 2006), en cuanto a que el movimiento de aire del suelo depende de aspectos geométricos del sistema poroso en donde siempre se destaca la continuidad y organización entre los poros. Estas características se ven afectadas por el cambio de uso de suelo hasta los 20 cm de suelo, lo que se manifiesta en una menor capacidad para transmitir aire en C en comparación con BN y P30. Si bien es cierto que la pradera esta sometida a pastoreo, lo que implica ejercer una presión, los resultados demuestran que el tiempo de uso del recurso (> 30 años) ha permitido la creación de un sistema poroso continuo y en equilibrio con dichas presiones.

Efecto del cambio de uso de suelo sobre su resiliencia estructural y funcional

El coeficiente de extensibilidad lineal (COEL) muestra que el estrés mecánico produce una mayor deformación que el hidráulico (Fig. 2A). El cambio de uso de suelo aumenta su estabilidad mecánica a través de la alteración de la estructura y la compactación de suelo lo que se expresa en una reducción del COEL mecánico de 23% y 38% de BN a

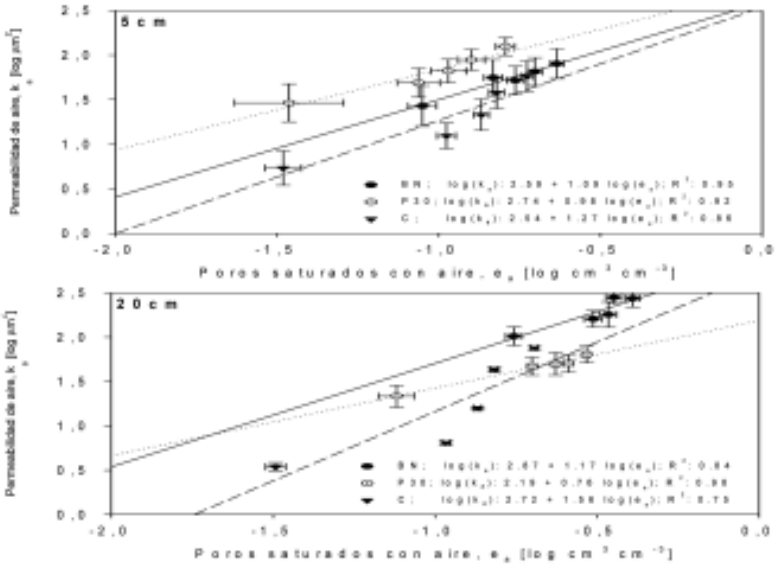

Figura 1. Permeabilidad de aire (k_a) en función de los poros saturados con aire (e_a) en muestras de suelo recolectadas a 5 y 20cm de profundidad en BN, P30 y C. Barras indican 1 error estándar. Ecuación de ajuste (Ball *et al*., 1988): log (k_a): log M + N log (e_a).

C y BN a P30 a 5 cm de profundidad. Tendencias similares fueron observadas a 20cm de profundidad. Todos los horizontes estudiados son capaces de recuperar parte de su volumen original (Fig. 2B). Sin embargo, la resiliencia estructural después del estrés hidráulico (: 52% y 33% en 5 y 20 cm de profundidad) fue mayor que la generada después del estrés mecánico (: 28% y 19% en 5 y 20 cm de profundidad) demostrando que las cargas aplicadas en el ensayo de consolidación superaron largamente el valor de precompresión del suelo mientras que el estrés hídrico sometido durante la curva de contracción no superó el nivel máximo de secado histórico alcanzado en condiciones de campo. El cambio de uso de suelo afectó la resiliencia estructural del suelo, particularmente, después de la consolidación. Esto último, que no fue tan claro después del estrés hidráulico, está estrechamente relacionado con el COS (Ellies 1988). Finalmente, la deformación del suelo altera la estructura (Fig. 2C-D) y consecuentemente la función de los poros expresada a través de la conductividad de aire (Fig. 2 E-F). Sin embargo, el efecto del estrés hidráulico y mecánico es diferente, o sea, mientras el primero induce una reducción de k_l como consecuencia de la compactación, el segundo provoca un aumento en k_l producto de la formación de grietas durante el secado.

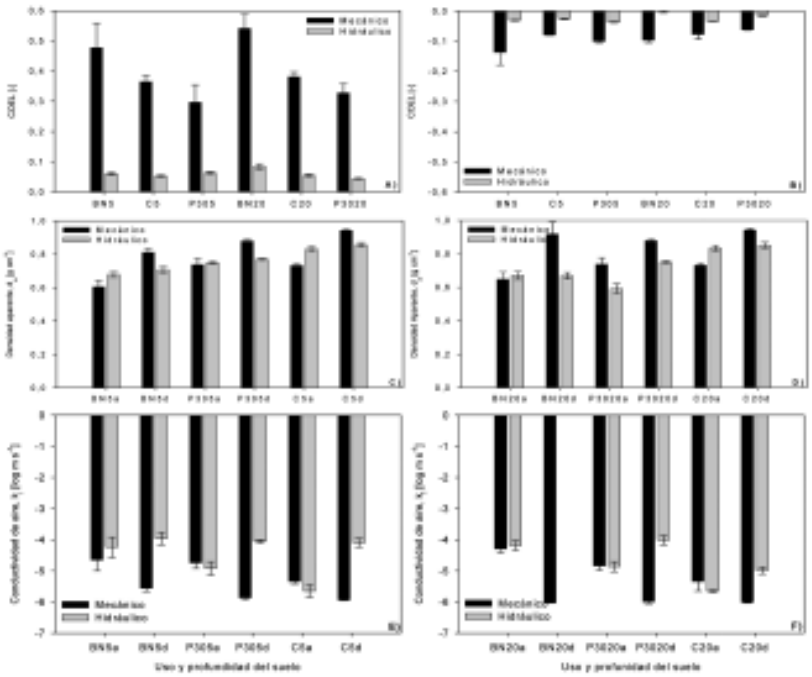

Figura 2: Coeficiente de extensibilidad lineal (COEL) después de estreses mecánicos e hidráulicos después de eventos de presión/contracción (A) y de descompresión/ hinchamiento (B). Efecto de estreses mecánicos e hidráulicos sobre la densidad aparente (A-B) y la conductividad de aire (C-D) del suelo en función de su uso. Valores medidos antes (a) y después (d) del ensayo de consolidación y de la determinación de la curva de contracción hasta 25ºC. Barras indican 1 error estándar.

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NATURAL SOIL REGENERATION ACCORDING TO PLANT SUCCESSION IN THE SANDY ANTHROPOGENIC «DESERT» IN THE MILITARY TRAINING GROUND

Michal Jankowski

Department of Soil Science, Institute of Geography, Nocolaus Copernicus University, Gagarina 9a, 87-100 ToruD, Poland tel. 48-56-611-25-54, mijank@umk.pl

Summary

Soil development parallel to plant succession was the subject of studies carried out in a small anthropogenic desert formed due to military activity in sandy area of the Torun Basin (Northern Poland). After removing of the natural forest vegetation, sandy soils very easily became a subject of deflation and erosion. In bare sands thus exposed plant succession begins and new generation of soils stars to develop. The succession proceeds in a primary or secondary way, depending on stage of soil profile erosion. In a case of primary succession, three developmental stages of soil evolution have been distinguished: initial with Protic Arenosols, intermediate with Haplic Arenosols and semimature with Albic Arenosols. Under vegetation of secondary succession ecological and soil-forming processes are accelerated and new species of plants occur. However anthropogenic deserts are effects of human's mismanagement in the area of studies (forest zone of the Central Europe) they constitute an important element of bio-geo-diversity, forming unique landscapes and being habitats for rare and protected plants.

Introduction

Present-day climatic conditions of Central Europe (temperate, humid climate) promote natural vegetation of leave or coniferous forests, depending on soil conditions. However in case of human-induced damages of plant cover, soils very easily became a subject of decrease in organic matter content as well as water and wind erosion. In areas built of poor, sandy sediments, degradation of the whole ecosystem is especially fast and anthropogenic «deserts» form easily. In such places both, natural ecological succession and intentional reclamation are very slow, due to very low fertility and insufficient water capacity. On the territory of Poland such situation can be observed mostly in ecological mismanagement places like mining areas and military training grounds. The biggest anthropogenic wasteland, so called «the Bledov Desert» of the maximum area of 32 km^2, existed in the landscape of Southern Poland since the Middle Ages until the end of XX Century (800-900 years; Rahmonov 2007).

Processes of early development of soils and vegetation in bare sands were reported from various natural landscapes (e.g. Chabarov 1977, Certini et al. 1998, Elgersma 1998, McBride, Wilson 1991, Stützer A. 1998). The aim of this study is to establish changes of soil morphology and basic properties at first stages of plant succession in anthropogenic bare land («desert») being an effect of long-time military activity. Understanding driving forces and mechanisms of natural reclamation of such wastelands by vegetation and soil-forming processes can be helpful in managing sandy areas degraded as a result of improper land use.

The studies were carried in the ToruD Basin, region located in Northern Poland, Central Europe (Figure 1). The landscape represents 25 km wide ice marginal stream valley of Late Pleistocene age, built of glaciofluvial sandy terraces and inland dunes of periglacial origin (Mrózek 1958). Climate of the area is of a temperate type with mean annual temperature 7.9 C and precipitation 520 mm (Wójcik, Marciniak 2006). Natural vegetation of pine (*Peucedano-Pinetum*) and mixed (*Querco-Pinetum*) forests has been removed on the area of over 12000 ha due to artillery activity at the break of XIX and XX Centuries and since that time small artificial sandy deserts exist in the landscape. Recently, after ending of use for military purposes, slow ecological succession proceeds, from time to time interrupted by occasional human activity.

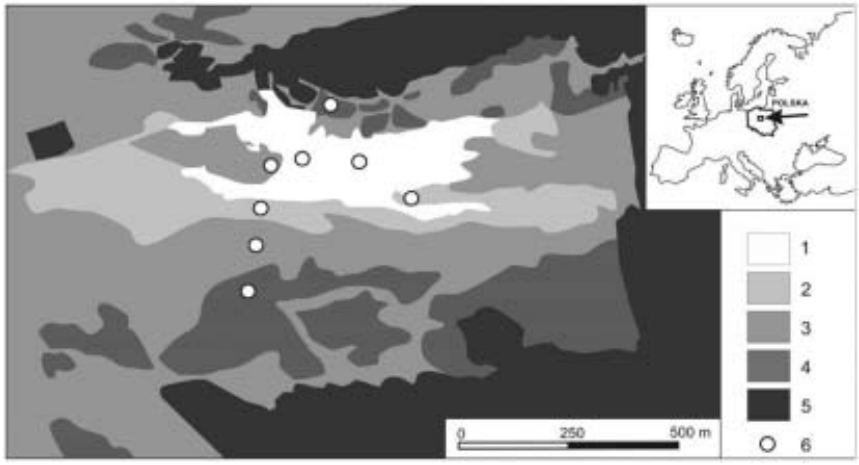


Figure 1. Location of the study area and soils/vegetation distribution
1 - bare sands/no vegetation, 2 - Protic Arenosols/single *Corynephorus canescens*, 3 - Haplic Arenosols/dense *Spergulo-corynephoretum*, 4 - Haplic Arenosols/*Calluna vulgaris,* single *Pinus sylvestris*, 5 - Podzolic soils (Albic Arenosols) /pine forest, 6 - soil pits

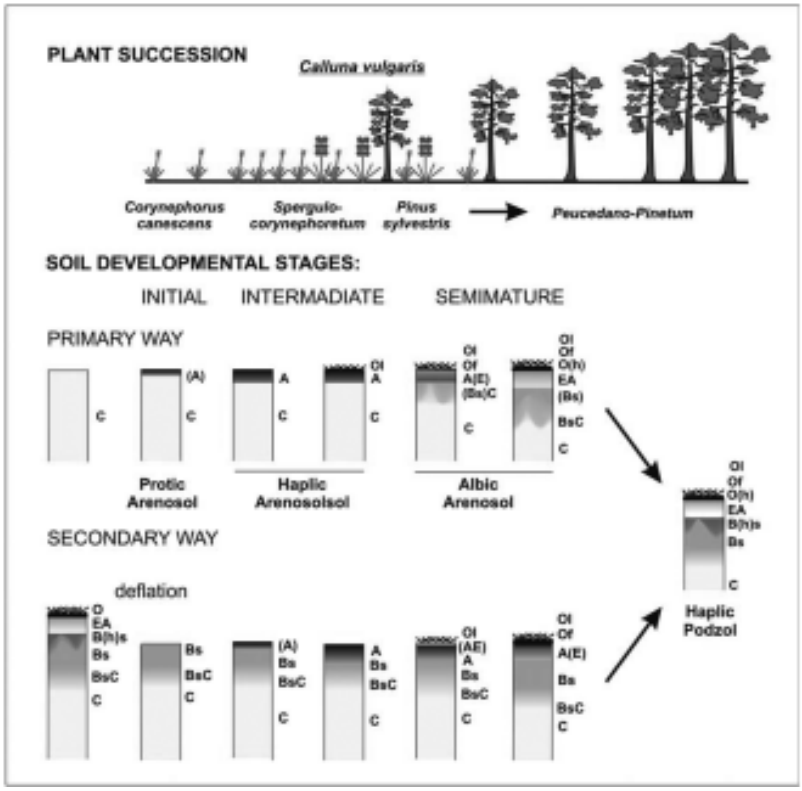
The biggest actually existing area devoid of vegetation was the object of studies. Typical aeolian forms of both, erosive (stony aeolian pavements, bowl-like depressions, deflational remnants) and accumulative (ripplemarks, hillocks or even small dunes) origin occur there.

Soils were examined in 20 pits located in transects from northern to southern border of surrounding pine forests. Morphology described in the field was the basis for to establish stages of soil development. In 8 representative profiles located in patches of plant groups representing following stages of ecological succession basic chemical properties were determined with standard methods used in soil science (grain-size distribution, C and N contents, C:N ratio, pH, oxalate extractable Fe and Al).

Examined soils are built of loose sands, with dominant fraction of fine and medium sand (0.1-0.25 and 0.25-0.5 mm) reaching over 90%. Quartz totally predominates in mineral composition (85-99%) and feldspar content does not exceed 15%. Thus they are excessively permeable and extremely poor in nutrients.

The area of the strict bare sands is now only ca 20 ha and it shrank since 1992 more than twice. Different stages of plant succession can be observed on area of 120 ha surrounding the «desert». Vegetation spreads from borders with neighboring pine forests to the centre.

Figure 2. Scheme of soil developmental stages according to plant succession



The general scheme of early soil evolution in connection with plant succession in the area of studies was reported in previous works (Jankowski, Bednarek 2000, 2002). Three developmental stages were distinguished: initial (represented by Protic Arenosols according to IUSS 2007), intermediate (Haplic Arenosols) and semimature (Albic Arenosols; Jankowski, Bednarek 2000). Newer studies show two lines of soil development dependently on form and degree of soil profile degradation. In places where soils were completely destructed or covered with thick layer of fresh aeolian sandy sediments, parent material is exposed on the surface and the ecosystem development has a character of «primary» succession (Figure 2). In that line initiation of soil-forming process is very difficult due to instability of land surface and sensibility of initial plants to destruction. Great role is played by Cyanobacteria and Algae (Rahmonov, Pitek 2007), which however is not significant in the soil profile. Initial soils - Protic Arenosols having only 1-2 cm deep initial humic horizon (A) appear under first clusters of psammophillous grass *Corynephorus canescens* and non continuous colonies of moss *Polytrichum piliferum*. Haplic Arenosols with clear A horizon develop when plant cover becomes continuous and more dense. If the succession is not interrupted, it takes ca 20-30 years from the beginning of colonization. On that stage lichens (e.g. *Cladonia* sp.) and more plant species occur, e.g. *Calluna vulgaris* and first trees of *Betula pendula* and *Pinus sylvestris*. It is worth to notice that many of psammophitic plants belong to species protected on the national and the whole European Union level (*Calluna vulgaris*, *Cetraria islandica*, *Carex arenaria*, *Elymus arenarius*).

Together with forest species invasion, the shadow increases and organic horizon starts to form *mor* type of humus. With time mature pine forest forms and psammophitic plants totally disappear. After about 50-60 years of dense pine forest domination, first clear effects of podzolization can be observed as a thin 1-5 cm deep grey Eh and 15-25 cm deep pale orange BC horizons (Jankowski, Bednarek 2002). Changes of soil chemical properties are clearly seen during their evolution. Organic carbon contents in upper mineral horizons increase from 0.2% in Protic Arenosols to over 1% in Albic Arenosols. Values of C/N ratio increase from 13 to 24. pH values measured in 1 M KCl decrease from 4.3 to 3.1. Oxalate extractable Fe and Al at first show a clear tendency to accumulation in a humic horizon but later to translocation down the profile, according to initiation of podzolization (Certini *et al.* 1998, Stützer 1998). In places, where former soils were not eroded completely, plant succession is accelerated and has a *secondary* character (Figure 2). In that situation soil development takes place in a top of remnants of older soil, which improves site conditions in the initial phase. Material reworked previously by soil-forming processes is more resistant to deflation and relatively more fertile. The acceleration is seen especially at the initial phase, when colonization by Algae and first plants is much more easy

than in a case of fresh sand according to a little better conditions of moister retention and nutrients availability. Plants characteristic for particular succession stages occur some years earlier and also new species appear. Similar way of a secondary succession was observed also in places with remnants of older, well developed soils buried with thin cover of aeolian sands (Rahmonov 2007).

Dynamic processes proceeding in sandy, anthropogenic «deserts» give a chance to observe mechanisms and tempo of ecological succession and soil-forming processes. This can be helpful in developing natural methods of reclamation of such type of wasteland occurring in Central Europe.

Three developmental stages of soil evolution parallel to plant succession were distinguished: initial, intermediate and semimature. Ecological processes run with different speed in primary or secondary way dependently on the degree of former soil cover erosion.

However such artificial geo-ecosystems are effects of human mismanagement, in Central Europe they constitute unique landscapes and ecosystems. Moreover, they can be a refuge for rare plant spices and thus should be protected on small areas as the important aspect of bio-geo-diversity.

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SUCCESS FACTORS FOR SOIL AND WATER CONSERVATION MEASURES IN THE SAHEL

Alexander Schöning[1], Martina Wegner[1] and Sabine Dorlöchter-Sulser[2]

[1] Division 45 - Agriculture, Fisheries and Food Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH. Dag-Hammarskjöld-Weg 1-5, 65760 Eschborn, Germany
Tel.: +49-6196-792076, Fax: +49-6196-79802076
alexander.schoening@gtz.de, martina.wegner@gtz.de
[2] B.P. 11 895, Niamey, Niger Tel.: +227-20740811sdorloechter@yahoo.de

Summary
Though desertification has lost significance in development cooperation, soil and water conservation (SWC) measures will gain new importance in the context of climate change. This study analyses success factors for SWC measures in the Sahel that have been implemented by the German development cooperation over the past decades. Results show that most of these measures had a positive impact on agricultural yields and rural development. Moreover, the analyzed measures have the potential to increase farmers' resilience to climate change. By providing a list of best practices and corresponding success factors, this study can serve as guidance for new investments.

Introduction
Following severe droughts in the Sahel in the 1970s, the international community recognized desertification as a major obstacle to development. In 1994, the UN Convention to Combat Desertification (UNCCD) was adopted, and National Action Programs (NAPs) were subsequently developed. German development cooperation has been engaged in combating desertification through SWC measures since the early 1980s. In recent years, however, international attention for desertification has been declining, though soil degradation processes are accelerating as a consequence of high population growth rates and non-sustainable agricultural practices. Increasingly, an additional factor is contributing to soil degradation and desertification: climate change. The threat posed by climate change is about to bring the discussion on soil degradation and desertification back on the agenda.
SWC measures that have been implemented to combat desertification over several decades will play an important role in this discussion. In order to successfully implement SWC measures as part of a strategy for climate change adaptation, their strengths and weaknesses as well as past experiences need to be evaluated in light of the new challenges. Eventually, approaches and technologies may have to be modified and adapted, and economic considerations may have to be based on changing risks.

As a first step, this study aims at evaluating success factors of selected SWC measures in the Sahel and their general potential to contribute to climate change adaptation. Besides an increase in temperatures (up to 3.5°C until 2050), predictions of climate change in the Sahel region remain uncertain. Therefore, SWC measures are evaluated against three climate scenarios that are derived from past experiences (Fig. 1): (1) continuation of the variable rainfall pattern of the past two decades, with 90 days vegetation period, (2) more humid climate, comparable to the situation between 1950 and 1967, with a vegetation period of 90 to 120 days, and (3) dry climate, similar to the period from 1968 to 1990, with a vegetation period between 60 and 90 days. The data presented in Fig. 1 is based on a set of studies that GTZ implemented within a pilot project on climate change.

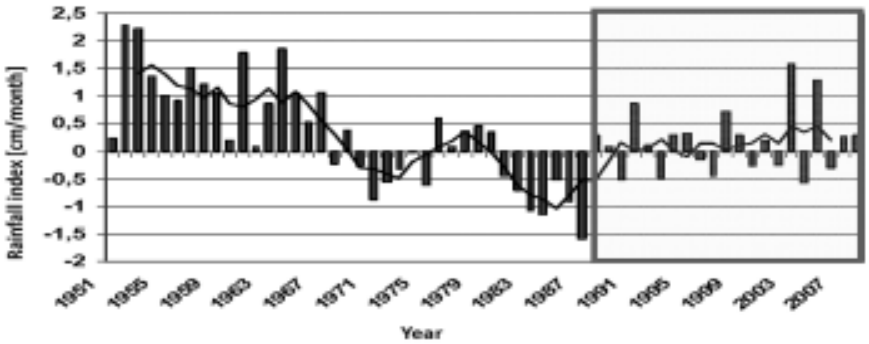

Figure 1: Development of rainfall pattern in Niger between 1950 and 2010 (deviation from long-time mean; Hiernaux 2010)

Materials and methods

The study consists of two phases: (1) an evaluation of available data from SWC measures implemented in the Sahel region by German development cooperation, and (2) a complementary survey at the project sites. This paper presents results of the first phase, which was conducted between April and June 2010. The second phase is scheduled to be implemented in 2011. The data evaluated have been produced over the past decades, particularly in the 1980s and 1990s. The study focuses on three German development projects in Niger and Burkina Faso (Table 1). These two countries have the longest standing experience in implementing SWC measures. Each of the three projects received more than 25 million Euros in funding. In total, 10 SWC measures have been evaluated: vegetation strips, contour stone bunds, permeable rock dikes, permeable rock dams, stone-lined terracing, water-spreading weirs, semi-circular bunds, Zai or Tassa (planting pits), manually excavated trenches, and sand dune stabilization.

Table 1: Background information on projects analyzed in this study

Project name	PATECORE	PDRT	PASP
Country	Burkina Faso	Niger	Niger
Average annual rainfall	1950 –1969: 700 mm 1970 –1980 : 555 mm 1981 –1985 : 381 mm	373 mm	350 mm
Project duration	17 years and 9 months	22 years, 9 months	16 years, 8 months
Area covered with SWC measures	97,940 ha	125,000 ha	264,158 ha

In the second phase, field studies will be conducted, and additional countries will be included (probably Chad, Senegal, and Mauritania). The current condition of selected SWC measures will be evaluated, and necessary modifications of the various measures in view of climate change will be analyzed.

Results and discussion

Before looking at the success factors of SWC measures, it is important to state that none of the reviewed projects has been able to reverse the overall trend of soil degradation in its respective intervention zone. This is not surprising, considering the multitude of factors contributing to soil degradation (population growth, cultivation of marginal lands, competition between sedentary farmers and nomads, reduction of field sizes due to the heritage system etc.). However, there have been considerable successes in all three projects: the speed of degradation has been reduced, and in some areas degradation could even be reversed. Particularly in the PDRT in Niger, the plant cover increased due to the interventions.

The study showed that all of the reviewed SWC measures lead to increased vegetation covers and helped to overcome longer spells of drought. Eventually, yields increased, leading to improved food security and income generation. Since all of the measures increase water infiltration and reduce wind and water erosion, and some also reduce soil temperatures (those that include plants), they have the potential to reduce the negative impact of climate change in all three scenarios used. Reij and Kaboré (2004) also found that a series of SWC measures allowed producers to increase their yields. In addition, the introduction of trees into the farming system helped them better integrate livestock farming. Water tables mounted, so that the water availability was improved. Overall, this resulted in an intensification of agriculture and a higher productivity.

However, negative impacts could also be observed in the reviewed projects: in some instances, conflicts arose when land was restored. Sometimes privileged groups appropriated restored areas of land that was previously of no or low value. Therefore, SWC measures have to be

planned carefully and adapted to the respective environmental and socio-economic conditions. In order for them to be sustainable, they have to show direct economic benefits for the respective land users. In addition, land use rights need to be clear and secure in order to encourage owners to invest in better soil quality and to avoid land conflicts.

In the three projects, the following factors made interventions successful: (1) combination of variable technical solutions, (2) technically simple measures, (3) measures on individual fields, and (4) measures that have quick and visible economic benefits. The last three factors are particularly important with regard to sustainability. Hampering factors were a lack of manpower to carry out some of the measures at certain times of the year (due to migration, peaks of farm work, loss of able-bodied workers, population weakened by famine) and the lack of maintenance.

It is not a new fact that the replication of measures outside of project areas or after the end of project support is usually weak. This has been confirmed in the three projects investigated: even though the exit strategies of all projects assumed that it would be profitable for the farmers to continue implementing SWC measures, only a minority of them actually did so. In the PASP for instance, famers implemented SWC measures on only 100 ha per year without project support, even though the project had established a local transportation system based on donkey carriages. One of the reasons was risk aversion: particularly in subsistence systems, but also in areas with weak market linkages, farmers did not want to invest in SWC measures without being certain about the economic benefits. Depending on the market conditions, higher yields do not automatically translate into higher incomes. The weak institutional support and the sometimes unclear and inappropriate land rights were also contributing to low replication of measures. As one would expect, scaling up of large scale measures like water spreading weirs was more difficult than spreading smaller measures that individual farmers could implement without needing to make huge investments.

Conclusions

The positive impact on agricultural productivity is obvious for all of the studied SWC measures. Such measures will gain even more importance in view of climate change since they address critical issues like drought, erosion, or water availability. However, some of these technologies may have to be adapted to changing climate conditions themselves, in order to withstand extreme weather events.

SWC measures have a great potential under different climate scenarios, especially when they are integrated in a wider approach of improved natural resource management. However, huge efforts are needed as the rapid population growth in the Sahel counteracts positive impact on smaller scales.

In order to achieve wider impact and sustainability, it is important to have a closer look at the profitability of SWC measures: farmers will only invest in SWC measures if they can expect economic benefits or increased food security, which are not guaranteed by increased yields alone. Risks linked to extreme weather events such as drought, heavy rainfalls and erosion have to be reviewed in the context of climate change, and need to be taken into consideration in such calculations. To support large scale measures, national funds should be set up by the respective governments as huge investments will exceed local capacities. Land rights need to be clear, and the functioning of local and participatory management committees needs to be improved.

Independent of the climate scenario that will realize in future, a combination of SWC measures is necessary to reduce both wind and water erosion as well as water run-off. Knowledge about socio-economic and technical success factors on individual as well as on communal land is therefore crucial to multiply best practices. For decision making purpose, a catalogue of measures with a description of advantages and disadvantages under different conditions is needed. This study represents a contribution to such a catalogue.

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RELACIÓN ENTRE LA EROSIVIDAD DE LAS LLUVIAS CON LA PÉRDIDA DE AGUA Y SUELO EN ÁREAS DE EXPLOTACIÓN PETROLERA DE LA AMAZONIA CENTRAL BRASILERA

Omar Cubas Encinas[1], Wenceslau Geraldes Teixeira[2], Marx Leandro Naves Silva [3], Rodrigo Santana Macedo [4], Adriana Costa Gil de Souza [5]

[1]Inpa - Embrapa Amazônia Ocidental, o_cubas@cpaa.embrapa.br, [2] Embrapa solos, wenceslau@cnps.embrapa.br, [3] UFLA-DCS, marx@dcs.ufla.br. [4] USP-Esalq, macedo.rs@usp.br, [5] Ufam - Embrapa Amazônia Ocidental, adriana@hotmail.com

Resumen

El objetivo de este trabajo fue cuantificar la pérdida de agua y suelo relacionadas con la erosividad de las lluvias en diferentes tipos de uso del suelo en áreas de explotación petrolera de la Amazonia central Brasilera. El experimento fue realizado utilizándose parcelas de pérdida de agua y suelo por escorrentía con dimensiones de 4 x 22 m para los tratamientos suelo descubierto y suelo cubierto con litera y 3 x 11 m para suelo sobre bosque primario. La mayor pérdida de agua y suelo se observo en el tratamiento con suelo descubierto, 34.47 mm y 58.03 g L^{-1} con erosividades de cada evento de 26.26 y 30.85 MJ mm ha^{-1} h^{-1} respectivamente y la menor perdida de agua y suelo fue observado en el tratamiento con suelo cubierto por bosque primario, 1 mm y 0.11 g L^{-1} con erosividades de 6.38 y 10.42 MJ mm ha^{-1} h^{-1} respectivamente. Se observó que las pérdidas de suelo fue más influenciado por el tipo de uso del suelo de que por las pérdidas de agua. Los tratamientos suelo descubierto y suelo cubierto por floresta presentaron las mayores y menores perdidas de agua y suelo.

Palabras clave: Urucu, Erosión, Energía Cinética.

Introducción

La erosión hídrica provocada por el escurrimiento superficial (run off) lleva consigo sedimentos ricos en materia orgánica y otras substancias químicas, degradando los suelos. Varios factores intervienen en la erosión, como las características de las lluvias, la declividad del terreno, la capacidad y/o la resistencia del suelo en absorber agua y la densidad de la cobertura vegetal (Braun, 1961). La lluvia es el factor más importante, el cual depende de sus características físicas, tales como: intensidad, duración, distribución y tamaño de las gotas para causar erosión, el cual es representado por el factor R, que expresa la capacidad erosiva de la lluvia en la ecuación universal de pérdida de suelo (USLE) (Wischmeier & Smith, 1958). El potencial de la lluvia en causar erosión

puede ser calculado por medio del índice de erosión. Wischmeier & Smith (1958) determinaron que el producto de la energía cinética (E) por la intensidad máxima en 30 minutos (EI_{30}) es la relación que mejor expresa el potencial de la lluvia en ocasionar erosión. En la Amazonia central Brasilera, fueron realizados estudios sobre índices de erosividad por Macedo *et al.* (2007), pero estudios de pérdida de agua y suelo relacionados con lluvias erosivas en esta región no existen. El objetivo de este trabajo fue cuantificar la pérdida de agua y suelo relacionadas con la erosividad de las lluvias en diferentes tipos de uso del suelo en áreas de explotación petrolera de la Amazonia central Brasilera.

Materiales y métodos

Este trabajo fue realizado en la Provincia petrolera del río Urucu Base de Operaciones Geólogo Pedro de Moura (BOGPM), Municipio de Coari, Estado de Amazonas-Brasil, localizado entre los paralelos de 4º 45' a 5º 05' S y los meridianos de 65º 00' a 65º 25' E. El clima, en la clasificación de Köppen, es de tipo Af, constantemente húmedo, correspondiendo al clima de bosque tropical. Los datos de precipitación fueron registrados en intervalos de cinco minutos en un pluviómetro automático conectado a un datalogger CR23x (Campbell – Utah - EUA). Los datos fueron agrupados en intervalos de erosividad: > 20, < 20 y > 10 y < 10 y > 6 MJ mm ha^{-1} h^{-1} respectivamente. Los datos fueron calculados para obtenerse la intensidad de la lluvia en intervalos de 30 minutos y los totales de cada evento. La energía cinética en MJ ha^{-1} mm^{-1} h^{-1} fue calculada conforme Wischmeier & Smith (1958):

$$E = 0.119 + 0.0873 \log I$$

donde **E**: energía cinética en MJ $(ha\ mm)^{-1}$; ***I***: intensidad de la lluvia en mm h^{-1}

Los cálculos de pérdida de suelo y agua fueron realizados en dos parcelas colectoras de erosión, con 4 x 22 m instaladas en la Yacida 21 de la BOGPM, siendo una con suelo descubierto y una con suelo cubierto por 5 cm de litera de bosque primario. Una tercera parcela de 3 x 11 m fué instalada en un área de dicho bosque. El agua de lluvia que cayó dentro de las parcelas y que no infiltró, fue conducida por una canaleta colectora hasta una primera caja de agua de 500 L, donde fueron realizadas las lecturas del volumen de agua utilizando una regla calibrada (Figura 1A, 1B).

Cuando el volumen de agua excedió el volumen de la primera caja, 1/15 de ese exceso fue colectado para la segunda caja de agua de 500L, donde se realizaron las lecturas de volumen de agua y se colectaron muestras de los sedimentos. Las colectas fueron realizadas a cada evento de lluvia considerada erosiva, siguiendo la metodología de Cogo (1978). Los datos fueron sometidos a análisis de variancia y las medias comparadas por teste de Tukey.

Figura 1A. Parcela descubierta y cubierta com litera, 1B. Parcela en bosque primario con cajas de agua.

Resultados y discusión

La mayor pérdida de agua y suelo se observo en el tratamiento con suelo descubierto, 34.47 mm y 58.03 g L^{-1} con erosividades de cada evento de 26.26 y 30.85 MJ mm ha^{-1} h^{-1} respectivamente y la menor pérdida de agua y suelo fue observada en el tratamiento con suelo cubierto por bosque primario, 1 mm y 0.11 g L^{-1} con erosividades de 6.38 y 10.42 MJ mm ha^{-1} h^{-1} respectivamente (Cuadro 1). Existe un aumento significativo del promedio de las pérdidas de suelo entre los sistemas de uso de la tierra con protección del suelo (suelo sobre bosque (0.46 g L^{-1}) y cubierto con litera (0.47 g L^{-1}) en relación al suelo descubierto (26.06 g L^{-1})) (Figura 2). No hubo diferencia significativa entre el suelo cubierto por el bosque y por La litera mostrando la eficiencia de la cobertura del suelo en la reducción del proceso erosivo. Entretanto, las pérdidas de agua fueron semejantes entre los tratamientos suelo descubierto (16.40 mm) y suelo cubierto por litera (14.35 mm), pero significativamente menores en las áreas con suelos de bosque primario (1.27 mm) (Figura 3). Esto probablemente está relacionado con la capacidad reducida de infiltración y trasmisión de agua en los horizontes sub-superficiales que fueron expuestos al retirarse los horizontes superficiales de las yacidas. (Teixeira *et al.*, 2004 a e b). Este proceso estaría agravado por los elevados valores de limo en estas camadas (Arruda, 2005), y la baja resistencia de los agregados que quedan expuestos en la superficie (Martins *et al.,* 2004).

Conclusiones

Mayores y menores pérdidas de agua y suelo fueron observadas en el tratamiento con suelo descubierto y suelo sobre bosque primario respectivamente.

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Cuadro 1. Valores de pérdida de agua y suelo por erosión hídrica para bosques naturales, suelo cubierto con litera y suelo descubierto en la provincia petrolera de Urucu, estado de Amazonas-Brasil.

EI_{30}	Pérdidas de agua			Pérdidas de suelo			Precipitación Pluvial	Erosividad
	Descubierto	Litera	Bosque	Descubierto	Litera	Bosque		
	mm			g L^{-1}			mm	MJ mm ha^{-1} h^{-1}
> 20	26.28	17.59	2.06	25.39	0.07	0.64	37.2	31.42
	25.6	19.88	2.64	58.03	0.49	0.51	35.8	30.85
	34.47	19.24	2.06	49.72	0.5	0.46	38.2	26.26
x ± dp	28.78 ± 4.93	18.94 ±	2.25 ± 0.33	44.38 ± 16.96	0.35 ± 0.24	0.54 ± 0.1	37.07 ± 1.2	29.51 ± 2.83
< 20 y > 10	16.4	16.4	1.94	20.46	1.35	1.76	24.4	14.124
	15.89	12.14	1.09	33.18	0.42	0.31	18	12.5
	12.14	6.85	1	12.27	2.31	1.01	17.2	11.63
x ± dp	14.81± 2.33	11.8 ±	1.34 ± 0.52	21.97± 10.53	1.36 ± 0.95	1.03 ± 0.73	19.87 ± 3.9	12.75 ± 1.27
< 10	16.4	10.94	1.27	9.84	0.17	0.11	19.2	10.42
	17.59	14.35	1.18	37.30	1.32	0.41	18.2	9.41
	9.92	7.36	1	26.06	0.31	0.3	11	6.38
x ± dp	14.84 ± 4.13	10.89 ±	1.15 ± 0.14	24.40 ± 13.81	0.6 ± 0.63	0.27 ± 0.15	16.13 ± 4.4	8.54 ± 2.1

* Promedio ± Desvio Padrón

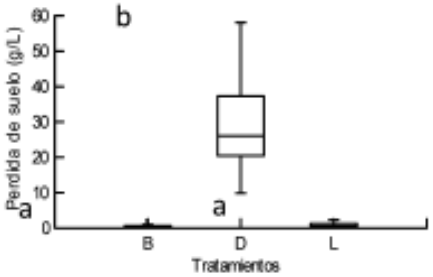

Figura 2. Diferencia de pérdida de suelo entre los tratamientos bosque primario (B), suelo descubierto (D) y suelo cubierto con litera (L).

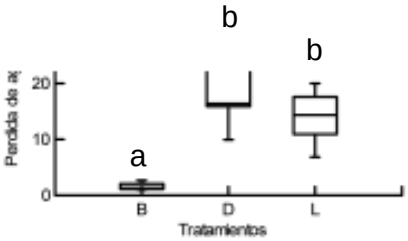

Figura 3. Diferencia de pérdida de agua entre los tratamientos bosque primario (B), suelo descubierto (D) y suelo cubierto con litera (L).

LAND USE AND DEGRADATION IN A BASIN BELONGING TO THE ROLLING PAMPA OF ARGENTINA: TENDENCIES AND PROCESSES

Celio I. Chagas[(1)], Oscar J. Santanatoglia[(1)], Mario G. Castiglioni[(1)], Marcelo J. Massobrio[(1)], Filipe B. Kraemer[(1)], Esteban A. Palacín[(1)], Alfonso Bujan[(2)]

[(1)]College of Agronomy, University of Buenos Aires. Av. San Martín 4453, (1417) Buenos Aires. Argentina. Mail: chagas@agro.uba.ar
[(2)]CNEA National Commission of Atomic Energy, Argentina. Mail: bujan@cae.cnea.gov.ar

Summary

Soil erosion significantly affects the most productive lands in Argentina, particularly the so called «Pampa Ondulada». Local long term investigation in a representative basin of this region is helping to understand and to prevent land degradation and contamination processes. This region has slope gradients between 0 and 2.5 % and slopes lengths up to 800 m long. Annual rainfall, usually ranges between 900 and 1100 mm. Regarding erodibility, upland and also lowland topsoil are prone to sealing and crusting processes due in part to their high silt content and also to the lack of freezing and thawing processes. Local hydrologic long term studies regarding rainfall-runoff processes in small watersheds showed that the actual time of concentration parameters were much larger than expected. During the past 50 years, the use of the upland arable soils consisted mainly in annual crops under conventional tillage in rotation with cattle feeding pastures. Fertilizers were rarely used. A recent ^{137}Cs field study showed that between 11.5 and 36 Mg ha^{-1} y^{-1} were lost by long term water erosion, beyond tolerance. Similar quantities were registered as net sedimentation in footslopes and bottom soils. This happened in spite of the medium rainfall amounts, low gradients and large time of concentration parameters aforementioned and shows the fragility of the agroecosystems involved. Recently, the widespread adoption of direct drilling technique dramatically increased the use of conservation tillage in the region. However, since 1990 these soils have been devoted mainly to soybean and to a lesser extent, wheat, maize and sunflower. Soybean leaves scarce surface residue which on the other hand, is easily decomposed due to warm humid weather. Regarding lowlands, these bottom hydrohalomorphic soils were historically used for extensive cattle production. However, for the past 3-5 years the area devoted to soybean under no tillage has been continuously increasing even in these fragile soils. As a consequence, and in spite of the widespread adoption of conservation tillage, land

degradation is still active in the study area in terms of runoff and erosion processes. These facts show the need for sustainable land use planning in the Rolling Pampa region.

Key words: Runnof, water erosion, sustainability

Introduction

The Rolling Pampa («Pampa Ondulada») is the most productive region in Argentina in terms of rain fed agriculture production. Loess soils are rich in mineral nutrients with neutral pH, high potential for rooting exploration and adequate soil moisture and temperatures. Upland and lowland regional soils have silty loam topsoils which are prone to surface crusting and sealing processes under the impact of raindrops and also to water erosion. In spite of the small regional slope gradients of less than 3% and the relatively short agricultural history soil erosion by water is very important. Official reports state than almost 36% of this region is already moderately to severely eroded (SAGYP-CFA 1995). It is possible to find sheet, rill and gully erosion signs and also depositional sediments in uplands as well as in lowlands. At the same time adjacent water courses can be at risk because of physical, chemical and biological contamination promoted by runoff and soil erosion. The objective of this paper is to compile and gather information about land use and degradation that has been carried out during the last years in a representative basin of the Rolling Pampa region but also in related soils in order to analyze their processes and tendencies.

Materials and methods

The Tala River´s basin has *ca.* 800 km^2 and it is located in the NE portion of Buenos Aires Province within the Rolling Pampa region, 180 km NW of Buenos Aires City. It has a humid temperate climate with 1000 mm annual rainfall. The relief is gently undulated. Dominant arable soils are Typic and Vertic Argiudolls with almost 4% organic matter, 60% silt, 15 % very fine sand and 25% clay. Lowlands occupy approximately 20% of the area; located in floodplain positions and with hydromorphic and saline/alcaline characteristics. Dominant soils are Natrabolls, Natraqualfs, Argialbolls and Natralbolls. Rainfall is being registered by different stations located as follows (34°48’25"S/ 59°54’37"W; 33°50’36.75"S/ 59°45’13.51"W; 33°41’S/ 59°41’W). The river discharge and small watersheds were continuously monitored by automatic water stage gauge transforming height into discharge rates. Field and laboratory simulated rainfall experiments were carried out employing a drop former. It applied 4.7 mm diameter drops falling from 1.5 m height with 60 mm h^{-1}intensity. Water physical, chemical and biological analyses were performed following standard methods. Soil

aggregate stability was measured through a modification of De Boodt and De Lenheer method (Chagas *et al.* 1995). ^{137}Cs measurements were performed in the CNEA. Analysis of variance and linear regression were carried out (Snedecor and Cochran, 1980).

Results and discussion

There are many factors that indicate the high level of fragility from soils belonging to the Rolling Pampa region. During the past 50 years, the use of the upland arable soils consisted mainly in annual crops under conventional tillage in rotation with cattle feeding pastures. Fertilizers were rarely used. A recent ^{137}Cs field study in the Tala basin (Bujan *et al.* 2003) showed that between 11.5 and 36 Mg ha^{-1} y^{-1} were lost during that period by long term water erosion, beyond tolerance. These losses were related significantly to slope length rather than to slope gradient. For a long time, conservation practices in the studied region have consisted mainly in the use of terraces and diversions. However the adoption of these practices has been rather infrequent. The time of concentration is necessary for designing structural practices but also it shows how fast water moves along the slopes. Recent investigations in the study area showed that the time of concentration in 300 ha watershed devoted to conventional tillage was larger than expected. Local data fitted well to models developed for flat areas of USA but not to classical models. This parameter was nearly 1 hour following Kirkby but up to 5 hours following Sheridan (Castiglioni *et al.* 1998). In spite of the relatively low slope gradients (less than 3%) and long time of concentration values, signs of interrill, rill and sometimes even gully erosion were regionally widespread particularly after intense storms in soils under conventional tillage. The vulnerability of local soils became evident in long term experiments using continuous and contrasting crops and tillage systems in silty loam soils from nearby region. After 15 years of continuous soybean under conventional tillage the aggregate stability index was only 20% (Chagas *et al.* 1995). This same soil class showed intense slaking and dispersion processes when subjected to high intensity rainfall under a bare, refined and smooth soil condition simulating a seed bed under conventional tillage (Chagas 1995). During the decade of 1990 land use under direct drilling practices dramatically increased, leading to regional sustainable land use. However the increment of continuous soybean cultivation in arable soils during recent years did not help to reduce runoff problems in the study area (Chagas *et al.* 2008). In fact, aggregate stability in experiments with other silty loam soils under no tillage was higher with continuous corn than with continuous soybean (Chagas *et al*. 1995). This highlights the need for rotations with crops that provide large quantities of organic carbon to the soil. Soybean leaves scarce surface

residue which is easily decomposed due to warm humid weather. Also surface cover can be easily removed by runoff, leaving the soil unprotected and more vulnerable for the following storm to occur unless special management practices like contour farming are implemented. Soil cover is extremely important for sustainable agriculture even under direct drilling in the study area. Two local field experiments showed that undisturbed soils under long term direct drilling subjected to intense simulated rainfalls, had a range of 22-26 mm/h equilibrium infiltration rate but only a range of 11-13 mm/h when surface cover was hand removed (De La Vega *et al.* 2004, Utin *et al.* 2010). Soil loss under a bare condition was significantly higher than that for the covered soil. Laboratory experiments using undisturbed big cores from the same soils showed that under bare conditions, surface soil structure became intensely degraded by drop impacts. Soil particles moved through soil cores vertically and some of them occluded macropores, reducing dramatically infiltration and saturated hydraulic conductivity as compared to the same soil cores completely covered with crop residue. All these experiments highlight the fragility and vulnerability of the topsoil structure even under long term direct drilling system. Another fact that threatens regional sustainability is the insufficient use of fertilizer as farmers do not replace soil nutrients exported through crop grains. On the other hand many soils from the bottomland in the study area are not suitable for annual cropping because they can be hydromorphic and even sodic from the very topsoil. Severe erosion features in these bottomlands are visible. Local simulated rainfall experiments indicated that these soils had equilibrium infiltration rates between 1 mm/h and 13 mm/h and erosion rates up to four times the ones for the arable soils (Utin *et al.* 2010). However, for the past 3-5 years the area devoted to soybean under no tillage has been continuously expanding over the alluvial plains even on some marginal non arable sodic soils. Cattle that used to graze these bottomlands are now being concentrated in smaller fields on the same alluvial plain promoting sometimes overgrazing, land degradation and even water biological contamination risks. Kraemer (2010) found that soils from bottomlands in the study area were able to adsorb and retain lesser quantities of *Escherichia coli* compared to arable soils from uplands. This information highlights again the risk of water contamination from bottomlands adjacent to water bodies. There is also a regional tendency to establish feed lots. Equilibrium infiltration rates under simulated rainfall reached 0 mm/h in local feedlots. Moreover, high concentration of sediments, dissolved phosphorus, total coliforms, steptococci and enterococci were measured in feedlot runoff waters (Chagas 2007, Chagas *et al.* 2007).The consequences of these managements are yet unknown regarding both land degradation and water quality implications (Santanatoglia *et al.* 2006).

Conclusions

The aforementioned show the need to enhance land use planning in the study area. This includes the rational use of crop rotations, cattle management, tillage, fertilizers and agrochemicals regarding land vulnerability. These actions should be carried out in order to sustain agricultural production but also to protect human environment as well.

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CHANGES IN SELECTED PROPERTIES OF A VERTIC CALCIXEROLL SOIL WITH NO TILLAGE IN SEMIARID AREA OF MOROCCO

Najib Saber

Hassan II University, Sciences Faculty of Ben Msik Casablanca, Morocco
najib_saber@yahoo.fr

Abstract
The need to optimise wheat grain production in Moroccan land areas have contributed to emergence of no tillage technology in his region. A field experiment was conducted to investigate the effects of no tillage and conventional tillage under crop rotations (continuous wheat; fallow-wheat; fallow-wheat-corn; fallow-wheat-forage and fallow-wheat-lentils), on selected properties of a vertic calcixeroll soil including total and particulate organic matter, pH, total Nitrogen and aggregation, subjected for 11 and 12 years. The 3-years wheat rotations including fallow tented to improve soil quality attributes more than 2-year wheat rotations. The other important finding is the accumulation of organic carbon and total nitrogen in the tillage surface layers without depletion at the deeper horizon. Better stability aggregates was demonstrated by significantly greater aggregation index at the soil surface. Consequently the increased yield associated with no till system can explained by both better water conservation and soil quality improvement.
Key words: no tillage; soil quality; aggregation; soil organic matter

Introduction
Recent research has shown that increased wheat yields may result from shifting from a conventional to a no-tillage system [4,22, 33] in semiarid Morocco. These authors explained increased wheat production under the No-Till (NT) system either to water storage if wheat is preceded by a fallow or to improved water use if continuous wheat is concerned [21]. However, those yield improvements could also be due to changes in soil quality under NT compared with intensive tillage systems [23, 25]. It has been-found that NT increased soil organic matter (SOM) and extractable nutrients compared with Conventional Tillage (CT). These differences were attributed to accumulation of crop residues on the soil surface, resulting in a wetter, cooler, and less oxidative soil environment under NT [11, 19, 23,46].
Soil organic matter (SOM) is a small but highly active component of soil, significantly influencing biological, chemical and physical properties. It is considered to be the most important soil quality indicator [12, 26].

Agricultural management practices influence the amount of soil organic matter and cause changes in the rate of its turnover. Tillage can affect SOM in several ways. In semiarid conditions where decomposition near the soil surface may be restricted by dryness [7], the adoption of conservation tillage practices may reduce evaporation water losses and increase crop yield, thereby favoring organic matter accumulation from the higher inputs of residue [6]. Finally, intensive tillage may enhance organic matter loss by rendering the soil more susceptible to erosion. In Morocco, the low organic matter levels and associated decline in the soil structure of dryland soils are due to widespread use of tillage, summer clean fallow and overgrazing of stubble, which has resulted in soil organic matter loss and intense wind and water erosion [32]. It is of paramount importance to maintain and improve the organic matter levels of our soils in order to increase soil fertility and to achieve sustainable cropping systems. Achieving these systems requires residue retention [42].

SOM can stabilize aggregates against slaking; it is generally thought to act through binding or cementing mechanisms [15, 36, 41]. Soil structural stability has been found to be related to soil organic matter quality, and SOM quality is more prone to changes in soil management strategies than total SOM [5, 18, 34]. Particulate organic matter (POM) has been defined as a labile fraction of soil organic matter which is thought to be physically protected from biodegradation when within soil aggregates [5, 16].

In Morocco, the combined effects of tillage and crop rotation on soil organic matter and structural stability have not been investigated yet. Changes in soil properties are often difficult to detect, and so need to be examined over a long period.

The specific objective of this study was to quantify the effect of contrasting tillage and cropping systems on the organic matter and structural qualities of a Calcixeroll soil after 11 years.

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Materials and methods

The experimental site is located at the INRA experiment station in Sidi El Aydi, 15 km North of Settat, Morocco (31°15' N, 7°30' W). The soil is a medium deep clay loam (Vertic Calcixeroll). The long-term average annual precipitation is 370 mm and drought is frequent at various wheat stages [40, 47]. On this site, a long-term experiment was conducted to investigate the effects of various rotation and tillage systems on wheat production. The experiment started in 1987-88. The initial soil profile description in terms of chemical and physical properties is presented in Table 1.

Table 1. General soil properties of the Sidi El aydi soil.

Property	Description (0-20 cm)
Soil type	Vertic Calcixeroll
Slope (%)	< 10
Clay (g kg^{-1})	530
Silt (g kg^{-1})	255
Sand (g kg^{-1})	215
Gravel (%)	<1
pH (water)	8.25
Organic carbon (g kg^{-1})	13
Inorganic carbon (g kg^{-1})	200
Total soil carbon (g kg^{-1})	213
Average bulk density (Mg m^{-3})	1.22
Soil moisture at 30 kPa	0.38

The experimental design was a split-plot arrangement in a randomized complete block design with four replications. The factors investigated were rotation, assigned to the whole plots, and tillage, applied to the subplots. Whole plots were 12 m x30 m, subplots were 6 m x30 m. The rotations studied were continuous wheat *(Triticum aestivum* L.) (WW),

Wheat-Fallow (WF), Fallow-Wheat-Corn *{Zea mays* L.) (WCF), Fallow-Wheat-Forage *(Avena sativa* L.+ *Vicia sativa* L.) (WFF) and Fallow-Wheat-Lentils *(Lentis culinaris* L.) (WLF). Each rotation was established in two whole plots within the same replication so that all phases of the sequence occurred each year. However, continuous wheat cropping was confined to only one whole plot per replication. The tillage treatments were no-tillage (NT) and reduced tillage with V-Blade Sweep (1987-1993), and changed to conventional tillage (CT) with off-set disk (1993-to present). All management practices (e.g. seeding rates, seeding dates, harvest dates, fertilization, and weed and pest control practices) from 1986 to the present time are recorded and summarized in Kacemi [21] and recently in El Brahli *et al*. [13].

The samples were collected from the non-traffic areas between the crop rows before cultivation and sowing during July 1998 in fallow phases and in Wheat-Wheat (WW). Samples of the topsoil zones were collected from 3 layers: 0-2.5 cm; 2.5-7 cm; and 7-20 cm. Two cores from each depth in fallow and 4 cores in WW were collected. Each soil core per layer was used for analysis. All analyses were done in duplicate in the laboratory.

Aggregate size distribution was measured as the mean weight diameter (MWD) of soil aggregates using the dry sieving technique described by Kemper and Rosenau [24]. The samples were air dried and dry sieved through a series of screens with: 10-, 8-, 6-, 4-, 3-, 2-, 1 and 0.25 mm openings. The sieving was performed with the portable sieve shaker for a fixed time period of 5 min.

The MWD was computed as follows:

The soil fraction between 1 and 2 mm obtained from the MWD sieving was used to study the wet aggregate stability:

4 g of this fraction were transferred to the sieving machine (Five Star Cablegation and scientific supply, 303 Lake ST, Kimberly, ID 83341). The four grams were placed into the sieve and wetted with sufficient distilled water to cover the soil when the sieve was at the bottom of its stroke for 3 min. The soil that passed through the sieve was collected oven dried and weighed. The soil that had not passed through the sieve was dispersed for 30 min in a solution of sodium hexametaphosphate. Sand particles that did not pass through the sieves were discarded, and the dispersed soil that passed through the sieves oven dried and weighed. Aggregate stability was determined as the ratio of the weight of the soil found in the dispersing solution to the sum of this same weight and sowing during July 1998 in fallow phases and in Wheat-Wheat (WW). Samples of the topsoil zones were collected from 3 layers: 0-2.5 cm; 2.5-7 cm; and 7-20 cm. Two cores from each depth in fallow and 4 cores in WW were collected. Each soil core per layer was used for analysis. All analyses were done in duplicate in the laboratory.

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The MWD was computed as follows:

$$MWD = Wi \times Xi$$

Where Xi is the mean diameter of the size fraction and Wi the proportion of the total sample weight.

The soil fraction between 1 and 2 mm obtained from the MWD sieving was used to study the wet aggregate stability: Aggregate stability was determined as the ratio of the weight of the soil found in the dispersing solution to the sum of this same weight and the weight of non-dispersed soil aggregates (water stable aggregates = WAS).

Soil organic carbon was assessed using the wet oxidation method of Walkley and Black [33]. Organic carbon was converted to TSOM by the multiplication factor of 1.724.

Total nitrogen was determined using the semi-micro Kjeldahl digestion method [29].

The particulate organic matter (POM) was measured using the Cambardella and Elliott method [5]:

25 g subsamples of soil from each subplot were dispersed in 100 ml sodium hexametaphosphate by shaking for 1 h on a reciprocal shaker. The dispersed soil samples were passed through a 53 um sieve and, after rinsing several times with water, the material that was retained on the sieve was dried at 50 °C overnight. The dried sample was weighed and ground with a mortar, passed through a 250 um sieve and analyzed for total organic carbon (POMC) (Walkey and Black method) and total nitrogen (POMN) (Kjeldahl digestion method).

Soil pH (1:2 soil: water) was measured using a pre-cal-ibrated glass electrode [30].

The data were statistically analyzed as a split-plot design for each depth using the GLM procedure of the Statistical Analysis Systems [37]. Analysis of variance was utilized to find the significance of effects of tillage and rotation on soil quality attributes and a Least Significance Difference Test (LSD) was used to seek differences between treatments (P level of 5%) [39].

Results and discussion

***Aggregation*:** Significant differences were found in aggregate stability indexes between wheat rotations and tillage systems (Tab. II). The MWD ranged from 2.56 to 5.04 depending on soil depth and rotation, while WAS ranged from 0.42 to 0.72.

Dry aggregation was higher in the intermediate horizon (2.5-7 cm) except in WFF and WLF, as found by Kacemi [21]. In the surface horizon, rotations including fallow did not differ but had improved dry aggregation as compared to continuous wheat. More distinct effects were found in the 2.5-7 horizon with a tendency for WF to promote higher structural stability, determined using the dry sieving technique. For the grouped horizons, WF exhibited a higher dry aggregate index (3.98 mm) followed by WFF (3.72 mm) and WCF (3.68 mm). Nevertheless, the no-till system favored dry aggregation in both horizons (0-2.5 and 2.5-7 cm) as compared to the conventional tillage system (CT). In the deeper horizon (7-20 cm), dry aggregation was much higher under CT than NT (Tab. II). Higher MWD under NT as compared to CT was also observed in several studies [2, 43]. This explains that aggregates under NT with maintained plant residues in the soil surface were less subject to slaking than those under CT. In addition, surface residues physically protect the soil surface against raindrop impact, thus reducing aggregate breakdown by rainfall under NT. In semiarid climates, dry aggregate size and stability are often of more interest than wet stability because of the greater incidence of wind erosion than water erosion problems.

Concerning water-stable aggregation, continuous wheat permitted the highest index (0.72), triennial rotations were intermediate (0.58) and WF was lowest (0.48) in the surface horizon (Table 2). WFF had improved WAS in the intermediate horizon as compared to other rotations, as well as WW. In the 7-20 cm horizon, WCF and WFF had low WAS (0.42 and 0.44) and the other rotations had higher values (0.50-0.51). For the whole profile, overall WAS improvement was recorded under WW followed by WFF and WLF.

Soil under NT showed greater overall improvement of its water-stable aggregation compared to a tilled system in the 2.5-7 and 7-20 cm

Table 2. Water-stable and dry aggregation as affected by wheat rotation and tillage

Depth	0-2.5 cm		2.5-7 cm		7-20 cm		0-20 cm	
	MWD[a]	WAS[a]	MWD	WAS	MWD	WAS	MWD	WAS
Rotation								
WW	3.02C	0.72A	4.37B	0.57AB	2.56C	0.50A	3.31C	0.60A
WF	3.61AB	0.48C	5.04A	0.42C	3.31B	0.51 A	3.98A	0.47C
WFF	3.74A	0.57B	3.65C	0.60A	3.79AB	0.44B	3.72AB	0.54B
WCF	3.37B	0.58B	4.32B	0.49BC	3.40B	0.42B	3.68B	0.49C
WLF	3.74A	0.60B	2.69C	0.48BC	4.40A	0.51A	3.57B	0.53B
Tillage								
NT	3.78A	0.59A	4.52A	0.54A	2.85B	0.51A	3.71A	0.55A
CT	3.21B	0.58A	3.51B	0.48B	4.11A	0.44B	3.61B	0.50B
Average	3.49	0.59	4.01	0.51	3.48	0.48	3.66	0.52

« MWD = Mean Weight Diameter (mm).

[b] WAS = Wet Aggregate Stability (stability of 1-2 mm aggregates).

In each column, values followed by the same letter are not significantly different at $P < 0.05$ using LSD Test.

horizons. The no-tillage system tended to improve aggregation but the degree of this improvement is rotation-dependent [10,45]. The WAS index was not different between tillages (sweep and no-till) when averaged over rotation at the Sidi El Aydi site for the soil surface (0-2.5 cm) [22]. However, for the horizons 2.5-7 and 7-20 cm, NT (2.55 mm, 2.32 mm) had a higher MWD than sweep (2.23 mm, 2.12 mm) [21]. Comparing these results and those obtained in Table 2, there is a tendency for increased aggregation on the NT plots.

***Soil Organic Matter*:** Continuous wheat conserved a higher level of total soil organic matter (TSOM) than other rotations at the 0-7 cm horizon (Table 3). At 0-2.5 cm, WFF and WCF were comparable in terms of TSOM and WLF and WF conserved the least amount of SOM. At the (2.5-7 cm) horizon, WW and WFF helped to maintain more TSOM than other rotations. For the entire profile (0-20 cm), WW sequestered more TSOM, followed by WFF as shown in Table 3. The differential effects of wheat rotations on TSOM reflect the importance of crop morphological characteristics and residue type in TSOM build-up as outlined by Dinel and Gregorich [10]. The contributions of WLF and WCF to TSOM were variable between soil depths, which could be due to root biomass and morphology of these crops. These results agree with the responses of Wood *et al.* [46] who reported a higher level of organic carbon under a wheat-corn-millet-fallow rotation compared with a wheat-fallow rotation, after only 3.5 years.

Table 3. Total soil organic matter and total organic carbon in particulate organic matter as affected by wheat rotation and tillage.

Depth	0-2.5 cm		2.5-7 cm		7-20 cm		0-20 cm	
	TSOM[a]	POMC[b]	TSOM	POMC	TSOM	POMC	TSOM	POMC
Rotation								
WW	3.91 A	4.05 A	2.74 A	4.61 A	2.00 BC	2.18 B	2.88 A	3.61 A
WF	2.92 C	2.70 C	2.37 C	2.24 C	2.14AB	2.04 C	2.48 C	2.32 C
WFF	3.23 B	3.43 B	2.61 B	2.66 B	2.19AB	2.28 A	2.68 B	2.79 B
WCF	3.29 B	3.21 BC	2.41 C	2.47 BC	1.95 C	2.12 B	2.55 C	2.60 BC
WLF	2.90 C	3.58 AB	2.41 C	2.46 BC	2.29 A	2.02 C	2.53 C	2.68 BC
Tillage								
NT	3.98 A	4.11 A	2.57 A	2.74 B	2.13 A	1.98 B	2.89 A	2.94 A
CT	2.51 B	2.68 B	2.45 B	3.04 A	2.10 A	2.30 A	2.35 B	2.67 B
Average	3.25	3.39	2.51	2.88	2.11	2.14	2.62	2.80

[a] TSOM = Total Soil Organic Matter (g/100 g).
[b] POMC= Organic carbon content in Particulate Organic Matter (%).
In each column, values followed by the same letter are not significantly different at $P < 0.05$ using LSD Test.

Total organic carbon content was higher in the 0-2.5 cm and 2.5-7 cm depths under NT than under CT, particularly for the 0-2.5 cm horizon. However, the difference in the 2.5-7 cm horizon is small but statistically significant. At the 7-20 cm horizon, there is no significant difference in TSOM between NT and CT.

Particularly, TSOM is higher in the entire profile (0-20 cm) under NT, which helped to conclude that there is a stratification of TSOM in the surface horizons without any depletion of it at the (0-20 cm) horizon compared to CT. Elimination of soil mixing in NT led to a concentration of organic matter at the soil surface. In other terms, low storage of TSOM under CT was probably due to high oxidation rates, release of organic compounds in soluble form and greater microbial activity.

***Total organic carbon in particulate organic matter*:** In the 0-2.5 cm depth, 3-yr rotation permitted similar levels of POMC, while WF resulted in lower POMC. In the 2.5-7 cm horizon, WW conserved more POMC than other rotations, followed by WFF (Table 3). In the 0-20 cm horizon, WW and WFF accumulated more total organic carbon in particulate organic matter. These differences in POMC between all the rotations suggest differences in root biomass length and residue inputs from crops. The effect of NT on the POMC pool was not consistent. Standing stock of POMC under NT was greater than under CT in the (0-2.5 cm) horizon, but in the other horizons POMC is higher under CT than under NT. Hence, the correlation between this SOM fraction and aggregation needs to be investigated in-depth. It was found that NT practices increased OM-C and POMC contents by 25 and 70% compared with conventional tillage at the soil surface [44]. However, the lower horizon (5-17.5 cm) lost its carbon content by 4 and 18%. In contrast, these results do not seem to agree with the present study. In other ways it has been found that a fraction of POM is lost due to tillage and is responsible for micro-aggregate formation (< 250 um) [38]. This could explain low POMC and WAS under CT in our experiment. Hence, the correlation between this soil organic fraction and aggregation needs to be investigated.

***Total nitrogen in soil and in particulate organic matter*:** Total N (TN) concentration was influenced by both cropping system and tillage in the two surface horizons. Total nitrogen was higher under WW at all depths and for the whole sampled profile. The other rotations did not differ considerably in their nitrogen content (Table 4). Most of the differences in N between tillage systems occurred in the seed-zone (0-7 cm), where most soil disturbance happened. In other ways, NT conserved more nitrogen in 0-7 cm than CT. However, these tillage systems had equal nitrogen content at 7-20 cm. In other words, like total organic C, total N concentrations were higher in NT than in CT in 0-2.5 cm and 2.5-7 cm (Table 4). Hence, the CT has accelerated breakdown of organic matter while NT helped an accumulation of organic N materials near soil surface. Higher total N values under NT than under CT imply that N was incorporated in microbial biomass near the soil surface and that less was available for mineralization or leaching. Recently, Power and Peterson [35] have shown that, under no-till, fallow nitrogen balance

was positive; however, for plowed fallow some N loss occurred. They related these results to slower oxidation of organic N in the cooler, more aggregated, moister conditions found under NT. They also found less nitrification under NT, which disfavors nitrate leaching as well. All these hypotheses could explain the high nitrogen in the soil under NT in this experiment. The analysis of variance of an 11-yr experiment did not indicate any influence of tillage system on organic C and N contents at any depth of a silt loam soil [1]. These results are contradictory to our findings. This may be explained by differences in the clay and silt content which influence the soil capacity to store carbon and nitrogen [20]. The high clay content of Sidi El Aydi soil justifies this high storage of carbon and nitrogen under NT. In other ways, NT helped WF to store more carbon and nitrogen than continuous wheat after 11 years of experimentation on a clay soil in southwestern Saskatchewan, Canada [8, 9]. This also happened for WFF in this experiment. However, in a silt loam of the same region, differences between tillage and cropping systems were not significant in terms of soil C and N after 12 years of study. Carbon and nitrogen were not found to be sensitive to soil management after 12 years of study. Most differences in N content between tillage systems were in the 0-10 cm topsoil, because of greater disturbance under tillage; the off-set disk manipulated 10 to 12 cm of soil [25].

Table 4. Total nitrogen in soil and in particulate organic matter as affected by wheat rotation and tillage

Depth	0-2.5 cm		2.5--7 cm		7--20 cm		0--20 cm	
	TN[a]	MOPN[b]	TN	MOPN	TN	MOPN	TN	MOPN
Rotation								
WW	0.182 A	0.214A	0.151A	0.163 A	0.122 A	0.125B	0.152 A	0.167A
WF	0.146C	0.125C	0.148AB	0.115C	0.119A	0.114C	0.138B	0.117C
WFF	0.154BC	0.149BC	0.140BC	0.133B	0.117A	0.135A	0.137B	0.139B
WCF	0.16B	0.162B	0.133C	0.130B	0.118A	0.114C	0.137B	0.135B
WLF	0.151BC	0.169B	0.135C	0.124B	0.120A	0.113C	0.135B	0.151AB
Tillage								
NT	0.184A	0.195A	0.149A	0.13A	0.120A	0.115B	0.151A	0.149A
CT	0.133B	0.132B	0.134B	0.128B	0.120A	0.126A	0.129B	0.129B
Average	0.159	0.164	0.141	0.133	0.120	0.121	0.129	0.129

« Total nitrogen in soil = TN (%). [b] in % of the MOP

Nitrogen content in POM is higher under WW for the 0-7 cm horizon, followed by 3 yr rotations. For deeper horizons, WFF retained more POMN than WW and other rotations. The no-tillage effect on POMN was confined to 0-2.5 cm; however, for other depths differences were slight between tillage practices. Retention of maximum levels of crop residues on the soil surface and lack of soil disturbance apparently created a more favorable environment for POM build-up. The high levels of POM under NT also express abundant microbial biomass and available nutrients.

Soil pH: The overall average pH ranged from 7.9 at a depth of 0-2.5 cm to 8.2 at a depth of 7-20 cm, indicating the calcareous origin of the soil. Reducing soil alkalinity of the soil surface horizons is apparent under WW and WF as compared to WFF, WCF and WLF in all horizons, and under NT as compared to CT for 0-2.5 cm (Table 5). There were no significant effects of tillage or rotation on pH throughout the 2.5-20 cm profile. A 0.2 unit pH difference in (0-2.5 cm) is very important for calcareous soils of Morocco in terms of nutrient availability for crops, especially phosphorus fertilization requirements [27]. Lack of soil mixing due to no-tillage increases the acidity of the soil surface, particularly if fertilizers are used [3]. However, Laryea and Unger [27] did not find a significant effect of tillage systems on soil pH at depths ranging from 0-15 to 100-125 cm. Karlen *et al*. [23] noted a 0.4 pH unit difference between NT and conventional tillage with a chisel and disc plow after 12 years of continuous corn. Grant and Bailey [17] did not find significance in tillage effect on pH at all measured depths for the 0-2.5 cm to 60-120 cm horizons for two different soils. The same results were presented by Karlen *et al.* [23] for an Iowa soil. Edwards *et al.* [14] reported a pH decline of 0.2 units between NT and CT.

Table 5. Soil pH (water) as affected by wheat rotation and tillage systems

Horizon depth	0-2.5 cm	2.5-7 cm	7-20 cm
Rotation			
WW	7.6 B*	7.9 B	8.1 B
WF	7.7 B	8.0 B	8.1 B
WFF	8.0 A	8.1 A	8.3 A
WCF	8.0 A	8.2 A	8.2 A
WLF	8.0 A	8.1 A	8.2 A
Tillage			
NT	7.8 B	8.1 A	8.2 A
CT	8.0 A	8.0 A	8.2 A
Average	7.9	8.1	8.2

Conclusions

Till surface horizons without depletion at deeper horizons compared to treatments receiving tillage. The type of crop in rotation seemed to have affected the processes of soil organic matter accumulation and aggregation of Sidi El Aydi soil. Identifying an increase in TSOM after a period of 11 years is the most important finding of this soil-test evaluation. The reason for this is that Moroccan semiarid soils generally have very low organic matter content and a small change in TSOM can have substantial effects on nutrients and water retention. In addition, TSOM is a storehouse of plant nutrients and hence may help to reduce dependence on mineral fertilizers.

The high levels of TSOM and N under NT also express or correlate well with microbial biomass and available plant nutrients. High C and N under

NT in the soil surface explains that the soil retained more C and N under NT than incorporated residues under CT. The high total N found under NT justifies that nitrogen losses are minimum and that more nitrogen is available to wheat under this system without heavy reliance on fertilizers. The research presented here suggests that no-tillage management is effective at maintaining or increasing aggregate stability and slowing the decomposition loss of newly plant-derived POMC and POMN. Adoption of sustainable management practices, such as no-tillage, may promote the maintenance of this important soil organic matter fraction and enhance the fertility of intensively managed soil.

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ORDENACIÓN AGROFORESTAL Y CONSERVACIÓN DE SUELOS

Alvaro Sotomayor

Instituto Forestal, Chile. (asotomay@infor.cl)

Resumen

En esta ponencia se muestra un trabajo de ordenación agroforestal predial, con el fin de demostrar la factibilidad de recuperar un predio eminentemente degradado, considerando los recursos naturales y de suelos, después de más de 50 años de un uso agropecuario extractivo. En la planificación de la ordenación predial, en primer lugar se realizó una actividad de priorización en función del levantamiento de información técnica de sistemas productivos con fines agroforestales, actividades de terreno con el objetivo de visualizar las condiciones de los sitios, e identificar los factores relevantes para el diseño de las propuestas y programación de las actividades de intervención. Paralelamente con ello, se realizaron diferentes análisis a los antecedentes edafoclimáticos y topográficos de los sectores involucrados y de la información técnica existente de los sistemas productivos agroforestales factibles de implementar en cada uno de ellos. En base a los estudios realizados, se determinaron las siguientes propuestas según condición de sitio, que se implementaron bajo un esquema de ordenación agroforestal predial: a) Suelos con baja pendiente: sistemas silvopastoral con estepa de Acacia caven; sistema silvoagrícola con especies arbóreas y arbustivas y pradera asociada; recuperación de cursos de agua degradados; b) Suelos con pendiente media: sistema silvopastoral con *Pinus radiata*, *Eucalyptus globulus*, trigo y pradera asociada; c) Pendiente media-alta: Forestación de protección con *Pinus radiata* y *Eucalyptus camaldulensis* y *Acacia* sp., y recuperación de suelos

Introducción

Los sistemas agroforestales se orientan a permitir actividades productivas en condiciones de alta fragilidad, con recursos naturales degradados, mediante una gestión económica eficiente, alterando al mínimo la estabilidad ecológica, lo cual contribuye a alcanzar la sostenibilidad de los sistemas de producción y, como consecuencia, mejorar el nivel de vida de la población rural. En consecuencia, persiguen objetivos tanto ecológicos como económicos y sociales (Sotomayor *et al.,* 2009; Murgeitio, 2009; Sotomayor *et al.,* 2004; Sotomayor y Garcia, 2003; Nair, 1987) La característica principal de los Sistemas Agroforestales es su

capacidad de optimizar la producción del territorio (unidad predial) a través de una explotación diversificada, en la que los árboles cumplen un rol fundamental. Los objetivos o beneficios de un Sistema Agroforestal pueden ser diferentes para cada situación y región del mundo pero, algunos de estos son ampliamente reconocidos, como: mejor protección y mejoramiento del suelo; mas de un tipo de cosecha o producto para los propietarios, lo cual le asegura una mayor estabilidad y retornos económicos en el mediano y largo plazo; obtención de subproductos como, leña, postes, miel y otros, que mejorara la calidad de vida de los propietarios; dado el reconocido aumento en la eficiencia biológica del sistema, ayudará a un incremento de la productividad no solo para un granjero, sino que para toda la comunidad o región.

Existen distintos tipos de manejo agroforestal, dependiendo de los recursos incorporados a este manejo, las condiciones edafoclimáticas, y el objetivo de producción, utilizando entre otros los componentes arbóreo, cultivos, pratense, y animal. Dentro de los más frecuentes, figuran el manejo agrosilvícola, silvopastoral, cortinas cortavientos, y últimamente ha surgido con importancia la protección de riberas y cursos de agua (Sotomayor *et al.* 2004; Nair 1994).

Agroforestería y Conservación: Los modelos agroforestales han sido reconocidos por diversos autores como sistemas de uso de la tierra que favorecen la conservación de los recursos naturales, especialmente suelo, agua y vida silvestre. A continuación se abordan antecedentes de erosión, y diversos elementos vegetacionales o de cobertura, utilizando sistemas agroforestales o no, que hacen disminuir la erosión. En un estudio realizado por Ranjith *et al.* (2009), se compararon durante tres años tres microcuencas sembradas con maíz y soya. Los tratamiento fueron T1: cuenca testigo sin tratamiento, T2: cuenca con fajas de pasto en contorno intercaladas, y T3: Agroforestería (árboles y fajas de pastos intercaladas). En ambos tratamientos se aprecia que existe una reducción de la escorrentía y pérdida de suelos versus la cuenca control. Durante este periodo se observaron reducciones de 10% y 1% para los tratamientos T2 y T3 versus la control. La escasa efectividad en el tratamiento 3 (Agroforestería), se debe a corto periodo de evaluación, solo tres años, donde el componente forestal no ha desarrollado todavía su potencial de intercepción de la precipitación y aumento de la infiltración. Ramirez y Oropeza (2001), desarrollaron un estudio para evaluar la eficiencia de las prácticas productivo-conservacionista para controlar la erosión y el escurrimiento en terrenos agrícolas de ladera en Chiapas-México. Se probaron tres tratamientos, durante los años 1996 y 1997: a) sistema tradicional (ST) como testigo, b) barrera viva de *Gliricidia sepium,* con surcado en contorno (Bv-Sc) y, c) labranza de conservación (LC), usando maíz como cultivo de evaluación. Los

resultados indicaron que los tratamientos Bv-SC y LC redujeron la perdida de suelos en 64% y 70% respecto al testigo en 1996, y en 1997 las eficiencia fueron de 23 y 60%. Iroume *et al.* (1989) midieron el efecto de la vegetación en la pérdida de suelo cerca de Valdivia, X Región de Chile, durante un período de 4 meses (agosto-septiembre). Estos encontraron que en parcelas sin cobertura vegetal y 30% de pendiente se perdieron 1.563 kg/ha de suelo, mientras que bajo vegetación arbustiva que se instaló al año después de una cosecha forestal sólo se perdieron 133 kg/ha, y bajo plantaciones de *Pinus radiata* de 6 a 33 años, se midió el arrastre y fue de 75 y 70 kg/ha respectivamente. En un estudio de control de erosión mediante técnicas de labranza y conservación (Peña, 1984), realizado en suelos trumaos, de lomajes, derivados de cenizas volcánicas en la Precordillera Andina de la VIII Región de Chile, con 16% de pendiente, se obtuvo una disminución de pérdida de suelos desde 50-65 t/ha/año en situación de manejo convencional, en una rotación de trigo-avena-rapas, a 3-4 con la utilización 2 t de residuos al suelo.

Material y método

Con el fin de demostrar la factibilidad de recuperar suelos degradados afectados por actividades agropecuarias extractivas e intensivas, se seleccionó un predio en la comuna de Cauquenes, VII región de Chile, que mostrara altos grados de erosión y baja productividad, donde se implementaron sistemas agroforestales apropiados para esa zona agroclimática, bajo ordenación agroforestal predial.

Antecedentes Edafoclimáticos: El predio seleccionado el año 2003, se ubica en la localidad Los Aromos, a 23 km al norte de la ciudad de Cauquenes perteneciente a la zona agroecológica de secano, en una ladera con exposición noreste. El clima, es templado mesotermal mediterráneo semiárido, presente en cuencas y valles costeros, secano interior (Santibañez y Uribe, 1993). Las temperaturas oscilan en promedio entre una máxima media en enero de 29º C y una mínima media en julio de 4,9º C. El período libre heladas es de 259 días, con un promedio de 6 heladas por año. La precipitación media anual es de 696 mm, y un período seco de 7 meses. Según Peralta (1976), los suelos de esta zona pertenecen a la clasificación de suelos graníticos de la costa, es decir, suelos de los órdenes Alfisoles (suelos con buen grado de evolución) e inceptisoles (suelos de desarrollo incipiente que forman inclusiones entre las regiones V y VIII). En la vertiente oriental de la Cordillera de la Costa los suelos se han desarrollado directamente a partir de roca granítica.

Tipología Productiva: De acuerdo a un estudio tipológico productivo realizado por INFOR para identificar la realidad productiva actual de la

pequeña propiedad, en esta zona se observa una tipología polifuncional costera chacro/viñatera, que se refiere fundamentalmente a una comuna pobre, con campesinos que se dedican a actividades tradicionales de chacarería, trigo y ganadería ovina, donde la diversificación de la producción asegura un ingreso en distintos momentos del año.

Planificación de la intervención: Para la identificación de las intervenciones a desarrollar, se estudió las condiciones de los sitios y los factores relevantes para el diseño de las propuestas productivas y de conservación de suelos, y programación de las actividades de intervención. Paralelamente con ello, se realizaron diferentes análisis a los antecedentes edafoclimáticos y topográficos de los sectores involucrados y de la información técnica existente de los sistemas productivos agroforestales factibles de implementar en cada uno de ellos. De acuerdo a los antecedentes recogidos y los análisis efectuados, las propuestas agroforestales se planificaron de la siguiente manera:

- *Identificación de la superficie a intervenir;*
- *Análisis de sistemas productivos agroforestales y de recuperación de suelos a implementar;*
- *Análisis de especies vegetales factibles de establecer.*
- *Estudio de necesidades socioeconómicas requeridas por el propietario.*
- *Implementación de propuestas.*

Resultados

De acuerdo a los análisis realizados, se seleccionaron los siguientes sistemas agroforestales a implementar, bajo un ordenamiento agroforestal predial:

a) Áreas con baja pendiente, inferior a 10%:

Sistema silvopastoral de manejo de espinal y establecimiento de pradera. Dada la existencia de una estepa de espinales (*Acacia caven)* con un regular estado de conservación, y el uso productivo ovino que el productor realizaba en el predio, se privilegió la recuperación y manejo de esta estepa, de forma de mejorar su productividad en forma sustentable. Para ello se manejó el espinal en una superficie de 05 ha, con poda aérea y de formación para llegar a una cobertura de copa de 40%, con objetivos forrajeros y de protección al suelo y a los animales. Se dividió la superficie en mitades y en una de ellas se estableció una pradera mejorada con las siguientes especies: trébol subterráneo (*Trifolium subterraneum*), trébol balansa (*Trifolium michelianum)* y hualputra (*Medicago polymorpha*), y en la otra un mejoramiento de la pradera natural con aplicación de fertilizantes: mezcla de superfosfato triple, urea, muriato de potasio, boronatrocalcita y yeso agrícola. Con

esta intervención se logró mejorar la cobertura herbácea protectora del suelo y subir la productividad de la pradera desde 1.100, en situación testigo, a 4.500 kg MS/ha en la pradera sembrada y 4.000 kg en la pradera natural.

Sistema agrosilvícola de recuperación de suelos agrícolas con plantaciones en camellón y siembra de pradera intercalada. En un sitio donde regularmente el propietario realizaba prácticas de cultivo de trigo-pradera natural, con evidentes síntomas de erosión moderada, y sin cobertura arbustiva ni arbórea, se estableció un sistema agrosilvícola con prácticas de conservación de suelos en camellón, con establecimiento de especies arbóreas y arbustivas en el camellón, para asegurar su conservación y otorgar protección a la pardera. Se realizaron las siguientes actividades: a) Formación de camellones en curvas de nivel cada 20 a 30 m, y plantación en el camellón, en tresbolillo, con especies arbóreas como quillay (*Quillaja saponaria), Acacia saligna*, fresno (*Fraxinus sp.)* y tagasaste *(Chamaecytisus palmensis);* b). Establecimiento de pradera, con las especies trébol subterráneo, trébol balansa y hualputra, con aplicación de fertilizantes (mezcla de superfosfato triple, urea, muriato de potasio, boronatrocalcita y yeso agrícola). Con esta intervención se logró mejorar la cobertura herbácea protectora del suelos y subir la productividad de la pradera desde 1.100, en situación testigo, a 2.500 kg MS/ha.

b) Áreas con pendiente media, entre 10-30%:

Sistema silvoagrícola con plantación de Pinus radiata y Eucalyptus globulus, siembra de trigo intercalado, y pradera establecida. Se establecieron las plantaciones en dos densidades: en fajas de dos hileras, cada hilera a un espaciamiento de 3 m y a 2 m en la hilera, y a 7 m y 14 m entre fajas según la densidad. Densidad de 1.000 pl/ha con un espaciamiento 2x3 y 7m entre fajas, y a 500 arb/ha, con de 2x3 y 14m entre fajas. Siembra de trigo entre fajas de plantación, asociado a pradera con las mismas especies indicada en punto anterior. Se logró mejorar la cobertura herbácea protectora del suelo entre fajas, con una productividad de la pradera de 2.800 kg MS/ha.

c) Áreas con pendiente media, entre 10-30%:

Sistema forestal con Pinus radiata y Eucalyptus camaldulensis y obras de control de erosión. La plantación se realizó en surcos en curvas de nivel, con arado y tracción animal, plantación a 3.0 m en los surcos y 2,5 m entre surcos con una densidad aproximada 1.250 pl/ha. Se establecieron obras para el control de erosión, de acuerdo al grado de fragilidad y erosión presente, implementando zanjas de infiltración, canales de desviación, empalizadas y diques.

Conclusiones

Después de 7 años de trabajo, se ha podido comprobar la factibilidad de la implementación de sistemas agroforestales, bajo ordenamiento predial, con el fin de recuperar ambientes degradados en la Región del Maule, Chile. Los sistemas silvopastorales y agrosilvícolas, asociados a prácticas de conservación y recuperación de suelos, no solo lograron disminuir los procesos erosivos, sino que establecer una cubierta arbórea y arbustiva que permitió dar protección a los suelos degradados y mejorar la productividad de la pradera con fines pecuarios productivos. Finalmente el componente arbóreo, constituido por *Pinus radiata*, *Eucalyptus globulus* y *E.canaldulensis*, le permitirá al productor generar otros ingresos producto de la madera.

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CERO LABRANZA CON MANEJO DE RESIDUOS Y LABRANZA CONVENCIONAL, EN VID DE MESA *Crimson Seedless*, EN LA COMUNA DE MONTE PATRIA

Carlos Sierra B. ; Roberto Olivares V.

INIA-INTIHUASI Colina San Joaquín s/n L Serena
csierra@inia.cl agronomo.olivares@gmail.com

Resumen

El estudio se realizó en el valle del río Huatulame, comuna de Monte Patria. El trabajo consistió en evaluar dos parcelas experimentales de vid de mesa cv. Crimson Seedless de seis años de edad sobre pié franco. En un caso, manejada a través de la técnica de cero labranza con acumulación superficial de sarmiento repicado durante seis años, localidad Los Tapia y en otro caso el mismo cultivar, con suelo manejado con labranza convencional e incorporación de sarmiento repicado y estiércol, localidad Las Chacarillas. Ambos sitios corresponden a suelos de origen granítico de lomajes de cerros, separados por 6 kms entre sí. El manejo agronómico general realizado en cada sitio fue distinto. La principal diferencia de manejo en los últimos seis años correspondió al manejo del suelo, en un caso bajo cero labranza con aplicación de residuos y el otro con laboreo e incorporación de residuos. Por lo tanto, el trabajo consistió en comparar dos casos de manejo distinto del suelo. Se colectaron muestras a profundidades de 0-5, 5-10, 10-20, 20-30, 30-50 cm. en tres calicatas abiertas en cada uno de los predios. Las muestras se analizaron para caracterizar química y físicamente los suelos. Otros parámetros de actividad biológica del suelo fueron medidos, nematodos, saprófitos, biomasa microbiana y actividad fosfatásica del suelo. En las plantas se evaluó, fenología, número de racimos, peso de racimos y rendimiento total de las plantas, además de cantidad y grosor de raíces. En los primeros 20 cm de suelo manejado en cero labranza con manejo de sarmientos repicados se incrementó claramente el contenido de materia orgánica, respecto del manejo con labranza convencional. Además, en cero labranza con manejo de residuos se incrementó de manera significativa la biomasa microbiana y la actividad fosfatásica del suelo. También, las plantas manejadas en cero labranza presentaron un mayor desarrollo de raíces finas comparado con el suelo cultivado. La producción de fruta fue mayor y de mejor calidad en cero labranza con residuos, respecto del manejo con labranza convencional. Además, esto se logró con una fertilización N-P-K bastante menor.

Palabras clave: Cero labranza, vides, residuos vegetales

Introducción

El historial de manejo del suelo en parrones en el norte chico, se ha caracterizado por el laboreo anual mediante rastrajes, con el objetivo de mullir el suelo y además controlar malezas. Sin embargo, más recientemente en los últimos 20 años, los viñedos se han estado manejando con cero labranza, pero sin manejo de residuos. Esto ha determinado una fuerte compactación de los suelos, afectando el crecimiento radicular y el movimiento del agua en el perfil. Los métodos utilizados, en la actualidad, consisten en trabajar el sarmiento para que éste sea incorporado al suelo mediante labranza convencional y en el peor de los casos, la quema de éstos.

El objetivo del presente trabajo, consistió en evaluar en suelos del mismo origen granítico, pero en dos localidades distintas, el efecto del manejo del suelo durante seis años con incorporación superficial de sarmiento repicado y con manejo de labranza convencional, sobre las condiciones químicas, biológicas del suelo y el comportamiento de las raíces y de las plantas en cuanto producción y calidad de la fruta obtenida.

Materiales y métodos

El estudio se realizó en la localidad de Chañaral Alto, en el valle del río Huatulame de la comuna de Monte Patria, región de Coquimbo, Chile, en los predios de Carsal y San Lorenzo.

El estudio consideró dos parcelas experimentales de vid de mesa cv. Crimson Seedless de seis años de edad sobre pié franco, en un caso, manejada a través de la técnica de cero labranza con acumulación superficial de sarmiento repicado durante los mismos seis años y en otro caso, el mismo cultivar, con suelo manejado con labranza convencional e incorporación de sarmiento repicado y estiércol.

En cada sitio se identificaron cinco bloques con diez plantas cada uno, esto implica un total de 50 plantas muestreadas por localidad. Además en cada sitio se colectaron muestras de suelo a profundidades de 0-5, 5-10, 10-20, 20-30, 30-50 cm. en tres calicatas abiertas en cada uno de los sitios.

A nivel de suelo se realizaron análisis de fertilidad. Además, se midió el nitrógeno biomásico mediante el método de Jenkinson, análisis nematológico y actividad fosfatásica. Análisis Físico, constantes hídricas, C de Campo y P.M.P., Humedad aprovechable y Granulometría.

A nivel de planta se realizaron análisis, de macro y micronutrientes en pecíolos a plena flor y de lámina en envero, análisis de arginina en sarmientos, evaluación de masa radical mediante el método de la trinchera, mediciones fenológicas y. de largo de brote, de producción y componentes de rendimiento.

La información obtenida corresponde al análisis de dos casos de manejo de suelo.

Resultados y discusión

En el Cuadro 1 se aprecian los parámetros de suelo relacionados con la dinámica del nitrógeno, en ambos sistemas de manejo del suelo y muestreado a cinco profundidades. El contenido de nitrógeno disponible en cero labranza presenta contenidos ligeramente más bajos en las primeras estratas del suelo. En relación al contenido de carbono el tratamiento con cero labranza presenta una mayor cantidad comparado con labranza convencional especialmente en los primeros 10 cms de suelo. La relación C/N es más alta y normal en cero labor y baja en labranza convencional corroborando lo señalado en el sentido de que, en labranza convencional el carbono se acumula menos, debido a que se oxida más fácilmente.

En los primeros 5 cms el tratamiento de cero labranza duplica el contenido de carbono presente en el tratamiento con labranza convencional. De 5-10 cms el contenido de carbono es similar entre ambos tratamientos. Las diferencias en contenido de nitrógeno total es importante en las dos primeras estratas, en profundidad estos contenidos son similares.

Cuadro 1. Contenido de nitrógeno disponible, porcentaje de nitrógeno total, materia orgánica, carbono y relación carbono nitrógeno a cinco profundidades de suelo en Cero labranza con manejo de residuos (CL) y Labranza convencional (LC) en cv. Crimson Seedless.

Prof.	Cero labranza					Labranza convencional				
	$N_{Disponible}$	N_{Total}	M.O.	C	C/N	$N_{Disponible}$	N_{Total}	M.O.	C	C/N
cm	mg/kg	%				mg/kg	%			
0-5	7	0,19	5,7	2,85	15	15	0,17	2,9	1,45	8
5-10	8	0,06	1,8	0,9	14	9	0,10	1,6	0,8	8
10-20	6	0,04	0,8	0,4	10	6	0,05	0,7	0,35	7
20-30	4	0,03	0,6	0,3	10	5	0,03	0,6	0,3	8
30-50	5	0,02	0,3	0,15	7	5	0,02	0,3	0,15	10

En el Cuadro 2 se aprecia la variación de la reacción del suelo, la conductividad eléctrica y el fósforo disponible en las 5 estratas de suelo. La acidez del suelo es ligeramente más baja en labranza convencional y la salinidad es ligeramente más alta en cero labranza en todo el perfil de 50 cms. Sin embargo, en ambos casos los niveles de salinidad no son altos. La menor salinidad en San Lorenzo se explica seguramente por el mayor riego que se aplica en este predio. En relación al fósforo, los niveles detectados en ambos sitios son muy altos, destacando los mayores niveles encontrados en San Lorenzo.

Actividad biológica del suelo

En relación a la biomasa microbiana, los valores encontrados en ambos tipos de manejo del suelo son bastante distintos, en los primeros cms de suelo ambos contenidos no son muy diferentes, pero en profundidad se produce una gran diferencia a favor de la cero labranza (Cuadro 3).

En el Cuadro 4 se aprecia la actividad fosfatásica medida, en ambos sistemas de manejo del suelo. En cero labor la actividad fosfatásica (P-asa) es muy superior a la que presenta el suelo manejado en labranza convencional.

Cuadro 2. pH, conductividad eléctrica y fósforo disponible (cmol/kg) a cinco profundidades de suelo en Cero labranza con manejo de residuos (CL) y Labranza convencional (LC) en cv. *Crimson Seedless.*

Profundidad	Cero labranza	Labranza convencional
cm	mg/kg	
0-5	25	13
5-10	46	19
10-20	58	8

Cuadro 3. Nitrógeno de la biomasa microbiana en tres profundidades de suelo en Cero labranza con manejo de residuos (CL) y Labranza convencional (LC) en cv. *Crimson Seedless.*

Profundidad	Cero Labranza	Labranza convencional
cm	P-asa ug	
10-20	122	39,9
20-30	130	12,8

Cuadro 4. Actividad fosfatásica (P-asa) a dos profundidades de suelo en Cero labranza con manejo de residuos (CL) y Labranza convencional (LC) en cv. *Crimson Seedless.*

Prof. cm	Cero labranza			Labranza convencional		
	pH	C.E.	$P_{Disponible}$	pH	C.E.	$P_{Disponible}$
		Ms/cm	ppm		mS/cm	ppm
0-5	7,9	3,40	99	7,8	2,31	169
5-10	7,9	1,71	28	7,9	1,38	103
10-20	7,9	1,37	13	7,7	0,95	41
20-30	7,9	1,79	6	7,7	0,74	29
30-50	7,7	1,81	5	7,7	1,13	6

Información generada por el Dr. Fernando Borie, Universidad de la Frontera de Temuco (UFRO).

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EFECTO DE LA EXTRACCIÓN DE AGUA SUBTERRÁNEAS SOBRE ECOSISTEMAS TERRESTRES DEPENDIENTES DE ESE SUMINISTRO HÍDRICO EN LA REGIÓN ALTIPLÁNICA DE CHILE.

Mario Ahumada
Servicio Agrícola y Ganadero mario.ahumada@sag.gob.cl

Resumen

La presencia de humedales en la ecorregión altiplánica depende en la mayoría de los casos del aporte hídrico de las aguas subterráneas, que determina la estabilidad de características del sitio asociadas principalmente al sustrato que lo sustenta, como es el caso del contenido de materia orgánica y presencia de sales en superficie y en el perfil. Conocer la dinámica de cambio y las variables que determinan la presencia de un determinado tipo de vegetación es fundamental para manejar y mitigar impactos generados por diversas actividades que contemplan extracción de aguas subterráneas. Para lograr lo anterior se describió la vegetación y características de sustratos de 30 humedales distribuidos en la ecorregión con la finalidad de proponer un esquema de clasificación de sitio que considera el componente hidrófilo de la vegetación, arquitectura de crecimiento de las plantas y las características de sustrato de afloramiento salino en la época de mayor déficit hídrico en el año. Con estas tres variables se propone una clasificación de grado de sensibilidad a la extracción de agua para cada tipo considerando que la conjugación de éstos determina un mayor o menor nivel hidromórfico en el sistema. Esta clasificación se complementó con seguimientos sistemáticos realizados a tres humedales que están sometidos a extracción de agua, en los que se ha evidenciado la secuencia de cambios en el tiempo.

Palabras clave: humedales, vegetación hidromorfa, ecorregión altiplánica.

Introducción

Los sistemas vegetacionales azonales hídricos de altura corresponden a ecosistemas ampliamente distribuidos en la cordillera de los Andes, sin embargo pese a su vasta presencia, a lo largo de toda la cordillera de Los Andes, es un recurso muy escaso en la zona Norte y Centro Norte del país, constituyéndose en lugares de alta relevancia por su particular diversidad biológica y por el rol que representan para los sistemas productivos de las comunidades locales, basados en técnicas ancestrales.

La importancia de conservar este tipo de ecosistemas radica en que cumplen una serie de funciones asignadas por el hombre, dentro de las que destacan: fuente de aprovisionamiento de agua de bebida y para uso industrial y aporte de forraje en cantidad y calidad óptima para la crianza de ganado. Sin embargo, es necesario considerar otras funcionalidades de estos ecosistemas tales como fuente de biodiversidad y «pool» genético, corredores biológicos especialmente para aves migratorias y reguladores de ciclos hidrológicos (Quezada, 2001).

Cualquier alteración que se produzca en este tipo de ecosistemas por las experiencias que se han presentado, tiene períodos de recuperación natural muy extensos, lo que puede constatarse si se analizan los planes de cierre presentados por empresas que contemplan medidas de mitigación o reparación que superan largamente los 20 años de aplicación.

Materiales y métodos

Se describieron 30 humedales comprendidos entre las regiones de Arica y Parinacota y la parte norte de la Región de Atacama analizándose información de descipción de Formación vegetacional con inventario florístico, que corresponde a aquel punto del cual se cuenta con información de la Formación vegetacional (estructura de la vegetación y especies dominantes) acompañado del inventario florístico del punto caracterizado que incluye información más específica sobre cubrimiento de las especies presentes, porcentaje de suelo desprovisto de vegetación (a nivel de rastrojo, suelo desnudo y afloramiento salino).

La información recopilada en terreno se utilizó para agrupar las formaciones vegetacionales según las especies dominantes y características de sitio utilizando los siguientes criterios de clasificación:

- Crecimiento cespitoso o no cespitoso (forma o no forma champa).
- Crecimiento en cojines compactos o no.
- Altura de crecimiento de las especies dominantes.
- Superficie cubierta por afloramientos salinos.
- Por bibliogfrafía se recurre a la clasificación de sustrato en función del contenido de materia orgánica.

Con esta agrupación se define la sensibilidad de los diferentes tipos vegetacionales a la alteración del suministro hídrico para determinar aquellas formaciones más sensibles a disminución de humedad en el sustrato.

Para determinar el funcionamiento vegetacional se define un marco teórico conceptual para identificar y definir el funcionamiento normal de la vegetación en la cuenca, a través de un modelo teórico que permita utilizarlo como herramienta de apoyo orientado a identificar criterios para determinar el área de influencia del acuífero en la cuenca, considerando la distribución espacial de la flora dependiente de la fuente hídrica. Para

esta situación no sólo se proponen elementos estrictamente vegetacionales, sino que es necesario considerar otros elementos del suelo, como es el caso del rastrojo, mantillo y afloramiento salino. En este contexto, es necesario identificar las principales formaciones vegetacionales respecto a sus especies dominantes de acuerdo a su mayor o menor dependencia de la humedad proveniente de napas subterráneas, sea ésta por saturación de suelo debida al ascenso capilar a través del sustrato que las sostiene o bien por afloramientos hídricos en superficie.

Resultados y discusión

En relación con la clasificación de la vegetación se identifican los siguientes tipos vegetacionales, considerando las especies, hábito y altura de crecimiento:

- Bofedales; presentan vegetación que desarrolla cojines en forma semiglobosa, formando cuerpos compactos en superficie. Son plantas muy compactas y entre cojines es posible encontrar especies que crecen formando césped corto.
- Vegas; en la que se presentan especies vegetales de crecimiento no cespitoso, desarrollando un césped parejo o con desarrollo de pequeños cojines herbáceos y,
- Pajonales; hídricos, en el que desarrollan especies vegetales de crecimiento cespitoso con desarrollo de follaje aéreo alto (mayor a 40 cm de altura), desarrollando cojines herbáceos de tamaño medio a grandes.

El componente salino diferencia a la formación vegetal como salina o no salina, y que para el caso de Bofedales, vegas y pajonales corresponde el valor umbral para ser considerado salino debe ser superior a 5, 20 y 30%, respectivamente.

Cuadro 1. Resumen de características bióticas y abióticas para cada tipo vegetacional definido.

Tipo vegetacional	Hábito de crecimiento	Altura de Planta (cm)	Afloramiento salino (%)
Bofedal	Plantas en cojín, no cespitoso en sustratos con alto contenido de materia orgánica.	Pastos bajos con crecimiento muy compacto	> 5% salino y <5% no salino.
Pajonal Hídrico no Salino	Cespitoso (forma champas)	> 40 cm.	< 30% no salino y > 30% salino.
Vega Salina	No Cespitoso (forma un césped corto).	> 40 cm	< 20% no salino y >20% salino.

Respecto al funcionamiento de la vegetación en la Figura 1 se resume las características de sitio que determinan que la vegetación sea más o menos dependiente al suministro hídrico, lo que determina una relación directa respecto a la sensibilidad y riesgo de impacto.

En términos generales se puede resumir que mientras menor sea el afloramiento salino y mayor el contenido de humedad en el sustrato más sensible resulta el ecosistema a la alteración del régimen hídrico, específicamente a la extracción de agua.

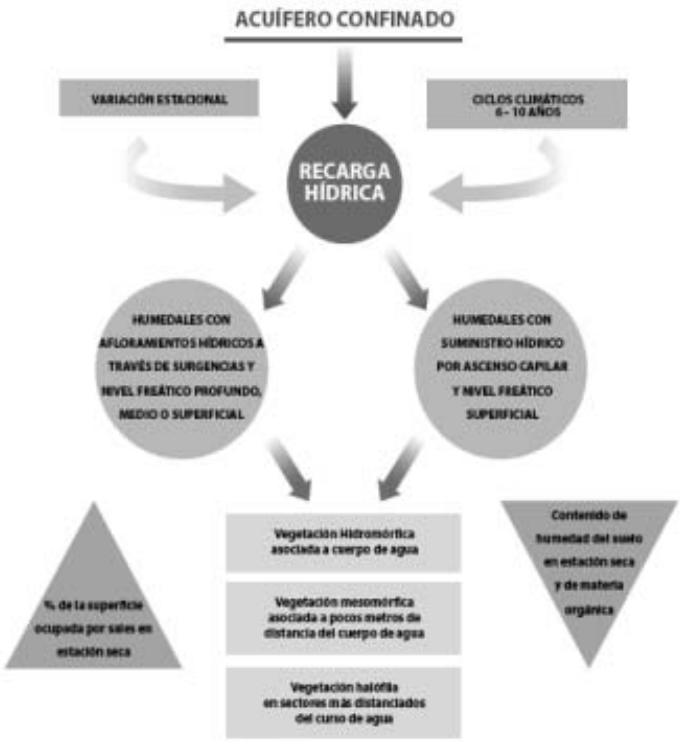

Figura 1. Componentes que determinan la presencia de los diferentes tipos de sistemas vegetacionales azonales hídricos en el Altiplano

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REHABILITATION OF POST-OPERATIVE MINE TAILINGS UNDER SEMIARID CLIMATE CONDITIONS: IMPORTANCE OF SOIL MICROBIAL ACTIVITY

Claudia Santibáñez V[a]., Rosanna Ginocchio C[b].

[a]Facultad de Ciencias Silvoagropecuarias, Universidad Mayor. Camino La Pirámide 5750, Santiago, Chile. Tel. +56-2-3281305 Fax. +56-2-3281413, claudiasantibanez@mayor.cl.
[b]CIMM, Av. Parque Antonio Rabat 6500, Santiago, Chile

Summary

Microbial properties have been reported to be useful indicators of soil quality and could serve as complementary assessment criteria for evaluating the progress and success of rehabilitation of post-operative mine tailings.This study examines the potential rehabilitation of copper mine tailings site using several organic and inorganic amendments and a native drought-tolerant herbaceous mixture. The evolution of several chemical and biological properties of the system was periodically evaluated by measuring: total organic carbon (TOC), dissolved organic carbon (DOC), microbial biomass C (MBC), basal respiration, and aerial plant biomass, during a 3-year field experiment under semiarid climate conditions in north-central Chile. Some relations between these parameters that are normally used as soil quality indicators, such as the metabolic quotient (qCO_2) and MBC/TOC ratio, were evaluated. Significant correlations between qCO_2 and MBC with plant growth were found in the present study suggesting that these parameters can be used as sensitive, effective and reliable indicators of rehabilitation progress on mine tailings.

Introduction

Post-operative mine tailings dumps are generally devoid of vegetation and have no soil structure. In semiarid areas these problems are exacerbated by high salt content of tailings. These materials are usually characterized by the absence of organic matter, nitrogen, and phosphorus, neutral to acid pH. Indigenous microbial communities associated with mine tailings often show limited density and diversity, relative to undisturbed sites (De la Iglesia *et al*. 2006). Therefore, physical, chemical, and biological characteristics of mine tailings interact to almost completely suppress seed germination, plant growth and microbial activity related to biogeochemical cycles (Petrisor *et al*. 2004). The establishment of a permanent vegetative cover is recognized as a potentially cost-effective and ecologically sound approach to containment of mine tailings and for initiation of soil formation processes. The primary objectives of

rehabilitation are to minimize environmental degradation and to facilitate re-establishment of a functional plant-soil system exhibiting long-term stability. This relies entirely on the development of a functional soil microbial community. Many of the functions of the microbial community can be induced through proper application of amendments into mine tailings, such as organic materials. The objective of this study was to evaluate the evolution in soil biological properties of mine tailings under different amendments and to identify their potential to be used as biological indicators of the progress and success of rehabilitation.

Materials and methods

A field experiment was conducted on La Cocinera tailings dump located in north-central Chile, an area under semiarid climate conditions, to evaluate the development of some biological properties on mine tailings amended with several organic and inorganic amendments (Table 1). The amendments used were discarded rubble from copper-oxide lixiviation piles (R); goat manure (M); sediment from irrigation canals (S); biosolids (B); grape residues (G); and olive residues (O). Experimental treatments and their doses of amendment are shown in Table 1.

Table 1. Experimental treatments and description of amendments and dose.

Treatment	Amendments and dose Ç
Control, C	—-
RM	Rubble (1000 t ha^{-1}); Manure (108 t ha^{-1})
RMS	Rubble (1000 t ha^{-1}); Manure (108 t ha^{-1}) ; Sediment (Layer of 5 cm)
B1	Biosolids (100 t ha^{-1})
B2	Biosolids (200 t ha^{-1})
G1	Grape residues (89 t ha^{-1})
G2	Grape residues (200 t ha^{-1})
O1	Olive residues (91 t ha^{-1})
O2	Olive residues (200 t ha^{-1})
GB	Grape residues(131 t ha^{-1}); Biosolids (20 t ha^{-1})
GM	Grape residues (91 t ha^{-1}); Manure (70 t ha^{-1})
OB	Olive residues (135 t ha^{-1}); Biosolids (19 t ha^{-1})
OM	Olive residues (96 t ha^{-1}); Manure (67 t ha^{-1})

Amendments were mixed on the upper layer of tailings (0 – 20 cm depth). The experimental layout was a complete randomized block design. Each experimental plot of 5 x 5 m with three replicates was first amended and then seeded with a mixture of local grasses/herbs previously collected from nearby wild areas and from a grass population (*Polypogon austr*alis) spontaneously established in a restricted area of the same mine tailings. Substrate samples were collected at the time of addition of amendments to tailings (2006) and after one (2007) and two (2008) years from three random points of each experimental plot .

The C-CO_2 evolution was determined periodically by titration (Anderson 1982). Microbial biomass C (MBC) was determined by the chloroform

fumigation extraction method described by Gregorich *et al*. (1990). The microbial metabolic quotient (qCO_2) was calculated as basal respiration (¼g C-CO_2 h^{-1}) per mg of MBC (Anderson and Domsch 1990).
Aboveground plant biomass was estimated by clipping vegetation at ground-level in randomly placed quadrats of 0.35 x 0.35 m in three locations of each experimental plot. Plant biomass was harvested and placed in a pre-weighed paper bag and dried in a forced air oven at 60 ºC.
Statistical analyses of data were conducted using InfoStat (2008) software. The significance of different effects was tested by one-way analysis of variance followed by the Tukey test. Pearson correlation analysis was done to determine correlations among variables.

Results and discussion

At the beginning of the experiment, respiration of microorganisms and microbial biomass C significantly increased in all amended treatments with respect to control (Fig. 1 y 2). However, these parameters decreased with time. The general increase of both basal respiration and microbial biomass C in all treatments amended with organic residues can be attributed to the incorporation of labile materials, which stimulate the authoctonous microbial activity of the tailings and to the incorporation of exogenous microorganism (Ross *et al.*, 2003). Subsequently, basal respiration fell during time possibly due to the mineralization of labile compounds. MBC was lowest in those treatments where C-CO_2 emission was also low. Sparling (1997) proposed the MBC to TOC ratio that could be used to compare substrates with different organic matter fractions. Jenkinson and Ladd (1981) proposed that a value of 2.2 reflects a good equilibrium between both C fractions (MBC and TOC). These biological ratios tended to decrease in time, with the exception of treatments where biosolids (B1 and B2) were incorporated, in which these values were highest at the end of the study (Table 2). The qCO_2 generally decreased with time, with the highest values recorded in treatments O1 and O2 throughout the observation period and the lowest values showed by the B1 and B2 treatments at the end of the observation period (Table 2). The average MBC to substrate organic C ratio is far below this value in all treatments of the present study. MBC content in the treatment with grape residues and biosolids (GB) was only 0.26 % at the end of the experiment, which value was even lower than the control. The generally low level of the MBC to substrate organic C ratio in these substrates is probably due to the unfavourable salinity effects. Bacterial communities may dominate in salt affected substrates and are less efficient at converting substrate C into cellular C than fungi, causing low substrate utilization efficiency (Sparling, 1992). The qCO_2 parameter is useful to evaluate the stability and degree of maturity of a restored system, and should be high in young

(inmature) soils and low in mature soils. On the other hand, soils under stress would also present higher qCO_2 values than non-stressed soils. According to this, the mine tailings treated with amendments corresponds to immature and non-stabilised systems and untreated mine tailings corresponds to stressed systems. The values of qCO_2 were elevated in all treatments at the beginning of the experiment in comparison to other results generally published in literature (0.5 – 3 µg C-CO_2 mg $Cbio^{-1}$ h^{-1}) (Kandeler *et al.* 1993). However, they decreased in time reaching values close to that of natural soils. These results are in accordance with the hypothesis suggested by Insam and Haselwandter (1989) that ecosystem succession is accompanied by a decrease in the qCO_2 of the soil microbiota. The highest qCO_2 values were determined in treatments with olive residues (O1 and O2), differing statistically from the other treatments. This might reflect low substrate quality and low efficiency of organisms functioning; since olive residues are a pure vegetative by-product containing a high organic and polyphenol content and is resistant to biodegradation. It has been reported that olive residues inhibits several groups of bacteria and fungus species *(Ramos-Cormenzana et al., 1996)*.

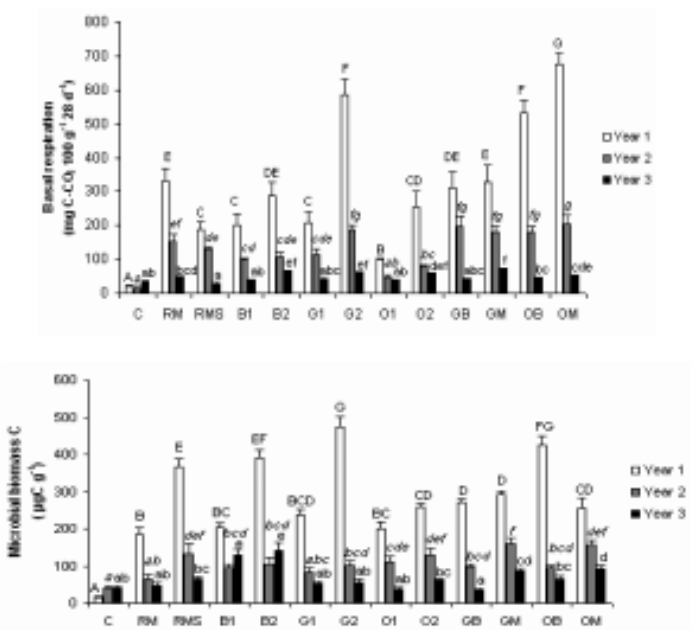

Figure 1. A: Evolution of accumulated basal respiration in experimental substrates (28 d). B: Evolution of microbial biomass carbon (MBC) in experimental substrates

Mean and standard deviation are shown (n = 3).Values represented in the bars of the same color followed by the same letter(s) are not significantly different at $p < 0.05$.

Table 2. Evolution of soil microbial biomass as percentage of substrate organic C and metabolic quotient (mean, *n* = 3) in experimental substrates (0 – 20 cm).

Treatment	Microbial biomass C ---------(% of substrate C)-----			Metabolic quotient ----------(µg C-CO_2 mg $Cbio^{-1}$ h^{-1})---------		
	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3
C	0.44	0.49	0.61	5.0 ± 0.75[a]	5.5 ± 0.86[a]	4.0 ± 0.83a
RM	0.83	0.44	0.31	3.0 ± 0.50[b]	3.8 ± 0.45b	2.0 ± 0.62b
RMS	3.09	1.00	0.51	3.0 ± 0.35[b]	2.3 ± 0.38c	1.6 ± 0.71b
B1	0.70	0.71	1.22	6.9 ± 0.68[c]	1.7 ± 0.64d	0.6 ± 0.51c
B2	0.99	0.59	1.12	7.5 ± 0.71[d]	3.3 ± 0.72b	0.9 ± 0.77c
G1	2.45	0.35	0.38	3.2 ± 0.51[b]	3.1 ± 0.58b	2.8 ± 0.68d
G2	3.00	0.41	0.28	3.4 ± 0.65[b]	3.1 ± 0.65b	1.2 ± 0.80bc
O1	0.81	0.88	0.35	7.1 ± 0.92[c]	5.3 ± 0.97a	4.7 ± 1.03a
O2	0.54	0.71	0.40	7.5 ± 1.09[d]	4.9 ± 0.77ab	4.8 ± 0.92a
GB	2.63	0.55	0.26	3.9 ± 0.71[bc]	3.1 ± 0.67b	1.6 ± 0.73b
GM	1.84	0.74	0.51	3.7 ± 0.78[bc]	1.7 ± 0.53cd	1.2 ± 0.50bc
OB	1.20	0.60	0.43	3.6 ± 0.80[b]	3.2 ± 0.48b	1.8 ± 0.62b
OM	0.64	0.86	0.80	4.7 ± 0.85[ab]	3.8 ± 0.52b	2.9 ± 0.75d

Values in the same column followed by the same letter are not significantly different at $p < 0.05$

Correlation analysis revealed significant potential relationship of basal respiration and plant aerial biomass with MBC, which values were positively correlated (Table 3). Furthermore, the qCO_2 showed a negative relationship with plant aerial biomass (Table 3). The MBC showed a relationship with plant aerial biomass. These parameters were positively correlated (Table 3).

Table 3. Pearson's correlation coefficients between a range of microbial and chemical properties and microbial biomass C (*n* = 39) or plant aerial biomass (*n* = 39).

Variable	Microbial biomass C	Plant aerial biomass
DOC	-0.23	-0.20
TOC	0.50	0.54
Basal respiration	0.81[a]	0.45
Metabolic quotient	0.30	-0.65[a]
MBC/TOC	0.47	0.60[a]
Cu in pore water	0.49	0.51
Microbial biomass C	—	0.60[a]
Plant aerial biomass	0.60[a]	—

[a] Correlation is significant at the 0.01 level (two tailed).

Conclusions

The success of rehabilitation is strongly related with plant cover thrive. Thus, the progress may be inferred from studies of the soil microbial parameters which are correlated with plant growth.Many studies use basal respiration and the ratio MBC/TOC as indicators of restoration, however, results of the present study demonstrate that they are not good indicators by themselves for rehabilitation of mine tailings, at least in early stages, since they were not correlated with plant growth and thus they do not represent suitable indicators for estimating vegetation changes. Both

microbial biomass C and metabolic quotient measurements were correlated with plant aerial biomass and thus they constitute valid indicators of rehabilitation in mine tailings. Microbial properties identified in the present study are useful tools for evaluating early changes in mine tailings after rehabilitation. However, collection of data during a longer term and in more rehabilited tailings sites will be needed to confirm conclusions made in the present study.

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DETERMINACIÓN DE LA EROSIÓN ACTUAL Y POTENCIAL DE CHILE

(Determination of current and potential Chilean soil erosion)

Juan Pablo Flores, Eduardo Martínez, Marión Espinosa

Centro de Información de Recursos Naturales. Manuel Montt 1164, Santiago, Chile
Dedicado a Patricio Lara Greene†.

Resumen

Este estudio estima la erosión actual y potencial del territorio de Chile mediante la aplicación de dos modelos cualitativos usando técnicas de geomática, teledetección y SIG. El estudio cubre un área estimada de 75 millones de hectáreas y tiene dos escala de trabajo dependiendo de la disponibilidad de información de cada región, nivel semidetallado 1:50.000 en sectores silvoagropecuarios entre la región de Coquimbo y Los Lagos y escala generalizada 1:250.000 en las regiones extremas y cordillera de los Andes. A nivel nacional, se puede observar que la mayor cantidad de suelos erosionados aumentan de sur a norte. Una superficie de 36,8 millones de hectáreas, equivalentes al 49,1% del territorio nacional presenta algún grado de erosión. Los sectores con mayores problemas de erosión actual lo lideran las regiones de Coquimbo, con el 84% de sus suelos erosionados; Valparaíso, con 57%, y la Región de O'Higgins con el 52% de sus suelos. A la espera de la validación final de los resultados de erosión potencial (diciembre 2010), los mayores problemas detectados que afectan al sector silvoagropecuario se concentran en las regiones de La Araucanía, Coquimbo y Los Lagos, donde la acción humana y los indicadores de agresividad climática, y la geomorfología de cuencas afectan significativamente las características de escorrentía.

Palabras clave: riesgo de erosión del suelo, índices espectrales, geomática, teledetección, erodabilidad del suelo, erosividad de la lluvia.

Introducción

En la actualidad la erosión de los suelos de Chile, constituye uno de los problemas ambientales más significativos del sector silvoagropecuario (Bonilla *et al.*, 2010), especialmente porque el recurso suelo no es renovable a escala humana y es altamente vulnerable a actuaciones antrópicas, condiciones de variabilidad climática y de cambio climático global. Sumado a ello, se deben considerar las exigencias ambientales de los mercados internacionales en la producción de recursos naturales y los actuales desafíos del país en el campo del manejo sustentable, sujeto a la «Convención Internacional de lucha contra la desertificación»

de las Naciones Unidas (Pizarro *et al.*, 2008). Enfrentar esta problemática requiere tener una cuantificación de la erosión actual y potencial en Chile, por cuanto los estudios de degradación de recursos naturales, erosión y fragilidad existentes en el país son escasos o se presentan a escalas generalizadas y los estudios de mayor detalle son muy localizados por el alto costo que ello implica.

Los primeros testimonios de la pérdida suelo en Chile se remontan a los estudios de Claudio Gay, Benjamín Vicuña Mackenna, R.E Mc Lure y Federico Albert quienes informaron sobre la enorme fragilidad de los suelos de Chile y las consecuencias que las malas prácticas silvoagropecuarias tendrían para las futuras generaciones. Posteriormente, diversos estudios sobre la condición de los suelos en Chile han sido desarrollados por diferentes instituciones públicas, privadas y universidades, destacando los trabajos de Elgueta y Jirkal (1943), Rodríguez (1957), INFOR (1964), IREN y Ministerio de Agricultura (1966), IREN (1979), Peña (1985), Honorato *et al.* (2001), Perez y González (2001), Soto (1997), Bonilla *et al.* (2010), Castro y Aliaga (2010), entre otros. Estos estudios revelan que existe una situación preocupante de superficie erosionada en Chile, especialmente en las zonas silvoagropecuarias del secano costero e interior, es decir, desde las regiones de Coquimbo y Los Lagos.

En las recientes décadas, los grandes avances en desarrollo de modelos empíricos, conceptuales y físicos (Merrit *et al*., 2003) que utilizan, en la mayoría de ellos, datos obtenidos de sensores remotos, integrados en sistemas de información geográfica (SIG), permiten obtener nuevas herramientas de gestión de recursos naturales (Datta y Schack-Kirchner, 2010), beneficiando con ello a las ciencias del suelo, al cubrir amplias extensiones a menores costos.

En este marco, el año 2004 y 2006, el Centro de Información de Recursos Naturales (CIREN), en conjunto instituciones del Ministerio de Agricultura, a través de proyectos con financiamiento CORFO, elaboró mapas de erosión actual y potencial, en varias zonas de Chile central. Ambos estudios revelan la preocupante situación de los suelos agropecuarios, en cuanto a su degradación antrópica.

Finalmente, en 2007, las instituciones CIREN, CONAF, SAG, ODEPA y el Instituto de Desarrollo Agropecuario (INDAP), todos pertenecientes al Ministerio de Agricultura, ejecutan el presente estudio, que tiene el objetivo de elaborar la cartografía de erosión potencial y actual de los suelos de Chile a nivel semidetallado 1:50.000 y generalizado a escala 1:250.000.

Metodología

El área de estudio para la determinación de la erosión actual corresponde al territorio continental chileno, aproximadamente 75 millones de hectáreas.

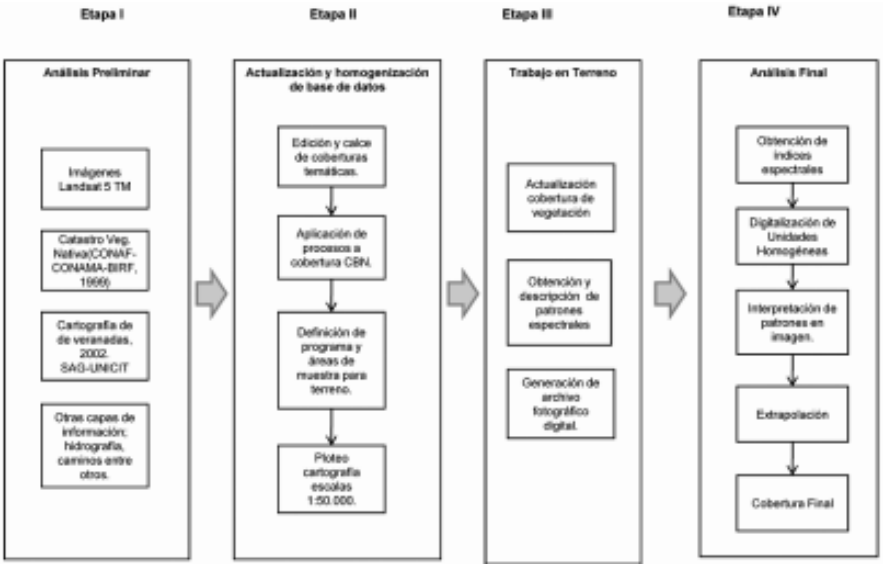

Figura 1. Diagrama metodológico del modelo satelital de erosión actual.

El estudio se desarrolló en dos fases: determinación de la erosión actual de Chile y estimación de la erosión potencial (fragilidad del suelo). En el primer caso la base metodológica consistió el análisis interpretativo visual de imágenes satelitales Landsat TM 5, datos de estudios agrológicos, curvas de nivel, e índices espectrales confrontadas con las observaciones tomadas en las campañas de terreno en todas las regiones de Chile. Tales capas de información se integraron mediante SIG, complementada con técnicas de Geomática (figura 1).

Para la clasificación de erosión de suelos se unificaron criterios de acuerdo a los estudios agroecológicos y los boletines técnicos de CONAF y el SAG, estableciendo un criterio con cinco categorías: nula o sin erosión, ligera, moderada, severa, muy severa y erosión no aparente.

Para estimar la erosión potencial de los suelos de Chile se utilizó un modelo empírico cualitativo (IREPOT), basado en la conceptualización de la erosión potencial descrita por Wischmeier y Smith (1978), el cual integra las características intrínsecas del suelo, topográficas, climáticas y biológicas (riesgo de erosión actual), que se relacionan en dos componentes principales, erodabilidad del suelo y erosividad de la lluvia (figura 2). El modelo se basó en el supuesto que la potencialidad de

erosión es independiente del uso y manejo actual del suelo. En otras palabras, las pérdidas, arrastre o transporte de partículas del suelo son las que tendrían lugar en caso de no existir vegetación alguna, esas pérdidas son las máximas o potenciales. Las variables básicas, así como los índices generados a partir de su combinación fueron discretizados y clasificados en función de su efecto sobre la erosión potencial en cuatro rangos: Bajo (1), Medio (2), Alto (3) y Muy Alto (4).

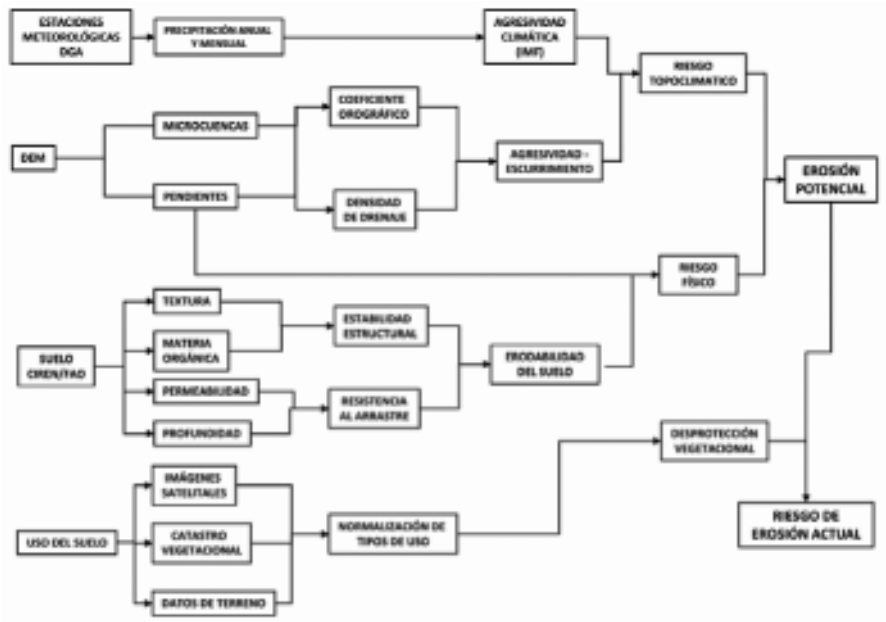

Figura 2. Diagrama metodológico del modelo IREPOT de erosión potencial.

Resultados y discusión

El presente estudio que ejecuta CIREN revela que existe una superficie de 36,8 millones de hectáreas (49,1%) con algún grado de erosión (Cuadro 1). Un 38% de la superficie está dentro de la categoría de erosión moderada, severa o muy severa. Las regiones más afectadas son: Coquimbo (84,3%), Valparaíso (56,7%), O'Higgins (52,5%). Mientras que las comunas más afectadas, entre la IV y la X región son las siguientes: Punitaqui (94,8% - IV), Llay-Llay (77,6% - V), Alhue (70,1% - RM), La Estrella (95,1% - VI), Cauquenes (83,4% - VII), San Fabián (VIII), Purén (64,3% - IX), Panguipulli (40,1% - XIV) y Castro (69,3%- X).

Las regiones del norte del país con proporción de erosión actual severa y muy severa superan el 35% del territorio (Coquimbo a Arica y Parinacota). Exceptuando la Región de Coquimbo, en estas regiones predomina ampliamente la erosión natural (geológica), situación que no reviste efecto apreciable en la agricultura, ya que son escasas las

superficies silvoagropecuarias. En la zona Central (Valparaíso a Maule), los porcentajes de erosión severa y muy severa varían entre 19 y 26%, pero las situaciones son muy distintas. Mientras en la zona norte predomina la erosión natural, en estas regiones lo hace la erosión antrópica o acelerada. Sin embargo, en las comunas de Quillota, Los Andes y Con-Con, estos resultados no concuerdan en magnitud con lo obtenido por Castro y Aliaga (2010), quienes utilizaron un modelo cualitativo de susceptibilidad de la erosión, metodología que fue adaptada de Märker *et al.* (2001). En las regiones de Bío-Bío y La Araucanía la erosión severa y muy severa varía en torno al 10%, aun cuando se mantiene el predominio del efecto antropogénico como factor acelerador de la pérdida de suelos. Parte de la explicación de la disminución de la erosión severa y muy severa se debe al aumento de la cobertura boscosa en estas regiones, lo que se traduce en una mayor protección del suelo contra el impacto de la gota de lluvia y a la vez aumenta la resistencia a la dispersión por los mayores niveles de materia orgánica del suelo. Las regiones de Los Ríos y Los Lagos son las que evidencian los menores niveles de erosión actual severa y muy severa (<5%). Es en estas regiones donde ha actuado con mayor fuerza los programas de mejoramiento y conservación de suelos degradados. Además, en estas regiones se combinan favorablemente tres efectos que favorecen la protección del suelo a la erosión: alta cobertura vegetacional (bosques naturales y praderas), suelos volcánicos o arcillosos ocupando fisiografías menos abruptas, y mayor homogeneidad en la distribución de las precipitaciones durante el año. Finalmente, las regiones del extremo sur (Aysén y Magallanes), tienen niveles de erosión severa y muy severa en torno al 10%, así como suelos con erosión no aparente (48 y 36%), y alrededor de un 30% de superficies calificadas como otro (arenas, glaciares, rocas).

A la espera de la validación final de los resultados de erosión potencial (Diciembre, 2010), la mayor cantidad de superficie potencialmente erosionable a niveles severo y muy severo son las regiones de La Araucanía (71,1%), Coquimbo (64,8%) y Los Lagos (60,2%). En estas regiones los indicadores de agresividad climática, la geomorfología de cuencas afectan significativamente las características de escorrentía sumado al hecho que la acción antrópica a través de la actividad silvoagropecuaria puede desencadenar niveles de erosión mayores a los actuales (Cuadro 1 y 2). Excluyendo las superficies no clasificadas como suelo la región de Aysén aumenta su susceptibilidad a la erosión severa y muy severa a un 83,3%.

La información generada en este estudio permitirá identificar con mayor claridad las zonas del país que requieren mayor inversión, dónde los procesos de degradación se han acelerado y pueden manifestarse por

en zonas críticas de deforestación. Asimismo, el manejo de información actualizada acerca de los procesos de erosión permite al Estado y a los particulares diseñar planes de conservación y recuperación de suelos. Finalmente, el estudio de determinación de la erosión de los suelos de Chile entregará información para enfrentar con mayor precisión y confiabilidad otros procesos edafoclimáticos adversos, como por ejemplo, la desertificación y el cambio climático global.

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Cuadro 1. Superficie de erosión actual (en miles de hectáreas) por Región.

Región	SIN EROSION	EROSION LIGERA	EROSION MODERADA	EROSION SEVERA	EROSION MUY SEVERA	EROSION APARENTE	OTROS USOS	AREA DE EXCLUSION	SUELO EROSIONADO*	SUPERFICIE REGIONAL ESTUDIADA
ARICA Y PARINACOTA	48,8	255,7	171,6	468,7	583,6	0,0	157,1	0,0	1.479,6	1.685,5
TARAPACA	80,8	1.046,8	602,3	1.153,2	838,4	0,0	524,4	0,0	3.640,4	4.225,6
ANTOFAGASTA	138,1	1.341,4	3.271,3	3.592,8	2.021,4	0,0	2.237,3	0,0	10.226,9	12.602,4
ATACAMA	178,5	825,2	536,6	2.029,9	629,1	0,0	3.330,4	36,8	4.020,9	7.566,5
COQUIMBO	210,0	571,6	1.142,3	1.213,9	492,5	25,5	403,5	0,0	3.420,4	4.059,5
VALPARAISO	162,0	244,2	324,6	258,2	80,0	162,6	368,4	0,0	906,9	1.600,0
METROPOLITANA DE SANTIAGO	354,5	93,4	189,5	213,5	186,8	68,0	435,0	0,0	683,2	1.540,6
O'HIGGINS	331,0	96,3	451,8	197,3	114,5	125,1	322,3	0,0	860,0	1.638,3
MAULE	655,9	349,0	416,1	377,8	335,8	453,3	446,2	0,0	1.478,7	3.034,0
BIO BIO	840,1	393,4	429,1	211,6	148,6	1.443,8	245,4	0,0	1.182,7	3.712,0
LA ARAUCANIA	1.131,9	280,5	240,9	243,9	145,9	944,3	182,8	16,3	911,1	3.186,3
LOS RIOS	427,0	262,3	197,6	79,6	5,6	668,0	173,5	3,7	545,3	1.837,4
LOS LAGOS	750,6	574,6	423,5	138,9	33,3	2.142,4	745,6	24,9	1.170,3	4.833,7
AISEN DEL GRAL CARLOS IBANEZ DEL CAMPO	234,7	894,7	743,5	383,1	583,4	4.550,6	3.361,1	0,0	2.604,6	10.751,0
MAGALLANES Y LA ANTARTICA CHILENA	1.718,8	1.122,9	1.287,8	590,0	761,5	3.088,5	4.247,7	4,3	3.762,1	12.821,4

* Suelo erosionado comprende las clases ligera, moderada, severa y muy severa. Sensor remoto no registra información en zonas con cobertura vegetal sobre el 75% (erosión no aparente).

Cuadro 2. Superficie de erosión potencial (en miles de hectáreas) por región.
*Suelos frágiles: suelos de erosión potencial moderada, severa y muy severa.

Región	EROSION BAJA	EROSION MODERADA	EROSION SEVERA	EROSION MUY SEVERA	OTROS USOS	AREAS DE EXCLUSION	SUELOS FRAGILES*	TOTAL	SUPERFICIE REGIONAL ESTUDIADA
ARICA Y PARINACOTA	551,4	354,9	338,6	281,9	159,5	0,1	975,4	1.526,8	1.686,4
TARAPACA	1.967,2	799,4	620,0	406,7	433,4	0,2	1.826,1	3.793,3	4.226,8
ANTOFAGASTA	7.350,7	1.908,2	1.219,6	580,8	1.543,2	1,8	3.708,8	11.059,5	12.604,6
ATACAMA	1.974,7	831,5	1.090,2	1.123,8	2.548,5	0,0	3.045,5	5.020,2	7.568,7
COQUIMBO	545,5	473,2	944,7	1.688,7	408,9	0,2	3.106,6	3.652,1	4.061,2
VALPARAISO	104,9	175,9	438,5	503,9	377,4	0,2	1.118,3	1.223,2	1.600,7
METROPOLITANA DE SANTIAGO	221,7	106,5	277,1	468,7	468,9	0,0	850,3	1.072,0	1.540,9
O"HIGGINS	284,0	196,7	363,0	602,5	192,4	0,0	1.162,2	1.446,2	1.638,6
MAULE	563,4	488,0	592,0	947,1	445,8	0,4	2.025,1	2.588,5	3.034,8
BIO BIO	966,8	628,6	763,7	1.112,9	249,6	1,7	2.505,2	3.462,0	3.713,3
LA ARAUCANIA	180,5	532,9	1.391,7	875,4	206,0	0,3	2.800,0	2.980,5	3.186,9
LOS RIOS	316,6	289,3	361,2	694,3	175,9	0,7	1.344,8	1.661,4	1.838,1
LOS LAGOS	411,6	715,2	843,7	2.073,9	780,4	17,9	3.632,8	4.044,4	4.842,8
AISEN DEL GRAL CARLOS IBANEZ DEL CAMPO	410,3	482,5	1.041,0	3.411,9	3.242,1	2.256,8	4.935,4	5.345,7	10.844,7
MAGALLANES Y LA ANTARTICA CHILENA	3.530,5	788,5	667,4	466,4	1.562,1	6.273,9	1.922,3	5.452,8	13.288,8

*Suelos frágiles: suelos de erosión potencial moderada, severa y muy severa.

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CUANTIFICACIÓN Y CONTROL DE LA ESCORRENTÍA Y EROSIÓN EN HUERTOS DE PALTOS CULTIVADOS EN CAMELLONES A FAVOR DE PENDIENTES ESCARPADAS

Cristian Youlton[1], Paulina Espejo[1], Jaime Biggs[1], Marcela Norambuena[1], Germán Ruiz[2], Marco Cisternas[1], Alexander Neaman[1], Eduardo Salgado[1]

[1]Facultad de Agronomía, Pontificia Universidad Católica de Valparaíso, Casilla 4-D, Quillota, Chile. cristian.youlton@ucv.cl
[2]Servicio Agrícola y Ganadero, Ministerio de Agricultura, Gobierno de Chile

Introducción

En la Región de Valparaíso (Chile) existen 14.000 hectáreas cultivadas con frutales en laderas con pendientes mayores a 8%, principalmente con paltos (*Persea americana* Mill.), seguido en menor escala con vides y cítricos (CIREN, 2007).

Para el cultivo de paltos en laderas se utilizan camellones a favor de pendiente, los que se construyen raspando el suelo y acumulándolo a lo largo de la ladera. Con ello se procura una mayor profundidad de enraizamiento, mayor aireación del suelo y un rápido drenaje del agua de lluvia que escurre por el entrecamellón (Hofshi, 2002). Normalmente los camellones están distanciados cada 6 m, con 1 m de alto, 2 m de ancho en su base y 0,6 m en la parte superior (Hofshi, 2002), y segmentados cada 50 m por caminos en la curva de nivel (Gardiazabal, 1998).

El cultivo en laderas con camellones a favor de pendiente aumenta la vulnerabilidad del suelo a la erosión hídrica, ya que este queda expuesto y disgregado. En el presente trabajo se evalúa el efecto de la aplicación de cobertura herbácea o lodos agroindustriales sobre la erosión y escorrentía en camellones construidos a favor de la pendiente, tanto en suelo desnudo como en un huerto frutal, comparado con la cobertura de vegetación silvestre.

Materiales y métodos

Área de estudio

Dos unidades experimentales en los sectores de San Pedro (33°57'S; 71°14'W) y La Palma (32°53'S; 71°12'W), Comuna de Quillota, Región de Valparaíso, Chile. Laderas de exposición norte, 30% de pendiente y excluidas de pastoreo. Los suelos son Alfisoles, con textura franco arcillo arenosa en superficie y arcillosa en el subsuelo (CIREN, 1997). Presenta clima mediterráneo, con precipitaciones invernales de tipo torrencial de mayo hasta agosto (Gastó *et a*l., 1987). La precipitación media anual es de 450 mm (Santibañez y Uribe, 1990).

Ensayo de campo

Se utilizaron parcelas de escorrentía de 28x6 m. Éstas cuentan con un sistema que almacena una fracción conocida de sedimentos y escorrentía, la que es colectada después de cada lluvia (Da Veiga y Do Prado, 1993). En laboratorio se determinó el peso seco de sedimentos transportados y se estableció el volumen total de escorrentía. Cada área experimental cuenta con un pluviógrafo marca Hobo con data logger.

Cuadro 1. Tratamientos

Sector	Tratamiento	Descripción	Años monitoreo
San Pedro	Silvestre	54% cobertura arbustiva (Acacia caven y Trevoa trinerva), 100% herbácea.	2004 - 2008
	Camellón Desnudo	Construido en 2004. Aplicación de herbicidas en toda su superficie.	2004 - 2008
	Camellón Paltos	Plantación 6x3 m en 2001. Riego, fertilización y poda. Árboles con 3-4 m de diámetro. Aplicación de herbicidas en entrecamellón.	2006 - 2008
La Palma	Camellón Desnudo	Construido en 2005. Aplicación de herbicidas en toda su superficie.	2006 - 2008
	Camellón Cobertura	Construido en 2005. Siembra de forrajeras y fertilización en entrecamellón.	2006 - 2008
	Camellón Lodos	Construido en 2005. Incorporación de 60 t ha de lodos agroindustriales en entrecamellón. Aplicación de herbicidas en entrecamellón	2006 - 2008

Análisis experimental

Para determinar si existen diferencias significativas en la escorrentía y erosión entre los tratamientos se realizó un análisis de varianza unifactorial, utilizando un diseño en bloques completos al azar, considerándose los años como repeticiones de los tratamientos.

Resultados

Cuadro 2. Comparación entre los resultados medios anuales de escorrentía y erosión para los distintos tratamientos y sectores experimentales. Los sectores no son comparables entre sí. (p<0,05. *n=5; **n=3).

a) San Pedro			b) La Palma		
Tratamiento	Escorrentia media (mm)	Erosión media (t ha^{-1} $año^{-1}$)	Tratamiento	Escorrentia media (mm)	Erosión media (t ha^{-1} $año^{-1}$)
Silvestre	2,5* a	0,03* a	Desnudo	41** a	10** a
Desnudo	14* ab	4,5* a	Cobertura	33** a	0,7** b
Paltos	52** b	0,5** a	Lodos	27** a	0,2** b

Discusión y conclusiones

Las diferencias de precipitaciones entre sectores se deben a factores orográficos. La mayor escorrentía se registra en camellones con paltos, posiblemente al efecto del riego que mantiene el suelo húmedo y genera una rápida escorrentía, o bien a que el suelo erosionado y/o encostrado presenta una superficie con menor capacidad de infiltración.

El momento más vulnerable a la erosión es el primer invierno tras la construcción de los camellones, perdiendo aproximadamente 20 t ha^{-1}. Esta situación es común para San Pedro y La Palma, debido a la exposición superficial de suelo disgregado, el cual es rápidamente arrastrado por la escorrentía. Posteriormente estos valores descienden, posiblemente por la reagregación del suelo o por la menor disponibilidad de partículas erosionables en superficie (Ollesch y Vacca, 2002).

Las medidas de enmienda logran disminuir la erosión, no así la escorrentía. Esto se debería a que el camellón dispuesto a favor de pendiente está diseñado para la rápida evacuación de las aguas de lluvia. Sin embargo, a pesar de la alta escorrentía, la cobertura herbácea y los lodos logran retener el suelo, reduciendo la erosión en 90%.

Para dimensionar el nivel de erosión es posible utilizar el concepto de pérdida tolerable de suelo, que es un valor teórico equivalente a la velocidad de formación del mismo. En condiciones frágiles, como en los casos de suelos superficiales o altamente erosionables, se recomienda que la erosión anual no supere 2 t ha^{-1} $año^{-1}$ (Morgan, 1997; Toy *et al.,* 2002). Utilizando el criterio anterior, es posible afirmar que la pérdida de suelos en camellones es alta, siendo especialmente crítica durante el primer invierno, la que puede ser reducida al nivel tolerable indistintamente con el establecimiento de cobertura herbácea o aplicación de lodos.

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PHYTASE-ENCODING GENES IN ENDOSPORE-FORMING BACTERIA PRESENT IN ACIDIC VOLCANIC SOILS FROM SOUTHERN CHILE

[1]Jacquelinne Acuña, [1]Daniel Menezes, [1]Oscar Martinez, [2]Milko Jorquera, [2]María de la Luz Mora

[1]Doctorado en Ciencias de Recursos Naturales, Universidad de La Frontera, Ave. Francisco Salazar 01145, Temuco, Chile. [2]Center of Plant, Soil Interaction and Natural Resources Biotechnology, Scientific and Biotechnological Bioresource Nucleus, Temuco, Chile. Tel. 56-45-325467; fax 56-45-325053; Email: acuna.sobarzo@gmail.com

Summary

Biofertilizer based on endospore-forming bacteria (EFB), mainly *Bacillus* strains, have been developed and commercialized. One of the main characteristics of these Bacillus strains is their ability to release phosphorus (P) from insoluble forms, and concomitantly, to improve P uptake by plants. Here we evaluated the occurrence of phytase-enconding genes in populations of EFB in the rhizosphere of pastures established on acidic volcanic soils (Andisols) of southern Chile. EFB were isolated on medium containing insoluble phytate, as sole P source, and phytase-encoding genes were detected by polymerase chain reaction (PCR). The sequences obtained were compared with those in Genbank database. The influence of low pH and metal cations (Al^{3+} and Mn^{2+} at 10 mM) on phytase activity of two selected EFB was also evaluated. Sequencing of DNA fragments amplified by PCR, revealed the presence of Bacillus and Paenibacillus carrying ^{2}-propeller type phytases. Phytase from *Bacillus* sp. showed an optimum of activity at pH 7.0. In contrast, phytase from Paenibacillus showed an optimum of phytase activity at pH 4.5. Moreover, the phytase activity was inhibited (30-60% in relation to control) with Al^{3+}, but not with Mn^{2+}. This study reveals that Chilean volcanic soils are a reservoir of EFB populations which can present mechanisms involved in the expression of phytases. To our knowledge, this is first reports on direct detection and identification of phytase gene in rhizospheric soils. Also, our results suggest that Andisol-associated factors (low pH and metal cations) may affect phytase activity of EFB. These factors should be take account in the application of biofertilizers in soils, particularly in Andisols.

Key words: phytase, phytate, rhizosphere, rhizobacteria, volcanic soils

Introduction

The biofertilizers are live microorganisms that are able to colonize the rhizosphere or internal tissues of plants, promoting the growth of host

plant through increase supply or availability of nutrients, such as nitrogen and phosphorus (P) (Richardson *et al*., 2009). Bacteria with capacity to release phosphate from insoluble P forms by organic acid production and enzymatic activity (phosphatase and phytase) are currently studied and commercialized to improve the growth, yield, and quality of crops as well as for biotechnological applications in other fields, such as animal and human nutrition, aquaculture and environmental protection (Jorquera *et al*., 2008). In this context, *Bacillus* is one of most studied bacterial groups and commonly is suggested and commercialized as biofertilizers. However, the genomics and ecology of *Bacillus* and other endospore-forming bacteria (EFB) in the rhizosphere in soils is clearly unknown and poorly studied, particularly in Chilean Andisols which have high P content and acidity with the consequent presence of metal cations (Al^{3+} and Mn^{2+}) in soil solution. The objectives of the present study were i) to evaluate the occurrence of genetic traits involved in the expression of phytase in EFB populations present in the rhizosphere of pastures from southern Chile, ii) and evaluate the effect of Andisol-associated factors (low pH and metal cations) on phytase activity of EFB.

Materials and methods

Sampling

Rhizospheric soil samples were taken from three pastures located in the La Araucania and Los Ríos regions from southern Chile, and inmediatelly transported to laboratory for their analysis. The chemical properties of rhizospheric soils are shown in the Table 1.

EFB isolation

EFB were isolated according to standard protocol (Holt and Gerhardt, 1994). Rhizospheric soil samples were treated at 80°C for 10 min and aliquotes were plated on phytase-screening medium (PSM; Kerovou *et al*., 1998) to detect EFB with phytate-mineralization capacity.

Phytase gene detection by PCR

Based on current literature and public database, a degenerate primer set for *Bacillus* phytases described by Tye *et al*. (2002) was chosen and used to detect phytase gene in rhizospheric isolates of EFB (Figure 1, B). The isolates showing positive phytase signal were selected and characterized by 16S rRNA gene sequencing. The presence of phytase gene was also confirmed by sequencing. The DNA sequences obtained in this study were compared with those present in Genbank database by BLAST tools.

Phytase activity and effect of metal cations

Bacillus and *Paenibacillus* were grown in PSM broth (pH 7) for 2 days at 30°C and phytase activities) were measured according to Greiner *et al.* (2004) at different pH values (3.5, 4.5, 6.5 and 7.0). The measures

obtained were then compared with standard curve of PO42-. One unit of phytase activity was considered as 1 µM P released in 1 min. To study the effect of cations on phytase activity the protein samples were preincubated with Al^{3+} and Mn^{2+} solutions at final concentration of 10 mM for 15 min at 37ºC immediately before performing the phytase assay (Greiner 2004).

Results and discussion

Despite of significant differences in the chemical properties among the soils sampled (except % organic matter), the results showed that between 77-91% of cultured EFB showed capacity to solubilise phosphate and/or mineralize phytate on agar (Figure 1, A). Two pastures showed high percentages of EFB with phytate mineralization capacity, 66 and 75% for pasture no.1 and no.2, respectively. In contrast, the higher percentage in pasture no.3 was observed in EFB with both phytate mineralization and phosphate solubilization activity. EFB with capacity to utilize insoluble P forms (phosphates and phytates) have commonly isolated from rhizosphere of different plants and suggested as plant-growth promoting rhizobacteria (McSpadden Gardener, 2004; Tilak *et al*., 2006; Lal and Tabacchioni, 2009). The analysis of DNA sequences revealed the presence of *Bacillus* sp. MQH-19 and *Paenibacillus* sp. SPT-03 carrying ²-propeller phytase genes (Figure 1, C). Phytase-producing EFB have been reported and ²-propeller phytases have been suggested as major phytate-degrading enzymes in nature (Jorquera *et al*., 2008; Huang *et al.,* 2009). However, some studies have failed in detection of bacterial phytase in environmental isolates, especially *Bacillus* (Hill *et al*., 2007). On the other hand, phytase activity was differently affected by pH and metal cations. Tye *et al.,* (2002) described an acid pH optimum for ²-propeller phytase activity from *Bacillus*, but our results also showed a optimum pH 7 for *Bacillus* sp. MQH-19 strain, but this enzyme also present some activity moderately acid pH, which can allow it to have some catalytic activity in pasture rhizospheric environments of acidic volcanic soils. However, the *Paenibacillus* sp. SPT-03 strains showed the highest phytase activity at pH under 4.5 (Figure 2, A). The acid pH of catalysis of *Paenibacillus* sp. SPT-03 phytase suggest that is an unusual ß-propeller, since this group typically present neutral to alkaline activity (Fu *et al*., 2008). In relation to the effect of metal cations on phytase activity, both strains showed moderately inhibitory effect by Al^{3+}, and unaffected by Mn^{2+} at concentrations of 10 mM (Figure 2, B). Greiner *et al*. (2004) studied a phytase from *Pantoea agglomerans* and, similar to our study, they did not observed effect on enzymatic activity by Mn^{2+}, but a strong inhibitory effect was observed by Fe^{3+}. It is commonly accepted that environmental factors affect the structure and activity of bacterial

community in the rhizosphere. However, few studies have been addressed to elucidate the effect of soil-associated factors on functionality of biofertilizers, particularly in enzymatic activity.

The great biotechnological potential of *Bacillus* sp. MQH-19 and *Paenibacillus* sp. SPT-03 in sustainable agriculture is commonly recognized (McSpadden Gardener, 2004; Tilak *et al*., 2006; Lal and Tabacchioni, 2009). The specific detection of phytase gene will allow further studies focused on the dynamics and expression of phytase gene in the rhizosphere plants, with the consequent importance in the application of EFB-based biofertilizers to improve the P nutrition in plants. To our knowledge, this is one of the few reports on detection and identification of phytase gene in environment, particularly rhizospheric soils.

Table 1. Average values of selected chemical properties of rhizospheric soils.

	Pasture		
	1	2	3
pH H_2O	5.0-5.1	5.3-5.8	5,7-5,9
P (ppm)	5	36	8
K (ppm)	70	454	224
Organic matter (%)	20	19	19
Al Saturation (%)*	30.8	2,8	0,5

*Calculated as = Al/cation exchange capacity [«(K, Ca, Mg, Na and Al)]×100

Table 2. Average values of EFB isolated from diverse pasture.

Pasture	SP(%)	MP(%)	SPMP(%)	NSM(%)	TOTAL(%)	TOTAL EFB(%)
1	1.4	65.9	11.3	21.4	100	77.2
2	5.2	74.7	15.8	4.3	100	90.5
3	2.5	17.5	66.0	14.0	100	83.5

SP=EFB that solubilize phosphate; MP= EFB that mineralize phytate; SPMP= EFB that solubilize phosphate and mineralize phytate; NSM= EFB that no solubilize phosphate and/or mineralize phytate.

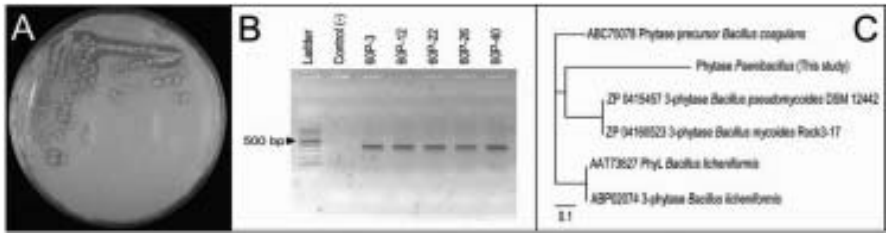
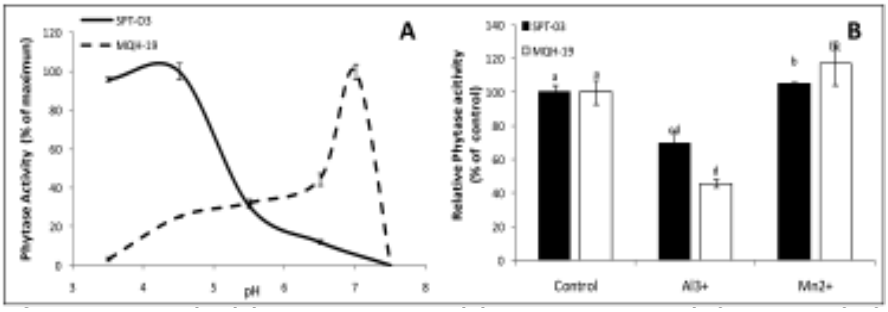


Figure 1. (A) Phytate-mineralization on agar by EFB. (B) PCR amplification of phytase gene in environmental isolates of EFB. (C) Neighbor-Joining tree showing phylogenetic affiliation of detected phytase and the closest relative phytases in Genbank database.



Paenibacillus **SPT-03 and** ***Bacillus*** **sp. MQH-09 in dLB broth. CT= control; Al= aluminium; Mn= manganese. Each value is the mean of three replicates. Values with the same letter on bars are not significantly different (Pd» 0.05) according to Turkey´s test analysis.**

Conclusions

This study shows the presence of phytase-encoding genes in endospore-forming bacteria present in acidic volcanic soils from southern Chile. Also, this study gives evidence on the effect of acidity and metal cations on phytase activity by endospore-forming bacteria.

Acknowledgements

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ASSESSMENT OF INFLUENCE OF OVERWINTER PROCESSES ON SOIL DEGRADATION BY WIND EROSION

Jana Kozlovsky Dufkova

Department of Applied and Landscape Ecology, Mendel University in Brno, Zemedelska 1, 613 00 Brno, Czech Republic, European Union, ph. 00 420 545 132 472, janadufkova@email.cz

Summary

Heavy clay soils that are normally resistant to wind erosion, from three study sites situated in the foothills of the Bile Karpaty Mountains, Czech Republic, were a subject of laboratory analyses. The analyses should found out the influence of overwinter processes on disruption of soil aggregates and thus reason of vulnerability to soil loss by wind. Two overwinter processes were observed – freezing and thawing, and freeze-drying of the soil. Both processes have indicated the increasing of erodible fraction in dependence of water content of analysed soil. Exposed frozen clay soils that freeze-dries during the winter in the foothills of Bile Karpaty, leaves soils highly erodible in late winter and early spring.

Introduction

Soils with higher content of clay particles (heavy clay soils) should not be vulnerable to wind erosion according to various data sources (Skidmore, 1997; Fryrear, 1995; Chandler *et a*l., 2005; Dufkova, 2007) due to the formation of clods and surface crust that resist the blast of wind. However, heavy clay soils can become as erodible as a sandy loam during specific climatic conditions – overwinter processes. Wetting and consecutive drying, freezing and thawing, and freeze-drying of the soil especially are the main reasons that make resistant heavy clay soils vulnerable to soil loss by wind (Bullock *et al.*, 2001).

In the Czech Republic, Central Europe, wind erosion is a problem on about 26% of agricultural soils of Bohemian part of the Czech Republic and 45% on Moravian one.

The study, supported by the Ministry of Agriculture of the Czech Republic (project No. MZE QH82099, Criteria of wind erosion expansion on heavy-textured soils and possibilities of its limitation with biotechnological control measures»), deals with the problem of wind erosion on heavy clay soils, which can be found in the south-east of the Czech Republic.

Materials and methods

Study Sites

The study is conducted over three consecutive winters (2009–10, 2010–

11, and 2011–12) in the foothills of the Bile Karpaty Mountains, Czech Republic. Three different study sites, where wind erosion on heavy clay soils occurs, are chosen (Tab. 1). All the three sites are cultivated using conventional tillage (heavy-duty cultivator, disk harrow) which resulted in a ridged, roughened surface with negligible residue cover. Soils of the three study sites pass through the laboratory analyses, which should find conditions that lead to the disruption of soil aggregates and to their loss by wind. According to some experiments that were made in the U.S. (Bisal & Pelton, 1971; de Jong & Kachanoski, 1988; Larney *et al*., 1994), the soil aggregate disruption is influenced above all by the climatic conditions - effects of freeze/thaw and freeze/dry processes.

Table 1. Basic characterization of three chosen study sites

Study site	GPS	Altitude (m)	Soil type	Mean annual precipitation (mm)	Mean January temperature (°C)
Ostrozska Nova Ves	49°0'21"'N 17°27'30"E	249	Chernozemic Clay Loam	600	–1,5
Blatnice	48°57'57"N 17°27'2"E	300	Chernozemic Clay Loam	594	–2,1
Sucha Loz	48°58'50"N 17°42'46"E	355	Chernozemic Clay Loam	791	–2,4

Dry Aggregate Size Distribution

At all three sites, 6 kg of representative sample of soil (Jandak *et al.*, 2001) is collected from the 0–2,5 cm depth for laboratory analyses (McKenzie *et al.*, 2002). The soil is sampled in the period when the soil surface is not cover by vegetation or snow, thus in the period when the soil is most vulnerable to the soil loss by wind.

All samples are air-dried and passed through dry aggregate size distribution (DASD) analyses. Dry flat sieving with an electromagnetic sieve shaker is used. According to Lopez *et al.* (2007), using of the mentioned sieving method adequately measures erodible fraction (EF) and it can be used as an alternative technique to the standard rotary sieve. EF (aggregates < 0,84 mm in diameter) are erodible by wind, and soils with an EF > 60 % are considered at relatively high erosion risk (Chepil, 1942).

Laboratory study

Non-erodible fraction is consequently exposed to the effect of low temperatures in the laboratory conditions. Effects of freeze/thaw and freeze/dry processes are observed. Freezing process of moist soil during winter causes expansion of ice crystals within aggregates, and subsequent shattering (Chepil & Woodruff, 1954). Freeze-drying occurs when the soil is exposed to a combination of the right climatic conditions – frozen soil surface, air temperatures of ~0°C, and high wind speeds (de Jong & Kachanoski, 1988).

Few field estimates of the impact of freeze-drying on aggregate size changes and wind erodibility have been reported (Anderson et Wenhardt, 1966). Most of the information on aggregate size changes due to freeze-drying has been derived from laboratory studies (Hinman & Bisal, 1968; Staricka & Benoit, 1995). These studies have shown that soil water content at the time of freezing is an important factor influencing soil disruption on freeze-drying. This is the reason why aggregates from the three study sites are wetted to water contents approximately equal to (Tatarko *et al*., 2001):

- saturation – full water capacity, is reached when all the pores are full of water,
- field capacity – is the amount of soil moisture or water content held in soil after excess water has drained away and the rate of downward movement has materially decreased,
- wilting point – is defined as the minimal point of soil moisture the plant requires not to wilt; if moisture decreases to this or any lower point a plant wilts and can no longer recover its turgidity when placed in a saturated atmosphere for 12 h.

Freeze/thaw process

Cutoffs of -2°C for freezing and +2°C for thawing are used to estimate the number of soil freeze-thaw cycles (Bullock *et al*., 2001). With regard to the fact, that freeze/thaw process occurs several times during winter, the cycles are several times repeated. DASD analyses are made after every cycle, and EF are found out. Non-erodible fraction is repeatedly exposed to low temperatures in the freeze/thaw process to investigate how many cycles are needed for disruption of all the non-erodible fraction (i.e. till the time, the particles retained on the sieve have the constant weight).

At the same time, measurement of soil temperature and moisture runs at the chosen study sites to find out how many freeze/thaw cycles exist in natural conditions.

According to Tatarko *et al.* (2001), timing and form of precipitation plays a major role in determining wind erosion risk than number of freeze/thaw cycles. Hence, the laboratory analyses are realized with soil aggregates that are sampled in three overwinter periods with occurrence of different form of precipitation (Bullock *et al*., 2001):

- autumn period – with occurrence of autumn rain/snow,
- winter period – with occurrence of winter snow (soil sampled in the period without snow cover),
- spring period – with occurrence of spring snow/rain.

Freeze/dry process

Analogous to mentioned, laboratory analyses concerning the freeze/dry

process are done for three water contents and three sampling periods. The soil samples are placed in a -40 °C freezer box for 24 h (Bullock *et al.*, 1999).

After freeze-drying, the samples are gently sieved until all disrupted aggregates < 0,84 mm pass through. The aggregates retained on the sieve are subjected to repeat cycles of prewetting and freeze-drying as outlined above.

Results and discussion

The study contains by that time just results of soil analyses from spring 2009 from the study site Ostrozska Nova Ves. Results from the other sites of the winter period 2009–10 follow when laboratory analyses, that are very time-consuming, will be finished.

Dry Aggregate Size Distribution

DASD analysis was done for the Ostrozska Nova Ves study site. The EF ranged from 43,4 to 60,2% in the spring period of 2009.

Freeze/thaw process

Soil samples from spring period (2009) of Ostrozska Nova Ves study site were wetted to water contents approximately equal to saturation, field capacity, and wilting point.

The highest number of freeze/thaw cycles (i.e. 8 cycles), needed for the disruption of soil aggregates, has soil samples with water content approximately equal to wilting point, and the lowest number (4 cycles) has soil with water content approximately equal to saturation. Results show that the most water soil contains the most vulnerable to wind erosion is, because of faster disruption of the soil aggregates. The increase in EF leads to increased erodibility of soil. Results from the study of Bullock *et al.* (2001) also indicate that precipitation, which directly influences soil water content, is necessary for freeze/thaw cycles to be effective in disrupting soil aggregates.

Freeze/dry process

Soil samples from spring period of 2009 of Ostrozska Nova Ves study site were wetted, as above mentioned, to water contents approximately equal to saturation, field capacity, and wilting point.

The highest number of freeze/dry cycles (7 cycles), needed for the disruption of soil aggregates, has soil samples with water content approximately equal to wilting point, and the lowest number (2 cycles) has soil with water content approximately equal to saturation. The laboratory study shows the importance of water content of soil at time of freezing on the disturbance of soil aggregates. Exposed frozen clay soils that freeze-dries during the winter in the foothills of Bile Karpaty, leaves soils highly erodible in late winter and early spring.

This relationship between water content at time of freezing and aggregate

disruption has also been reported by Anderson et Wenhardt (1966). They found that fall-irrigated soils are more prone to aggregate disruption by freeze-drying than non-irrigated soils.

Conclusions

The laboratory analyses have shown the influence of overwinter processes on disruption of soil aggregates. Both, freeze/thaw and freeze/dry process, have caused the increasing of erodible fraction, thus increasing of wind erosion risk. The results show the fact that content of water in the soil is the key driving force of the processes involved.

The above mentioned analyses will continue for the next three winters to find out which of the autumn, winter, or spring periods have significant impact on the aggregate disruption.

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SUSTAINABLE PIG SLURRY APPLICATION IN AGRICULTURAL SOILS IN CANCARIX AREA, SE SPAIN.

Yanarda 0.H. [(1)], Faz A. [(1)], Muñoz M.A. [(1)], Büyükkiliç Yanarda A.[(1)], Breton J [(2)].

[(1)] Sustainable Use, Management and Reclamation Soil and Water Research Group. Agriculture and Science Technology Department, Technical University of Cartagena, Paseo Alfonso XIII, 52. 30203-Cartagena. Murcia. Spain. tel:+34 968325634. fax:+34 968327046 email: ibrahim.yanardag@upct.es
[(2)] Environmental Department, CEFU, SA. Paraje La Costera, s/n. 30840 Alhama de Murcia. Murcia. Spain. Apdo. 55. jorge.breton@cefusa.com

Summary
Spain is the second largest pig producer in the European Union. Therefore, the slurry management is becoming an important environmental problem. On the other hand, pig slurry present high nutrient contents, so it can be applied to agricultural soils for fertilization purposes. It could be an alternative and valuable practice in some countries such as Spain where pig production is extremely high. However, sustainable pig slurry application must be carried out in order to prevent environmental risks, based on soil and crops properties.

Introduction
Spain is the second leading European country in swine population (22.4 million head in 2000), representing 18% of total production within the European Union, with a substantial increase over the last ten years (38% from 1990 to 2000) (Daudén and Quílez, 2004). Therefore, sustainable pig slurry application can be very important role on environment. The pig slurry applications can directly or indirectly affect soil physical, chemical, and biological properties. The aim of this study is to determine effects of different and raw-treated pig slurries application in agricultural soils and to supply of sustainable pig slurry application.

Materials and methods
Firstly soil and pig slurries were characterized prior to them; slurries came from liquid and solid livestock diet. The study area was located in the SE Spain. 96 soil samples from 24 plots considering two depths, 0-30 cm and 30-60 cm and three replicates were taken. Moreover, physico-chemical pig slurry properties were determined, before and after chemical treatments. The collected samples were taken to the lab, air-dried for 7 days, passed through a 2-mm sieve, homogenized, and stored in plastic bags at room temperature prior to laboratory analyses. The analyses for this study were determined as follow: pH measured in a 1:1 water soil ratio solution according to Peech´s method (1965); soluble salts according to Bower and Wilcox (1965); organic carbon and nitrogen according to Duchaufour (1970), texture analysis carried out by using the FAO-ISRIC system (1990).

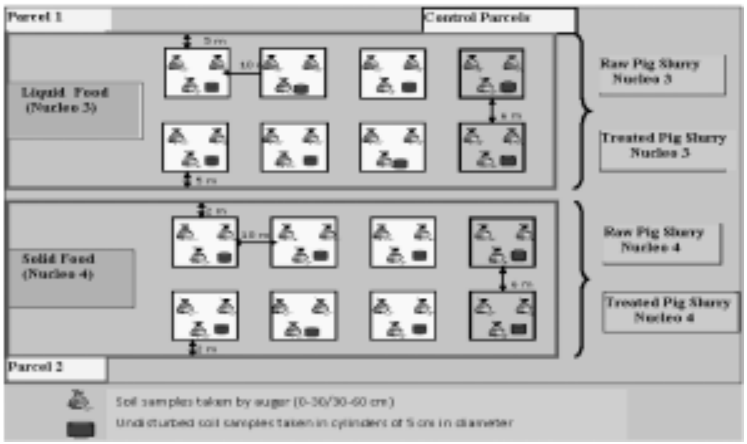

Figure 1. Distrubition of parcels and soil sampling.

Results and Discussion

Table 1. Some chemical characteristics of surface soils (0-30 cm) in studied area.

(0-30 cm.)	OC (g kg^{-1})			TN (g kg^{-1})			C/N		
Parcel				Raw pig slurry (N3)					
A	27,8	±	2,4	3,4	±	0,4	8,3	±	0,3
B	16,4	±	4,5	1,5	±	0,3	11	±	3,3
C	20,3	±	3,4	2	±	0,2	10	±	0,6
D	20,2	±	2,2	2,5	±	0,3	8,2	±	0,2
Parcel				Treated pig slurry (N3)					
A	21,1	±	2,7	2,8	±	0	7,6	±	0,9
B	31,1	±	5,2	3,7	±	0,6	8,5	±	0
C	16,9	±	4,1	2,2	±	0,2	7,6	±	1,3
D	16,4	±	2,6	2	±	0,5	8,4	±	2,2
Parcel				Raw pig slurry (N4)					
A	35,5	±	10,1	4,5	±	0,8	7,8	±	0,9
B	25,2	±	11,7	3,8	±	1,5	6,6	±	1
C	25,8	±	11,1	3,8	±	1,5	6,8	±	0,5
D	12,7	±	4,8	1,9	±	0,4	6,7	±	1,3
Parcel				Treated pig slurry (N4)					
A	24,8	±	4,9	3,4	±	0,6	7,2	±	2,9
B	29,4	±	12,3	4	±	1,5	7,3	±	0,9
C	17,1	±	4,9	2,4	±	0,8	7,1	±	0,3
D	22,4	±	3,3	3	±	0,5	7,6	±	1

Soil showed slightly-moderately alkaline pH, slightly saline, with loam texture and high calcium carbonate. Mean average carbon and total nitrogen contents were 1.6% and 1.9 g kg^{-1}, respectively, and C/N ratio was 8.8. Pig slurry results showed, generally, neutral pH and high electrical conductivity; raw pig slurry from the liquid livestock diet, without physico-chemical treatment, presented the highest total nitrogen contents.

Table 2. Some chemical characteristics of subsurface soils (30-60 cm.) in studied area.

(30-60 cm)	OC (g kg^{-1})			TN (g kg^{-1})			C/N		
Parcel				Raw pig slurry (N3)					
A	8,5	±	1,8	0,8	±	0,3	11,7	±	3
B	10	±	0,1	0,8	±	0,1	13,2	±	1,7
C	11,3	±	4,9	1	±	0,5	11,5	±	1,1
D	13,7	±	7,8	1	±	0,5	13,2	±	1,2
Parcel				Treated pig slurry (N3)					
A	4	±	1,2	0,6	±	0,2	7,3	±	0,9
B	12,9	±	1,2	1,7	±	0,1	7,6	±	1
C	15,8	±	2,1	1,4	±	0,1	11,5	±	2
D	9,5	±	1,4	0,9	±	0,1	10,4	±	1,3
Parcel				Raw pig slurry (N4)					
A	10,7	±	5,3	1,6	±	0,9	7,2	±	1,4
B	9,6	±	5,7	1	±	0,7	9,4	±	0,7
C	7,8	±	5,5	0,8	±	0,3	8,9	±	4
D	8,1	±	2,7	1,2	±	0,5	7,3	±	3,1
Parcel				Treated pig slurry (N4)					
A	7,7	±	2,8	0,8	±	0,1	9,9	±	0,4
B	8,3	±	4,5	1,1	±	0,6	7,6	±	0,5
C	14,4	±	3	1,6	±	0,3	8,8	±	0,7
D	13,8	±	1,3	1,4	±	0,2	9,9	±	0,3

Table 3. Some physico- chemical characteristics of pig slurries

	pH	EC (dS m^{-1})	NT (g L^{-1})
Raw (N3)	7,1	21,9	3,4
Treated (N3)	7,5	20,3	2,3
Raw (N4)	7,0	24,6	3,8
Treated (N4)	8,1	14,1	1,1

Conclusions

In conclusion, our soils exhibited moderately soil organic carbon and raw pig slurry showed higher nitrogen content than the treated ones. Pig slurries could improve some physico-chemical soil properties and soil organic carbon contents, but can also decrease C/N ration. Therefore, pig slurry applications can increase soil quality.

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A LONG TERM MONITORING OF RANGELANDS IN ARID ZONES IN ALGERIA: INDICATORS OF LAND DEGRADATION AND DESERTIFICATION

Nedjraoui D., Hirche A.

Département d'Ecologie-Environnement USTB BP 32 El Alia Bab Ezzouar Algiers
dnedjraoui@yahoo.com; a_hirche@yahoo.fr

Summary

In Algerian steppes, the follow-up mechanism of desertification is based on scientific related to the changes of the ecological systems. To understand the various phenomena and the mechanisms responsible for these changes and the desertification will allow constituting reliable and relevant databases on the various compartments of the systems, biophysic environment and anthropogene activities. The processing and the analysis of these data will have for purpose to emphasize the biophysics and socio-economic indicatorsexpression of various constraints and disturbances implied in the increase of the process of degradation. The ecological observation and its follow-up have to be based on a monitoring plan, essential to the implementation of a national project of combating desertification, through:

- Reference systems, i.e. a network of observation sites on the field in a national scale,
- spatiotemporal information system based on the analysis of the satellite data,
- Knowledge of the mechanisms, causes, consequences and scope of desertification in order to make the knowledge usable for decision-making

Key words: Steppe, monitoring, indicators of desertification

Introduction

Algerian steppes, in arid and semi-arid areas, were always the space of development of the ovin breeding. These natural rangelands, which play a fundamental role in this primarily extensive system of production, are subjected to an increasing pressure, generating an important degradation of these ecosystems. One of the principal factors is the overgrazing produced by an increasingly significant livestock (Aidoud 1989; Nedjraoui and Bedrani, 2008). It is exacerbated periodically by long and frequent periods of dryness. Several authors tried to demonstrate the tendency to aridity in the Algerian steppes (Labani *et al.,* 2006; Hirche, 2007).

The establishment of observatories in these areas, since several decades, and developed by ROSELT/0SS (designed as a long-term «monitoring network) in western steppes (OSS, Algérie, 2005), allow the monitoring, the follow-up of quantitative and qualitative evolution of plant diversity and the impact of agro-pastoral practices on soils.

Material and methods

Two approaches are used in environmental monitoring: monitoring of biophysical parameters (meteorology, vegetation, soil, water) and survey of socio-economic parameters.

The collection of data set, on a defined time step, products indicators of ecological changes, maps of sensitivity to desertification, ecosystems vulnerability; these results are necessary to improve the analysis of causes and consequences of various environmental degradation processes.

Results and discussion

1 Pressure indicators

1.1 Trend in aridity

The Algerian steppes are characterized by high interannual variability of rainfall. In addition, recent decades have seen a significant decrease in annual rainfall, sometimes with several consecutive years of persistent

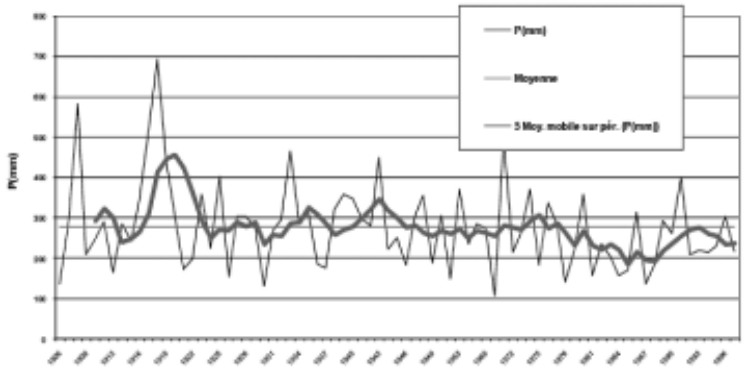

Figure 1. Rainfall evolution in Mecheria (Algeria) (Hirche 2007).

drought. The decrease in rainfall is about 18 to 27% and the dry season has increased by 2 months during the last century (Figure 1).

1.2 Overgrazing

The number of livestock grazing in the steppe zones, which component is the predominant breed of sheep (about 80% herd) has steadily increased since 1968 (6 Million) to 2000 (20 000). Overgrazing is related to growth of the population steppe (400 000 Hab. in 1968 and 5 millions Hab. in 2005) with a significant decline of nomadism (25 to 5%). The

retention of a sheep too high on the best pastures and around water points causes trampling, compaction and surface soil compaction, which significantly increases the risk of erosion. Sanding areas are formed at these levels, giving a picture of desertification.

2. Response indicators :change in vegetation and biodiversity

The change of vegetation cover and erosion of biodiversity (Table1) characterize the regressive evolution of all steppe. This loss of pastoral potential (Table 2) has reached a worrying level and often irreversible damage thresholds are observed in these fragile ecosystems by anthropogenic pressures constant.

The vegetation mapped in 1978 had completely disappeared and are replaced by others (Figure 3) which are indicators of degradation such as *Atractilys serratuloides*, *Peganum harmala*. Formations found today

Table 1. changes in vegetation and biodiversity (Roselt Algérie 2005)

Vegetation	1978	2004
Areas of vegetation (ha)		
Stipa tenacissima	252 197	40 916
Lygeum spartum	313 379	44 786
Artemisia herba alba	107 413	805
Floristic richness (number of species)		
Stipa tenacissima	73	34
Lygeum spartum	70	23
Artemisia herba alba	42	32

Table 2. Pastoral production (Pp) of main steppes.

Formations	Pp (UF/ha) 1978	Pp (UF/ha) (1993)
Stipa tenacissima	070-140	018-074
Artemisia herba alba	070-190	022-120
Lygeum spartum	080-200	025-082

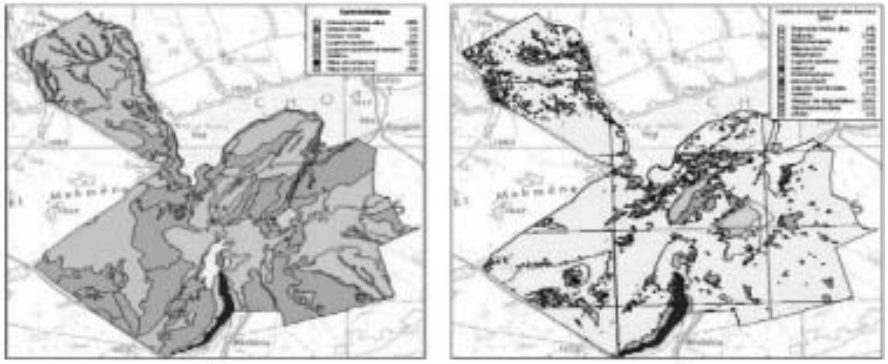

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Figure 3. Land use El Biodh : (1 :1978, CRBT 1981 ; 2 : 2003, ROSELT/Algérie 2005)

are altered both the density of vegetation cover in terms of their pastoral. In 1978, 2 / 3 of rangelands had a covering over 25% currently, only 1 / 10 show a recovery of that order in last period.

Conclusion

Rangelands in arid zones of Algeria, that play a fundamental role in the agricultural economy of the country are subject to recurrent droughts and an increasing human pressure: overgrazing, use of land unsuitable for crops.For over thirty years, they know a degradation becoming more pronounced for all components of the ecosystem (flora, vegetation, soil and its components, and wildlife habitat). This land degradation and desertification, which is the most advanced stage, resulting in the reduction of biological potential and the disruption of ecological and socio-economic balances.

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LAND-USE CHANGE AND BIODIVERSITY CASE OF A LOW MOUNTAIN LANDSCAPE IN NORTH CENTRAL ALGERIA

L. Berchiche, M. Dahmani-Megrerouche

Laboratoire d'Ecologie Végétale, Faculté des Sciences Biologiques, Université des Sciences et de la Technologie H.Boumediène. BP.32 El-Alia BabEzzouar 16111. Alger, Algérie. Email : malika_dahmani@yahoo.fr

Abstract

The ancestral human activity profoundly modified the Mediterranean landscapes (Quezel & Medail, 2003) and its action became more marked, these last decades, to the level of the Algerian landscapes, often engendering the habitats fragmentation and an impoverishment of their biodiversity and land quality. This study deals with the influence of the land-use changes on the low mountains landscapes (soil potentiality, biodiversity), more vulnerable by their accessibility. The cartographic analysis on four decades, reveals an important dynamics of the landscapes components marked by cycles *interest-desinterest* for the agricultural practices(mixed farming and especially olive growing) imposed by the demographic growth and the economic situation of the region. In spite of a current trend to the abandonment of farmland, the frequency of the fires facilitates the extension of matorrals in depends on forest landscapes. The influence of this landscapes artificialisation is indicated by a specific diversity decrease. It is revealing also by microclimatic and edaphic modifications accompanied with an increase of stress tolerant and ruderal species (thérophytisation) with the disturbances intensity. The tendency is to standardization and to trivialization of the flora linked to the extension of pluriregionals elements, altering the phytogenetic and soil heritage.

Key words: Algeria, land-use change, mountain landscape, land degradation.

Introduction

It is admitted that, with climate change, the land use change are at the origin of the major modifications observed to the biosphere,level and their impacts on the structure and the dynamics of the landscapes and biodiversity remain insufficiently studied (Barbault *et al*., 2005). In Algeria, the landscapes degradation was revealing by several papers treating forest or steppic ecosystems. The biological diversity erosion induced by the drastic anthropic actions, constitutes nowadays, one of the major preoccupations. In most of the research works led in this domain, the evaluation of the biological diversity is limited to the specific scale. For

some years, the research extended at the differents levels of perception, in particular that of the landscape.It is in this perspective that joins this study which tries to understand the consequences of the anthropic modifications of mountain landscapes. The objective is to identify, to map and to follow the evolution of the various components of these landscapes on several decades (diachronic approach), to understand the space management modes adopted by the local populations and to put in evidence their impact on the biodiversity and land preservation or erosion (Berchiche, 2004).

Methods

The evaluation of the plant diversity of a low mountain region (North central Algeria), was realized at two levels of perception:

1/ landscape Level: realization of a diachronic mapping in 1/25000 (Map Info logiciel), redrawing the dynamics of the landscape components throughout the last forty years (on 1959, 1973, 1983 and 1999) and the implementation of a S.I.G.

2/ Plant community level (identified by statistical analyses: AFC, CAH).

A stratified sampling is realized on the basis of vegetation type, Nearness of the villages, exposition and topography.

Results and discussion

Evolution of the population

The analysis of the anthropic factors reveals an important dynamics of the population, with a 1,47 % growth rate, and a various economic activities. Indeed, the population distributes administratively on several hamlets and villages. It knew a continuous growth these last years. Its density, estimated at 180 inhabitants/km ^{2} in 1948, did not stop growing throughout the years to reach 398 inhabitants / km ^{2} in 2002. This evolution of the population come with change in the spatial distribution of the inhabitants and their mode of land use. The diachronic study of four land use maps so realized for 1959, 1973, 1983 and 1999 reveals an important dynamics of the present various landscape components in the region especially in terms of occupied surfaces (figures 1 and 2).

The natural vegetation unit represented essentially by matorrals formations knew a fluctuation in its surface with a trend about a net increase during the last decades as shows it the figure 2: 34% of the total surface in 1959, 17% in 1973, 47% in 1983 and 54% in 1999 (36% for the high matorrals and 18% for the low matorrals). The mountain mixed farming unit knows at present a net regression: 28% of the total surface in 1959, 52% in 1973, 33% in 1983 and 19 % in 1999. The

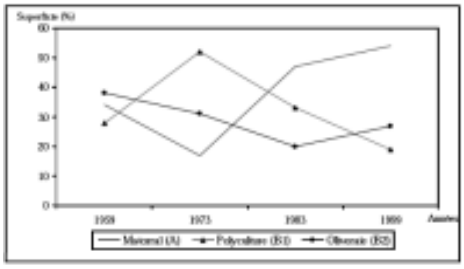

Figure 1
Landscapes components evolution

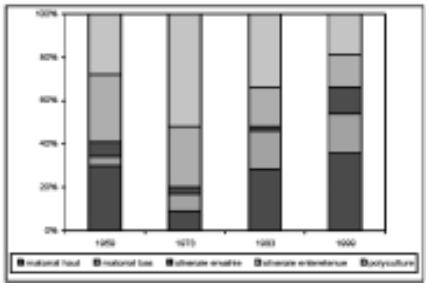

Figure2
Landscapes sub-units evolution.

oliveraie also underwent variations of surface during these last forty years; 38 % in 1959, 31% in 1973, 20% in 1983 and 27% in 1999.

Evaluation of the different landscape components biodiversity

The comparative study of the landscape components allowed to put in evidence the influence of the artificialisation on the region. The repeated elimination of the natural plant cover engenders floristic modifications in relation with microclimatic and edaphic changes. The amplitude of these modifications depends on the intensity and on the frequency of openings. This phenomenon is put in evidence by a wide therophytisation of the flora (development of stress tolerant and ruderal species (sensu Grime, 1977), as well as by the installation of a pluriregional species, indicator of a certain standardization and trivialization of the flora and vegetation, so altering the phytogenetic and soil heritage (Dahmani-Megrerouche, 1996). The quantitative evaluation (Table 1) underlines the influence of the intensity of the anthropic disturbance on the biodiversity. So the natural formation (matorrals) relatively less disrupted, are characterized by a relatively higher diversity index (H'=2,5; S= 61)) with regard to oliveraies (H'= 1,7; S=92).

The high richness in oliveraies explains by the presence of a very developed herbaceous stratum, facilitated on one hand, by the luminous climate (Floret *et al* 1992) and the edaphic drought, induced by the

Table 1. Quantitatifs parameters of biologic diversity

Groupements Biodiversity Parameters	Schrublands (A)	Laws (B1)	Oliveraie (B2)
Specific richness (S)	61	42	92
Shannon- Wiever index(H')	2,2	1,8	1,7
perturbation index (Ip %)	35	62	46

opening of the plant cover (Bonin *et al*, 1991) and on the other hand, the agricultural practices facilitating the diversity (fertilization by the pasture) (Romane *et al*., 1997) .

Conclusion

An important dynamics linked to the local population activities emerges from the cartographic analysis of the landscape. Indeed, traced on the economic situation of the region, we attend cycles *interest-desinterest* for the agricultural practices. If during the first decades we observe a dominance of the mixed farming, particularly the olive growing, the current tendency is on the return to the natural vegetation. However, the fires, which also play a major role in the distribution of the landscape components, facilitate the extension of matorrals in depends on forest landscapes. In spite of, the extension of the natural vegetation (matorral) during these last years, more than 50% of the region still remains artificialised. The evaluation of the biological diversity, through the comparative study of the various plant communites, underlines the impact of these anthropic modifications on the microclimate and the soil trophic quality, attested by tendency to therophytisation and trivialisation of the flora and vegetation.

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THE IMPACT OF THE ANTHROPIC ACTION AND THE ARIDITY ON THE PASTORAL PRODUCTION IN THE *Stipa tenacissima* L. STEPPS OF ALGERIA

H. Kadi-Hanifi, A. Sadji

Ecology and environment Laboratory Faculty of Biological Sciences – Sciences and Technology Houari Boumediène University B.p 32 El Alia Bab Ezzouar Algiers

Summary

The current state of the steppe rangelands came as a result of a precarious environment constraints (climatic and edaphic aridity) and of an old and a more and a more intense anthropic exploitation. To asses the pastoral production of the alfa steppes, a matrix of 183 statements and 499 species collected in all the Stipa tenacissima formations (alfa) of Algeria, was subjected to factorial analyses of the correspondences combined with ascending hierarchical ranging. Thus ten (10) distinguished groupings were characterized on the floristic, ecological, biological phytochoric and pastoral scale. The latter can be apprehended by two methods, the first one, quantitative, consists to cut the vegetation and asses its energetic value. The second one which is qualitative and simpler deals with giving a pastoral value to a grouping starting from the values coefficients assigned to each species as well as theirs relatives frequencies (Delpech, 1960 in Hirche, 1995). From the pastoral analysis, we notice that the pastoral value of the various alfa groupings has no correlation with the rainfall. The pasture intensity inhibits the beneficial effect of the rainfall.

Key words: steppe, anthropic action, pastoral value, desertification

Introduction

The *Stipa tenaciccima* L steppe is a habitat of national interest and even an international one because of its ecological interest (against desertification) and its economic one (paper pulp manufacturing). Similar to the other steppe formations of great importances (*Artemisia herba alba* and *Lygeum spartum*), the alfa formations knew an intense degradation involving either their disappearance in some areas of the country (reduction of 75% of the sheets in one century (1900-1990) (Lehouerou, 1995) or their regression into other formations such as those *Artemisia herba alba* or those of *Lygeum spartum*. This regression is obviously accompanied, in some cases by a fall in the floristic richness and appearance a «banal flora» for both man and the animals (Aidoud, 1997**.** The overgrazing, the waste lands clearing and the ploughings are the major causes of this situation which is worsened by the dryness. To the increasing concern towards this phenomenon, an awakening leads

the organizations and the government to think about the conservation and safeguarding of this ecosystem. In order to achieve, however, these goals effectively, it is necessary to know these steppes ecology of, their biological diversity and its assessment. The work that we present treats this point of view, it deals with the identification of the vegetable groupings and their characterization on the phytoecological and pastoral scale.

Methodology

The data used within the frame of this work belong to Kadi-Hanifi-Achour (1998). The sampling was carried out on the basis of data and whole of preliminary prospections of various cartographic documents.

The whole distribution surface of the alfa was sampled, integrating all the formations, ie : the pre-forest, the matorrals, the tree steppes and the alfa steppes. In this dition we only considered the two last formations. The statements consisted in a description of the station general features, the physiognomical and floristic features and the ground surface features. Moreover, each species in the statements was assigned a coefficient of abundance-dominance whose appreciations were established according to the Braun-Blanquet and *al*. (1952) scale

All the floristic data was treated by the correspondences factorial analysis of (AFC) combined with the ascending and hierarchical classification (CAH) which represents the completion to any correspondences factorial analysis. Their aim is to describe the relations between the environment and the vegetation and to make the distinction of the vegetable groupings. The treatment was carried out according to several stages:

A global analysis which treated a matrix of 183 statements and 500 species using the abundance-dominance criterion.

Thirteen (13) partial analyses were carried out after eliminating a certain number of statements which took a marginal position or after describing, through each analysis of a grouping which in its turn, is eliminated for the analysis to be continued. This operation allows the bursting of all the statements which were concentrated around the origin.

By Using ANAPHYTO software, we specified for each grouping a phytosociological table in which statements are given in column and species in line. Then we calculated the covering of each species in each grouping according to Tomasseli method (*in* Long, 1954). This is to give the physiognomical type or the two first dominant species of the grouping. For the floristic characterization, and by means of the phytosynthetic table prepared by the software, we retained for each grouping, the species which are exclusive for this characterization and those which particularly dependent on it.

The groupings were characterized ecologically by taking into account, on one hand the ecological variables of the constitutive statements of the grouping and the autoecology of their characteristic species on the other hand.

Two approaches are generally used to assess the rangeland quality: a phytoecological approach and a zootechnical one.

The first one, which is simpler aims quantifying the vegetation and at assessing its energetic value. It comes out with a pastorale production expressed in UF/ha after taking into account the seasonal energetic values, the production coefficients related to the plant its environment and the use coefficients related to animals. However this concept of pastoral production of the resources expressed in energy equivalent shows its limits even if it has the advantage of allowing the calculation of the load because of, amongst other things the requirement of a tiresome measurement protocol (Hirche, 1995). In order to mitigate the difficulty. Therefore, an easier classification of the rangelands was suggested. This classification deals with a total coefficient of the quality assigned to a pasture according to its composition in fodder species and their contribution to the vegetation.

The pastoral value (Vp) is, thus, obtained by multiplying, for each species, its specific contribution (Csi) to the vegetation by a quality index (Is) and then by adding the results for all the species (Floret, 1988).

Thus the qualitative aspect of the rangeland is expressed by the specific index of quality (Isi) and that of the quantity is appreciated by the specific contribution to the vegetation (Csi).

The formula used in various experiences related to the algerian steppe (CRBT, 1978; Aidoud, 1989; Boughani and Hirche, 1991) is as follows:

$$Vp = 0.1 \times \sum_{n=1}^{N} Csi \times Isi \text{ with } Csi = Fsi / \sum Fsi \times 100$$

Csi = the specific contribution of the species defined as the ratio of the specific frequency (Fsi) (absolute) with the sum of the specific frequencies of all the species listed on 100 sampled points. Isi = Specific index of quality.

It refers to an empirical expression of the food value of the plants. It is based on several parameters which are the speed at which the vegetation grows, its digestibility, its assimilability, its savour and its importance for animal etc.. It is noted on a scale of 5, 8 or 10 levels according to the authors. This shows the relativity of this index which can only be used on a purely comparative basis. According to Poissonet and Toure (1986 *in* Floret, 1988), indeed, it is not recommended to allot an absolute significance to the pastoral value of a pasture treated apart, because of the relative subjectivity of the indices, on a hand. On the other hand, the application of the latter allows very instructive comparisons between the pastures inside the same natural area.

An index of disturbance (IP) was calculated for each grouping in order to appreciate the individualized groupings degradation state. This index, defined by Hebrard and al. (1995) is given by the following ratio:

IP= Chamaephyte + therophytes / total number of the species.

Results

The total factorial analysis allowed the determination of the factors which would explain the distribution of the vegetation in these ecological groupings by searching the ecological significance of the factorial axes. The factors intervening in the vegetation distribution of the alfa studied formations would be: (i) rainfall; (ii) the thermophily; (iii) the anthropic degradation; (iv) the minima average of the coldest month (m) and (v) the ground surface state.

In order to obtain significant sets of statements, we took into consideration the CAH which classify them gradually on the basis of their floristic similarity until obtaining relatively homogeneous floristic unit. Ten (10) groupings were distinguished during these partial analyses and characterized on the floristic and ecological scale. They are as follows:

Grouping A: It corresponds to a *Stipa tenacissima Juniperus phoenicea* and *Globularia alipum* trees steppe.

Grouping B: This grouping corresponds to the *Stipa tenacissima and Arthrophytum scoparium* présaharian steppe formations.

Grouping C: It corresponds to the *Stipa tenacissima, Atractylis humilis* and *Rosmarinus tounifortii* steppe.

Grouping D : It corresponds to the *Stipa tenacissima* and *Lygeum spartum* and *Cutandia dichotoma* steppe.

Grouping E: It corresponds to the *Stipa tenacissima and Launea acanthoclada* steppe.

Grouping F: it corresponds to the *Stipa tenacissima, Artemisia herba alba* and *Asphodellus microcarpus* steppe

Grouping G: It is a grouping corresponding to a *Stipa tenacissima, Atractylis humilis and Helianthemum hirtum* steppe.

Grouping H: It corresponds to a *Stipa tenacissima, Eruca vesicaria* and *Artemisia herba alba* steppe.

Grouping I: This one corresponds to the *Stipa tenacissima Schismus barbatus* and *Artemisia herba alba* formations.

Grouping J: It corresponds to a pure *Stipa tenacissima* steppe.

The ten distinguished vegetable groupings belong, in major part, to the fresh and cold variables semi-arid bioclimate but the grouping B belongs to the fresh arid.

The geomorphological situation of the most of the groupings is variable (djebels slopes, glacis) except for the groupings A and C which are only located on the djebels slopes. Furthermore, we notice the presence of the harch elements in all the groupings with rates varying from 14% in grouping A to 40% in grouping H.

Table 1 shows the various pastoral values of the 10 groupings distinguished by the numerical analyses with their corresponding characteristics.

In general, the variation of the pastoral value between the various groupings is not significant According to figures 1 and 2 where the groupings are classified respectively according to the pluviometric and anthropic gradients, there is no correlation between the latter and pastoral value. Nevertheless, we can notice as for the pastoral value of the grouping C relative to alfa and romarin that it is relatively weak if we consider its rainfall (473.09 mm/an) and its floristic richness (247 species) which represente highest groupings with the second weak rate of therophytes (50.41%), however. This low value could be due to the fact that this grouping contains the highest number of species (21) non accepted by the cattle or toxics.

The grouping J is characterized by the lowest pastoral value (33,20 %), indeed, it covers 43 poor fodder species with a significant contribution to the vegetation (79,57%). However, the 77 good classified fodder species (77 species) only cover 12.96%.

Table 1. Groupings pastoral values.

Group	Formations	Pastoral Value	Floristic richness	Rainfall (mm/an)	Rate of therophyte (%)	Index of Disturbance (%)
A	*Stipa tenacissima and Juniperus phoenicea*	41,03	155	340,52	59,35	71,61
B	*Stipa tenacissima and Arthrophytum scoparium*	37,56	178	294,17	59,89	76,96
C	*Stipa tenacissima, Rosmarinus tournifortii and Atractylis humilis*	35,94	247	473,09	50,41	66,40
D	*Stipa tenacissima, Lygeum spartum and Cutandia dichotoma*	40,63	121	323,07	63,03	72,73
E	*Stipa tenacissima and Launea acanthoclada*	39,47	172	315,66	65,70	75,00
F	*Stipa tenacissima and Asphodelus microcarpus*	33,71	136	333,72	59,70	72,06
G	*Stipa tenacissima, Atractylis humilis and Helianthemum hirtum*	39,92	110	324,23	52,73	69,09
H	*Stipa tenacissima and Eruca vesicaria*	42,30	107	408,48	48,60	66,67
I	*Stipa tenacissima, shismus barabtus and Artemisia herba alba*	44,51	113	408,8	55,97	75,22
J	*Pure Stipa tenacissima*	33,20	161	302,95	61,61	70,81

Conclusion

The work presented aimed at the study of the floristic diversity of the Algerian alfa sheets alfa. The factorial analysis of the correspondences enabled us to carry out a global analysis using all the statements and the partial analyses to refine our interpretation.

The global analysis allowed us to determine the factors intervening in the vegetation distribution of the alfa formations. These factors are : the rainfall, the thermophily, the anthropic degradation, the minima average of the coldest month and the surface quality of the ground.

With the 13 partial analyses, we discriminated 10 vegetable groupings corresponding to the alfa trees steppe, the alfa steppes, more or less

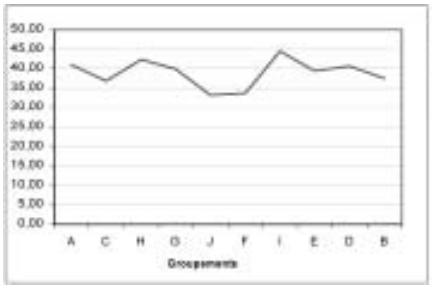

Figure 1. Pastoral values of the groupings classified according to the pluviometric gradient.

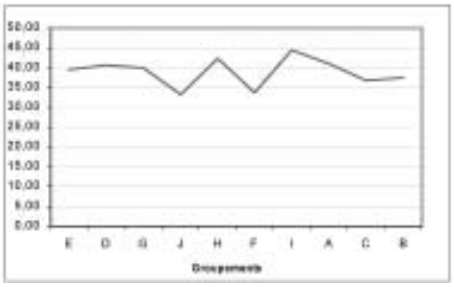

Figure 2. Pastoral values of the groupings classified according to the anthropic gradient

degraded of the fresh and cold semi-arid area and the *Arthrophytum scoparium* présaharian steppe formations.

The pastoral characterization of the groupings classified according to the pluviometric and anthropic gradients, does not show a correlation with the pastoral value. Anthropism inhibits the beneficial effect of the rainfall. Any thérophytes growth is immediately grazed.

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SOIL PHYSICAL ATTRIBUTES AND YIELD OF SUGAR-CANE IMPLANTED UNDER NO-TILLAGE SYSTEM

Laércio A. De Carvalho[(1)], Carlos A. Da Silva Junior[(2)], Ismael Meurer[(2)], José F. Centurion[(3)]

[(1)]Ph.D. in Agronomy, [(2)]Graduate student in Agronomy, Unit Aquidauana, State University of Mato Grosso do Sul, Km 12, countryside, zip code 79200-000, PO Box 25, Aquidauana, Mato Grosso do Sul, Brazil. Phone +55 67 3904 2940. lcarvalh@uems.br[(1)] and {carlos-junior89; ismael_meurer}@hotmail.com[(2)]
[(3)]Ph.D. in Agronomy, Department of Soils and Fertilizers. Faculty of Agricultural Sciences and Veterinary, UNESP, Jaboticabal, São Paulo, Brazil. Phone +55 16 3209 2672. E-mail: jfcentur@fcav.unesp.br

Abstract
The objective of this work was to study the effects of soil physical properties and resistance to penetration and productivity of the ratoon crop in no-tillage system. Treatment NT found high levels of soil density for ratoon cane, including the moisture retained by the greater accumulation of straw when compared to conventional treatments, which were also presented similar values for total porosity. Resistance to penetration NT showed higher values, caused by the minimum land mobility. There were no interactions ($p<0.05$) for the values of productivity in plant cane and the NT had lower cost for deployment. The tillage system was efficient as an alternative to deployment of sugar-cane.
Key words: Soil physical, productivity, no-tillage.

Introduction
The introduction of no-tillage system in Brazil has grown significantly in the last decade (Febrapdp, 2005), though with some impasse by presenting little tillage and increased humidity, combined with the performance of heavy machinery, causes some compaction in surface. The tillage system demands less labor and energy, stimulates the processes of flocculation and aggregation, reduces the rate of mineralization of organic matter (Castro Filho *et al.,* 1998) and minimizes erosion (Seganfredo *et al.* 1997).
In 2004/05 there were about 96 million hectares adopted the no-tillage system in the world and Brazil have been using no-tillage in about 25.5 million hectares (Febrapdp, 2008).
The objective of this study is to evaluate the physical properties of soil and yield of cane sugar in no-tillage conventional.

Materials and methods
The work was conducted at the experimental plant belonging to the ETH Bioenergy S/A, in Rio Brilhante, Mato Grosso do Sul, Brazil, during the

agricultural year 2009/2010, where it was cane sugar for the second year. The area is located in the geographic coordinates of 53° 57' longitude, west of Greenwich, and 21° 50' latitude south, with altitude of 650 meters. The soil of the area was classified as Acrustox, medium texture (Embrapa, 1999) and according to *Soil Survey Staff* (1998) it is an Oxisol. The climate of the region is Aw (tropical savanna), according to the classification of *Köppen*. Was recorded during the development of research a rainfall average of 1685 mm and average temperatures exceeding 80ºF.

The experimental design was completely randomized design with five replications, obtaining a total of twenty-five experimental units, each made with total area of 10,000 m^2 and spaced from the street ten meters in width, having a floor area to carry out the sampling of 200 m^2 (10m x 20m). The spacing used in the planting of the crop was 1.40 m between rows and two parallel rods at the bottom of the groove.

The treatments were deployed in May 2008 and consisted of two conventional tillage soil where conventional tillage (CTI) was the use of desiccation of soybean, followed by a disk harrow to 0.20 m, followed by an intermediate harrowing and plowing, after there was a leveling disk harrow to systematize the ground, the conventional II (CTII), consisted of only one subsoiling to a depth of 0.45 m, followed by opening of the groove for deployment seedpiece; For the treatment of no-tillage (NT) were controlled weeds with glyphosate, and without soil disturbance were opened between planting rows.

The attributes of soil physical quality of each treatment were evaluated in soil samples collected from January to February of 2010, understood the ratoon crop. Samples were collected in surface area of each experimental plot in the vertical direction, removing a sample of 0-0.20 and 0.20-0.40 m depth at two random points per plot, totaling twenty samples per treatment.

To determine soil physical quality for bulk density (Bd), water content () and porosity (TP), were used samplers like Uhland specific undisturbed samples with volume rings familiar, as they are immediately placed in foil and plastic bags and then placed in a freezer to prevent loss of structure and soil moisture, and subsequently dried in an oven for 48 hours at a temperature of 221° F, assigned to physical determination described above.

Additionally, it was realized in the field, the test of resistance to penetration (RP), using an impact penetrometer agricultural model IAA/Planalsucar the same soil depths, spaced at 0.10 m from where samples were collected.

The results in impacts dm^{-1} were converted to soil resistance to penetration by equation (Stolf, 1991):

$$RP\ (kgf\ cm^{-2}) = 5{,}6 + 6{,}89\ N(impacts\ dm^{-1})$$

Used the formula described for conversion of RP kgf cm^{-2} to MPa, multiply the result obtained by the constant 0.098.

At the seventh month of the ratoon crop was obtained stem diameter, measured using a caliper accurate to 0.05 mm in the third internode toward root apex, where they were randomly selected ten o'clock cane per plot, totaling of two hundred fifty measurements.
The data of production variables, the soil physical properties and penetration resistance were subjected to analysis of variance, using the statistical program SAS (SAS Institute, 1999), followed by the F test (p<0.05) and the averages were compared by Tukey test (p<0.05).

Results and discussion

The variable density of the soil to ratoon-cane showed interaction for the two layers are studied and shown in Figure 1. The no-tillage had higher values for soil density, probably because little soil disturbance.
In the long term, no-tillage system could possibly increase the dry matter accumulation and the lowest traffic machinery can contribute to reduction in density (Tormena *et al*., 2002).

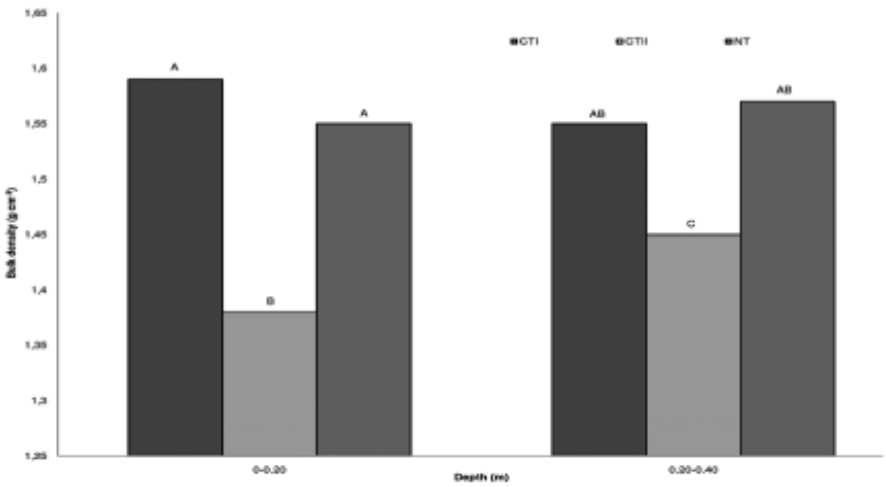

Figure 1. Test comparing the means of evaluation of the preparations for the density of soil at both depths. Capitalization equals not differ by Tukey test at 5%. *CT: conventional tillage; NT: no-tillage.*

For the variable porosity was found to interact with the layers 0-0.20 and 0.20-0.40 m as shown in Figure 2. It was found that for the CTII, was obtained for the two layers, higher amounts of total pores, and probably due to its preparation on the cane was at a depth of 0.45 m.
Total porosity for the other treatments are relatively similar, thus demonstrating the importance of the cultivation and preservation of the straw when performed tillage system.

Pointing to the other treatments was obtained considerable changes, especially for variable density, showing a steep rise.

The results of the evaluation of RP and soil moisture in the sugar-cane are shown in Figure 3. The value of RP and ¸ for the treatment NT has been relatively high compared to other preparations and in line with values found by Tormena *et al.* (2002), where resistance to penetration was higher in no-tillage system.

For Cavalieri *et al.* (2009), the tillage system shows signs of compression and that leads to long-term negative effects on some physical properties of soil, but by dynamic processes of these same properties kill the soil suitable for crop development.

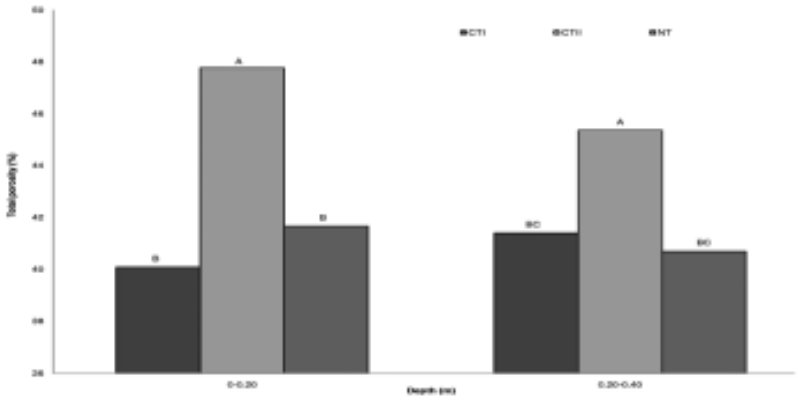

Figure 2. Test comparing the means of evaluation of soil tillage to total porosity in the two depths. Capitalization equals not differ by Tukey test at 5%. *CT: conventional tillage; NT: no-tillage*

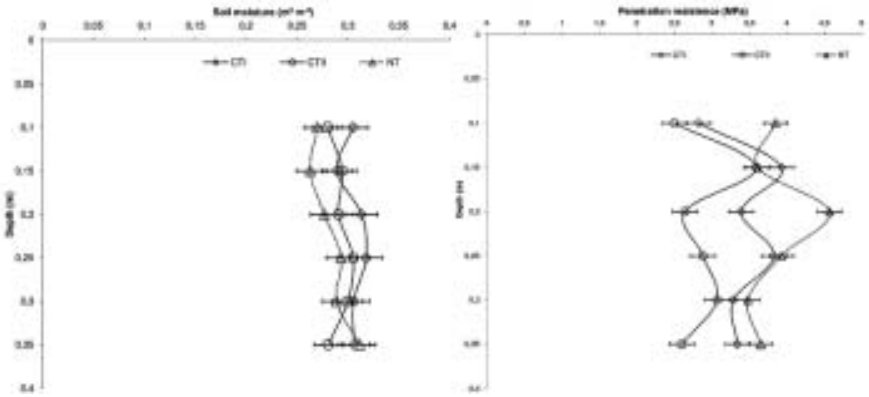

Figure 3. Resistance to penetration and soil moisture in different systems of tillage. The bars indicate the values of the average standard error and the overlap denotes the absence of differences between treatment means. *CT: conventional tillage; NT: no-tillage.*

For the variable stem diameter, measured in the sugar-cane, there was interaction (p<0.05) and is presented in Table 1, which relate the cost of each transaction in question. The treatment results showed NT in diameter and cost less than other treatments.

Table 1. Change in diameter of sugar-cane in different soil tillage, and the cost of each operation.

Parameters	Tillage			
	CTI	CTII	NT	CV (%)
	----------	mm	----------	
Stem diameter	23,54 a	22,62 ab	21,27 b	6,42*
	----------	R$ ha^{-1}	----------	
Cost	445,13	210,25	83,10	-

[ns]Non-significant.* Lowercase separate line, differ by Tukey test (p<0.05) between treatments.

Conclusions

The tillage system was feasible for the production of cane sugar and minimal degradation, and low cost deployment.

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SOIL PHYSICAL QUALITY RELATED TO SOME METHODS OF TILLAGE IN DEPLOYMENT OF SUGAR-CANE

Carlos A. Da Silva Junior[1], Ismael Meurer[1], Laércio A. De Carvalho[2], Marcos A. Camacho Da Silva[2], Walter S. Souza Júnior[1]

[1]Graduate student in Agronomy,
[2]Ph.D. in Agronomy, Unit Aquidauana, State University of Mato Grosso do Sul, Km 12, countryside, zip code 79200-000, PO Box 25, Aquidauana, Mato Grosso do Sul, Brazil. Phone +55 67 3904 2940. {carlos-junior89; ismael_meurer; juniorseraphin}@hotmail.com[1] {lcarvalh; camacho}@uems.br[2].

Abstract
The different systems of tillage promote changes in physical properties such as aggregation, density and porosity. Due to the compaction porosity is drastically reduced. Generally these properties function as indicators of possible restrictions on root growth of crops. The appropriate preparation of the soil, facilitating a better infiltration of water, contributes to erosion control. However, subsoiling practices, for example, aim to break layers impediment resulting from operations of machinery and vehicles, facilitate the process of conservation. The objective of this study was to evaluate changes in the physical structure of the soil in different types of preparation in the culture of sugar-cane from sampling through hardsetting depths of 0-0.20 m 0.20-0.40 m. The study was conducted from January to February 2009 at the Experimental Plant ETH-Unit Eldorado, evaluated from the collection of samples, the values of bulk density, penetration resistance of soil (RP). The use of minimum tillage showed the test results of bulk density for both layers 0-0.20 m and 0.20-0.40 m depth the highest values, the penetration resistance indicated in layer 0-0.20 m the conventional tillage I, II and III and lower resistance to penetration to the ground where the minimum tillage and subsoiling had considerable resistance, the layer 0.20-0.40 m, the preparations had a uniform resistance to all the same, considering the conventional tillage II with the lowest resistance.
Key words: *Saccharum,* soil compaction, conventional tillage.

Introduction
The sugar-cane (*Saccharum* spp) is showing the best answers when it comes to soil hydraulic conductivity compared to cotton production, because of their training be in the long run, seeing a restructuring of the soil on the porosity and general structure of their physical composition. As the management adopted for the implementation of culture, according to Lima *et al*. (2003), not only by direct effect of mechanical tillage caused during tillage, which favors its degradation, mainly by

the action of water erosion, but also by changes in soil environment, the influence of cropping systems.

The sugar-cane is set in grooves, with tractors and harvesters, traveling frequently in the rows. The pressure of machinery and implements on soil compaction can cause the same (Klein and Libardi, 2002). In this context, it was aimed to evaluate the effects of different management strategies adopted in the preparation of soil in the planting of sugar-cane in the physical attributes of soil quality and the effect on the mechanical resistance to root penetration.

Materials and methods

The study was conducted during the crop year 2008/09, in an experimental area belonging to the Eldorado Mill, located in the city of Rio Brilhante (Mato Grosso do Sul, Brazil), with geographical coordinates of 53° 57' longitude, west of Greenwich, and 21° 50' latitude south, with altitude of 650 meters. The climate characterized Aw, according to the *Köppen* classification, and soil is classified as Acrustox, medium texture (Embrapa, 1999) and according to *Soil Survey Staff* (1998) it is an Oxisol. During the development of research revealed annual rainfall of 1300 mm and average temperatures higher than 80ºF.

The physical characterization was performed on soil samples collected in layers of 0-0.20 and 0.20-0.40 m depth. The treatments consisted of three conventional tillage (CTI, CTII and CTIII), only one preparation using minimum tillage (MT) and subsoiling (S). Treatment CTI was characterized by the use of disk harrow disking, subsoiling to a depth of 0.45 m and a leveling disk harrow. On the CTII had made use of desiccation of soybean, followed by a disk harrow to 0.20 m, plus a harrowing intermediate, followed by plowing and harrowing for systematic leveling of the land. For the third tillage adopted (CTIII), we used two plows and a harrow harrowing harrows. In the fourth treatment (S) soil preparation consisted of only a subsoiling to a depth of 0.45 m, followed by opening furrows for sowing seed stalk. In the MT treatment was initially controlled the weeds with glyphosate and without tilling the soil, the furrows were opened sowing.

The treatments were arranged in a completely randomized design with six replicates, a total of thirty experimental units. Each experimental unit was formed with total area 10,000 m^2 floor area and to carry out the sampling of 200 m^2 (10m x 20m).

The physical attributes of soil in each treatment were evaluated in soil samples collected from January to February 2009, with the aid of samplers (Uhland) specific for undisturbed samples of volumetric rings (0.05 m in diameter and 0.05 m high). Samples were collected in surface area of each experimental plot in the vertical direction, removing three samples

in the middle layers of 0-0.20 and 0.20-0.40 m depth, for a total of thirty-six samples per treatment.

The samples were wrapped in aluminum foil and put in refrigerator, for minimal structural change and loss of water, held after the determination of the physical attributes of soil quality. Being obtained soil moisture on the basis of volume, bulk density (Bd), as determined by the ring and total porosity (TP), calculated using the formula described by Libardi (2005):

$$TP = \left(1 - \frac{Bd}{Pd}\right) x100 \qquad (1)$$

Additionally, it was realized in the field, the test of resistance to penetration (RP), using an impact penetrometer agricultural model IAA/Planalsucar the same soil depths, spaced at 0.10 m from where samples were collected. RP values obtained were calculated as Stolf (1991), using the following equation:

$$RP = \left(5{,}6 + 6{,}89\, x((\frac{N}{P - A}\, x\, 10))\, x\, 0{,}0981\right) \qquad (2)$$

Knowing that RMP is the soil resistance to root penetration in MPa, N is the number of impacts made with the hammer penetrometer to obtain a reading, A and P are, respectively, the readings before and after the achievement of impacts in cm.

Data obtained from the physical attributes of soil quality and the RP were submitted to variance analysis and verified through the statistical program SAS (SAS Institute, 1999), followed by the F test ($p<0.05$) and the averages were compared Tukey ($p<0.05$).

Results and discussion

For the 0-0.20 m depth were not identified statistical differences ($p<0.05$) between preparations for the variable Bd (Table 1). The results of 0.20-0.40 m depth showed statistically significant changes for Bd, with higher values for MT and CTIII. Similar values were also found by Carvalho Filho *et al.* (2007) when comparing various types of soil tillage. The highest values of Bd are due to less soil, thus maintaining its structure, which in addition to being grounded, were subjected to machinery traffic.

The result obtained by the evaluation of soil moisture () to the depth 0-0.20 and 0.20-0.40 m, is shown in Figure 1. It was observed that there was no significance among treatments and depths, with the largest value the MT, increasing gradually as the depth. This indicates that where there is less mobility of the soil, such as MT, CTIII and S, the environment has adapted to a more stable microclimate, being in favor for moisture.

Table 1. Statistical Summary of systems of tillage to bulk density (Bd), soil moisture () and RP for the layers 0-0.20 and 0.20-0.40 m deep, and the cost of each tillage.

Treatments	θ	Bd	RP	Cost systems
	$m^3\ m^{-3}$	$Mg\ m^{-3}$	MPa	$R\$\ ha^{-1}$
		Depht: 0-0.20 m		
CT I	0,32	1,35	3,02 b	331,27
CT II	0,34	1,37	2,91 b	445,13
CT III	0,31	1,29	2,91 b	197,94
S	0,34	1,31	3,70 ab	210,25
MT	0,37	1,41	5,12 a	83,10
F	$1,37^{ns}$	$1,26^{ns}$	$7,30^{*}$	-
C.V. (%)	13,45	6,96	22,15	-
		Depht: 0.20-0.40 m		
CT I	0,37	1,45 abc	7,00	-
CT II	0,38	1,47 ab	6,68	-
CT III	0,36	1,44 bc	7,78	-
S	0,39	1,38 c	6,96	-
MT	0,39	1,55 a	7,55	-
F	$1,00^{ns}$	$7,34^{*}$	$1,76^{ns}$	-
C.V. (%)	8,58	3,46	10,60	-

Means with different letters in the column, and depth differ by Tukey test (F<0.05). *F-test significant at 5% significance level. ^{ns}F-Teste non-significant at 5% significance. CT: conventional tillage; S: subsoiling; MT: minimum tillage.

As the values of RP, we obtain the minimum tillage as compared to other preparations have a greater resistance to penetration and also larger values of Bd, and results of least resistance and Bd when used conventional tillage matching the values obtained by Camilotti *et al.* (2005), which presented high values of Bd for the minimum tillage in raw sugar-cane, and smaller values when used plow.

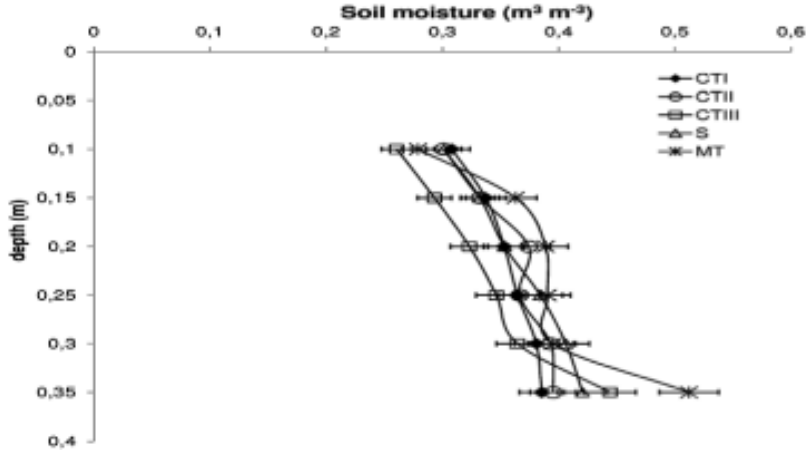

Figure 1. Moisture content of soil tillage in soil. The bars indicate the values of the average standard error and the overlap denotes the absence of differences between treatment means. *CT: conventional tillage; S: subsoiling; MT: minimum tillage.*

For the CTII has a better and efficient soil preparation for RP, showing lower value compared to minimum tillage, not differentiating well when applied to the other conventional tillage. Since the preparation with subsoiling, statistically, has a par with the minimum tillage, however, CTI has a low level to level of soil compaction.

Conclusions

The use of minimum tillage showed the test results of soil density and penetration resistance for both layers 0-0.20 m and 0.20-40 m deep soil with a smaller pore space leading to high levels. The conventional tillage treatments had significantly lower bulk density and penetration resistance. The MT and CTIII had lower production costs, while the CTII, CTI and S showed higher values.

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SPATIAL DEPENDENCE OF PHYSICAL PROPERTIES OF SOIL UNDER TWO CROPPING SYSTEMS OF SUGAR-CANE

Ismael Meurer[1], Laércio Alves De Carvalho[2], Carlos Antonio Da Silva Junior[1], Walter Seraphin Souza Junior[1] And Lucas Ponciano Ferrari[3]

[1]Graduate student in Agronomy, [2]Ph.D. in Agronomy, [3]Engineer Agronomy, Unit Aquidauana, State University of Mato Grosso do Sul, Km 12, countryside, zip code 79200-000, PO Box 25, Aquidauana, Mato Grosso do Sul, Brazil. Phone +55 67 3904 2940. E-mail: {carlos-junior89; ismael_meurer; juniorseraphin; lucas_poncianoferrari}@hotmail.com[1,3] and lcarvalh@uems.br[2].

Abstract

The production of sugar-cane (*Saccharum* spp) is influenced by a large number of environmental factors. Associated with climate, physical and chemical characteristics of soil are of great importance. The evaluation of effects of physical water quality of the soil has been made using different soil properties such as density, porosity and penetration resistance. The study aimed to evaluate the effect of two management systems of harvesting sugar-cane, mechanical and burning in two years of cultivation on physical indicators of soil quality in the layer 0-0.20 m. To study the physical quality of soil were analyzed the following variables: density, porosity and water content in soil. The results showed that the geostatistical methods used were adequate to describe the structure of spatial dependence of variable density. Only in the cropping system with burns showed the existence of spatial dependence, and had the same values of bulk density greater than the system of mechanized harvesting in the two study periods.

Key words: geostatistical, harvest, soil physics.

Introduction

The production of sugar-cane (*Saccharum* spp) is influenced by a large number of environmental factors. Associated with climate, physical and chemical characteristics of soil are of great importance. The evaluation of effects of physical water quality of the soil has been made using different soil properties such as density, porosity and penetration resistance. Generally these properties function as indicators of possible restrictions on root growth of crops.

Soil compaction affects growth and root development, increasing the density of the soil, nitrogen losses by denitrification, fuel consumption of the machines in the preparation of compacted soils and soil erosion by the lower water infiltration (Soane and Ouwerkerk, 1994). By decreasing the porosity, water and nutrients retained in the micropores under high tensions remain unavailable to plants (Kertzmann, 1996).

The management of crop-burning is done to facilitate cutting and loading, however this management practice is associated with high emissions of greenhouse gases, pollution of water sources and affect the maintenance of organic matter (Molina, 1995; Mendoza, 1996). Because of this, there was the implementation of a new management practice, the harvest of green cane prior call cane, thus the straw is left on the soil surface so crushed.

Maintaining the layer of plant material in the system can bring great benefits to the soil, among which we highlight the increase of water infiltration into the soil, reducing erosion losses, reduce water evaporation and improving the structure due to the presence of matter organic matter that acts as a cementing agent of the constituent particles of soil (Kiehl, 1979).

The objective of this study was to characterize the spatial variability of physical attributes in two management systems of harvesting sugar-cane, in two years of cultivation in Acrustox clay at a depth of 0-0.20 m.

Materials and methods

The study area is located in the municipality of Rio Brilhante, Mato Grosso do Sul, Brazil, the plant ETH Bioenergy S/A, located in the geographic coordinates of 53° 57' longitude, west of Greenwich, and 21° 50' latitude south, with altitude of 650 meters. The climate is tropical Bright Aw, with average rainfall of 119.29 mm/month. The experiment was conducted in two stands of cane, representing the same class of soil, classified as Acrustox clay texture (Embrapa, 1999) and according to *Soil Survey Staff* (1998) it is an Oxisol.

The experimental plot of each block presented in a georeferenced grid. Each loop had a length of 180 m with a width of 145.6 m covering an area with 90 points, which were collected soil samples in the 0-0.20 m depth and their physical.

The distribution of sampling points in the mesh was made in the form of a grid of nine rows by ten columns, with distal points from its neighbor at intervals of 20 m. Soil samples were collected in the agricultural year of 2007/2008 and 2008/2009, just after the second and third cutting cane, respectively.

To study the physical quality of soil examined the following indicators: soil bulk density (Bd), total porosity (Pt) and moisture (¸). In the pre-determined in advance and each patch studied, withdrew a sample of each point in the 0-0.20 m layer, making a total of 360 samples. The sampler used was of the type Uhland.

Soil samples were collected using volumetric rings undisturbed with volume already known. The sample was weighed wet and then dried in an oven at a temperature of 221º F until constant weight.

The data itself were previously analyzed using the procedures of statistical analysis, to visualize the general behavior and to detect outliers before the actual use of geostatistical tools.
Subsequently held the building through semivariograms of the variables to examine possible spatial dependence among the 90 points of each block to define parameters required to estimate values for non-sampled locations. At the end, it was necessary to apply the technique of kriging, which provided an interpolation of data to better understand the behavior of the factors studied, allowing the identification of areas with high compression.

Results and discussion

The values obtained for the descriptive statistics of the variable density in the soil layer 0-0.20 m in the study area are presented in Table 1.

Table 1: Summary statistics for the variable density (Bd) in the 0-0.20 m layer of harvesting management with burns and mechanized. Rio Brilhante, Mato Grosso do Sul, Brazil, 2007/2008 and 2008/2009.

Statistical measures	2007/2008		2008/2009	
	Burns	Mechanized	Burns	Mechanized
	----------	Mg m^{-3}	----------	
Mean	1,55	1.26	1,57	1.47
Median	1,56	1.29	1,58	1.47
Maximum	1,73	1.54	1,82	1.72
Least	1,33	0.87	1,17	1.17
Quartile more	1,59	1.41	1,66	1.58
Quartile lower	1,50	1.12	1,50	1.38
Variance	0,00	0.02	0,02	0.02
Deviation	0,07	0.16	0,13	0.13
C.V.(%)	4,51	12.69	8.15	8.65
Kurtosis	0,20	-0,84	0,78	-0.90

For values of mean and median, it is observed in Table 1 that in all the variables and the two cropping systems, in both periods, the ratio mean/ median is close to 1. Collaborating with these results Korah *et al*. (2004) studied the spatial variability of soil properties found that the values of the mean and median for all variables were similar, with medians showing values slightly smaller than average, despite the occurrence of some asymmetric distributions. According Cambardella *et al.* (1994), this may be an indication that the measures of central tendency are not dominated by outliers in the distribution.
The semivarigramas presented below (figures 1, 2, 3 and 4) correspond to two periods of analysis of the experiment, the burning and harvesting with mechanized.
It can be seen in Figures 1, 2 and 4 that all variables had low nugget effect, indicating that at small separation distances between points on

the variability is small, which means that this parameter to study the distance was adequate. Moreover, it is observed that the best fitted model is the spherical, in agreement with Baio (2001) and Ortiz (2003), where the spherical model provided the best fit to the semivariograms developed in their work.

Conclusions

The results showed that the geostatistical methods were appropriate to describe the structure of spatial dependence of variable density (Bd). Only in the cropping system with burns showed the existence of spatial dependence, and had the same values of bulk density greater than the system of mechanized harvesting in the two study periods.

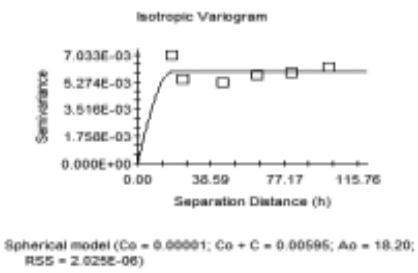

Figure 1. Semivariograma experimental and modeled in the system of management of the crop by burning-2007/2008.

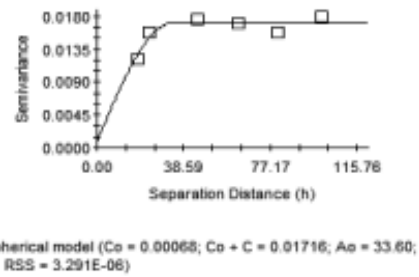

Figure 2. Semivariograma experimental and modeled on the management system of mechanized harvesting-2007/2008.

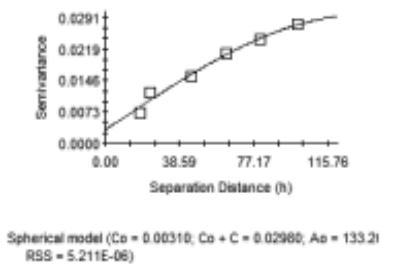

Figure 3. Semivariograma experimental and modeled in the system of management of the crop by burning-2007/2008.

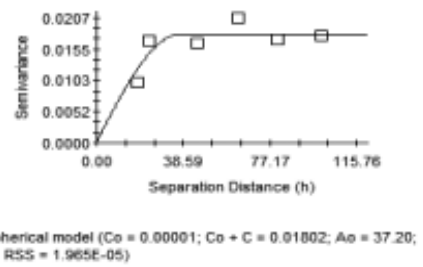

Figure 4. Semivariograma experimental and modeled on the management system of mechanized harvesting-2007/2008.

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QUALITY ASSESSMENT OF ENFORCEMENT IN THE IMPLEMENTATION OF WATER AND SOIL CONSERVATION LAW FOR STRATEGIC POLICY ADJUSTMENTS IN CHINA

Wang Ying, Zhang Xuejian

Department of Water and Soil Conservation, Water Resources Ministry of P.R.China,
Address: 2,Lane 2,Baiguang Road, XuanWu District, Beijing 100053, P.R.China.
Tel.: 00861063202847; Fax: 00861063202841; Email: wying@mwr.gov.cn

Summary

Water and Soil Conservation Law (WSCL) of China was issued in 1991 with an important objective of controlling human induced water and soil degradation resulting from intensive construction activities. This paper reviews the whole legislation framework and enforcement programs in order to identify how the enforcement system of WSCL could be improved more effectively. Applying the «Table of Eleven», a behaviour-analysis model with high practicability on compliance and enforcement assessment, we reveal the decisive factors affecting compliance behaviour of target groups and investigate the performance of the enforcement system in improving compliance. The behaviour of mining industries is studied in this research. The analyses involve the perceptions of both regulators and the mining companies with respect to the law and its enforcement. The result shows that during the past decades the enforcement programs have provided a solid legal foundation and mechanism to reduce water and soil degradation, supplied perception of high risk of being inspected to target groups, created the familiarity of the law, and well built the permitting process. However, the full compliance of law requirements is yet there. The research finds that the main factors encouraging the violating behaviours. And these factors also reflect main weaknesses of the enforcement system. Based on the analysis, we suggest that improvements in several aspects will constructively contribute in influencing target group s behaviour and enhancing the compliance. These improvements also accord with the main policy adjustments that Chinese legislators are trying to achieve during the process of revising Water and Soil Conservation Law right now.

Introduction

The most important purpose of enacting Water and Soil Conservation Law (SWCL) is to control soil and water damages through the regulations of various constructing activities. From the development of water and soil conservation law during the last nineteen years, we can discover a clear trace of the evolvement and adjustment of compliance strategies.

The first policy instrument used in the early stage of enforcement is building up the framework for enforcement. It composed several main measures such as creating the operational legal requirements, increasing the compatibility with related laws, building up the enforcement intuitional framework, providing authorities to these institutions, clarifying the roles and responsibilities of various levels of government and administrative agencies. The second policy instrument used in the middle stage of enforcement is confirming Soil and Water Conservation Program (SWCP), which is the design of the comprehensive measures to prevent water and soil loss from construction activities, as a prerequisite permit for the application of a construction project. The main objective of taking this policy is to create wide concerns of necessity of drawing and approval of SWCP among both related administrative agencies and regulated communities. The third policy instrument used in the recent years is the process control of implementing SWCP. The main components of this instrument are monitoring, third party supervision during construction, and completed acceptance check. Many enforcement activities involve various levels of inspections and non-compliance responses were carried on to detect and correct violations.

The fourth policy instrument through the whole enforcement stage is improving atmosphere of compliance. This instrument contains many compliance promotions approaches, such as educating and building public support, demonstrating values and publicizing success stories and enforcement information.

However, facing the acceleration of industrialization and violations by industry, enforcement of environmental law and regulations needs to be enhanced as soon as possible. The mining industry is a very important sector and largely responsible for soil erosions and related environmental problems, whereas, the compliance among numerous mining entities seems to be not commensurate with the purpose of sustainable development.

This research attempts to offer an insight into the reasons and considerations behind the behaviour of mining industries in order to reveal the linkage and mutuality between enforcement efforts of regulatory authorities and compliant decisions of regulated facilities.

This improved understanding of behaviour of target groups provides the present research the foundation and possibility to evaluate the performance of enforcement system with respect to SWCL and to find the solution for improving the effectiveness of this system.

Material and methods

Enacting pollution-control legislation is only the first step towards pollution reduction. Continued monitoring and enforcement is necessary to ensure

that firms invest in the appropriate control technology and operate it properly (Russell 1990). Achieving this goal involves finding out the factors that promote compliance and encourage noncompliance, utilising positive factors and overcoming negative factors, and removing barriers that prevent compliance.

The 'Table of Eleven' (T-11), a behaviour-analysis model, provides eleven generic dimensions (as shown in Table1.), which is helpful to systematically analyse the enforcement efforts of any enforcement organisation.

Based on the understanding of the compliance behaviour, T-11 provides an insight into the potential types of people complying or not with respect to the rules. The target group is divided into different kinds of violating and complying sub-groups: a) Unconsciously compliant sub-group; b) Unconsciously non-compliant sub-group; c) Spontaneously compliant sub-group; d) The sub-group deterred by enforcement or calculatingly compliant sub-group; e) Consciously or calculatingly non-compliant sub-group (The Dutch Ministry of Justice 2006).

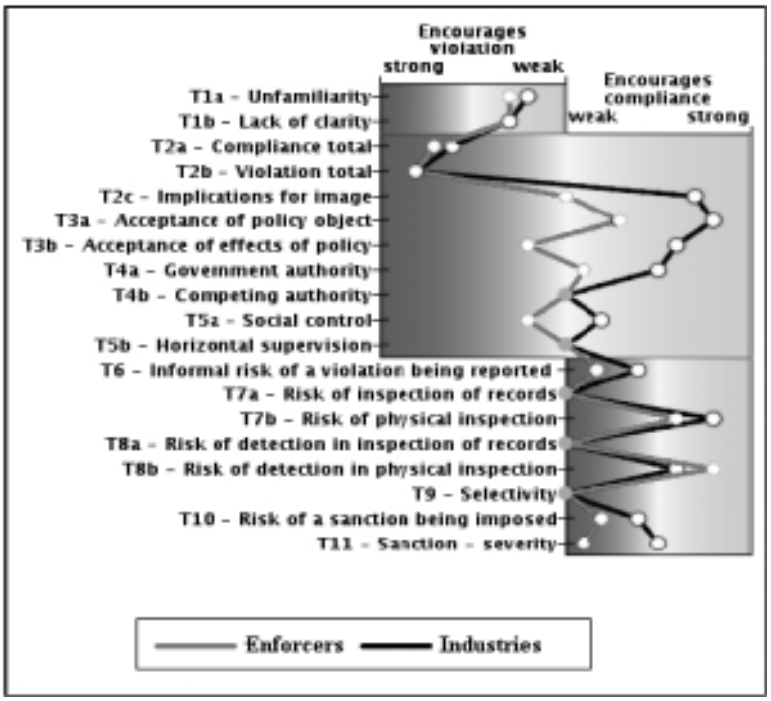
Table 1. Model of Table Eleven (Ruimschotel 2004)

Spontaneous compliance dimensions	Enforcement dimensions
•T1 Knowledge of rules	**•T5 Non-official, social control**
a. Familiarity of rules	a. Social control
b. Clarity of rules	b. Horizontal supervision ('by own members')
•T2 Cost/benefits	**•T6 Risk of being reported**
a. Economic cost/benefit for compliance	**•T7 Risk of inspection**
b. Economic cost/benefit for violation	a. Records inspection
c. Intangible costs and benefits	b. Physical inspection
•T3 Extent of acceptance	**•T8 Risk of detection**
a. Acceptance of policy objective	a. Detection in a records inspection
b. Acceptance of the effects of a policy	b. Detection in a physical inspection
•T4 Target group's respect for authority	**•T9 Selectivity**
a. Official authority	**•T10 Risk of sanction**
b. Competing authority ('group's own standards')	**•T11 Severity of sanction**

Results and discussion

Based on the data collected from interviews with both enforcers and mining companies. The result of the research shows the current compliance level of WSCL among mining industries is weak. The compliance profile of WSCL is shown in Figure 1. The profile describes the perceptions of two groups with respect to the influence of each dimension. It helps enforcers discover the reasons of the low compliance level and target on the motivations behind the behavior of mining industries.

Figure 1. Compliance Profile for Perception of Enforcers and Industries



Though there is difference existing in the perceptions between the regulators and the regulated group, some core factors affecting the behaviour of mining industries have been realized by both of them.

- Familiarity of the law among target group (T1a) and clarity of the rules (T1b) are helpful to decrease unconsciously violations.
- The dimension of intangible cost and benefits/fears of damages to reputation (T2c) is the main reason for spontaneously compliant behaviour. Especially the fear of delay or disapproval of construction project as the outcome of failure in the permit application of SWCP largely encourages many industries spontaneously apply the permit from water authorities.
- The dimensions of risk of physical inspection (T7) and risk of detection (T8) have stronger effects on deterring the industries into compliance than other enforcement dimensions.

However, the big economic benefits from non-compliance (T2a) and low cost of violations (T2b), low risk of being reported by social communities (T6), low risk of sanctions (T10) and minor severity of sanctions (T11) are the main dimensions that encourage calculatingly violating behaviour. The analyses from the dimensions of T-11 give a better understanding on the behaviour of target group. Meanwhile, the analyses from T-11

dimensions also facilitate to evaluate the performance of enforcement activities and to reveal the strength and weakness of current system in improving compliance of mining industries. The strengths of current enforcement system are as following:

1) Successfully building up the foundation and mechanism of enforcement and establishing approaches to reduce soil and water damages. The enforcers have been better authorized by the law and its following regulations. Various levels of institutions have been enhanced as well. The essential structure of control mechanism, which composed four important approaches: permit application (SWCP), monitoring, third-party supervision and completed acceptance check, has been established to ensure the implementation the requirements of the law. A set of regulation measures, standards and rules serve the practical operation. All these fundamental efforts enhance the enforceability of the law and provide potentials of the more effective enforcement.
2) Successfully supplying perception of high risk of being inspected to target group. The research shows the high risk of inspection conceived by mining industries is one of the major factors encouraging compliance. Although only 7% of interviewed officials think the enforcement resources are sufficient for detecting violations, the feelings of high risk of inspection have been created among mining companies. This reflects the big success of enforcement strategies adapted by water authorities. Variety of forms of inspections such as multi-sector, and entrusting inspection authorities to river basin organisations gather up and optimize the considerable sources of separately distributed resources and achieve in enhancing the effects and frequency of the inspections.
3) The successive publicity of the law and its requirements in the past nineteen years has successfully created the familiarity through the target groups. The strategies combined publicizing information, enhancing accessibility of public to enforcement information, educating and building public support, demonstrating values and publicizing success stories, also the grand-scale campaigns through various administrative levels have put big impacts on enlarging the knowledge of law among target groups. Due to the familiarity of the law, the unintentionally violations significantly decreases.
4) Permitting process becomes the threshold for environmental friendly activities. From the result of this research, both regulators and regulated group show their great respects on the importance of SWCP.

However, problems and weaknesses of the enforcement system are also discovered in current enforcement system.

Insufficiently creating atmosphere of deterrence

The research finds that compare to the high risk of inspection, the target group feels less risk of detection of violations. This shows mining companies feel that the violations are not be responded swiftly mainly for the following reasons: the sanction is too minor to deter the violations; the procedures for imposing sanction are very complex; the inspectors are not entitled enough by law to impose sanctions to violations;the intervenes of local governments put pressures on the inspectors;the response mechanisms seldom involve civil judicial and criminal enforcement; the sanction is not very easily predictable by the industries.

Failed to close up the policy loop through the cradle to grave process control

Among the four important elements to ensure implementation of the requirements of the law and to control soil and water damages-SWCP, monitoring, third-party supervision, and complete acceptance-only SWCP as the prerequisite controlling approach has been well accepted and implemented in a moderate compliance level. The monitoring and third-party supervision are extremely weak. Furthermore, a most important step missed in this controlling loop is the post-monitoring mechanism to evaluate and maintain the effects of the SWCP and detect the changes and new problems of water and soil resources. The direct outcome of this unbalance and unclosed enforcement loop is that the widely applied permits may become licenses for pollution.

Inadequate utilisation of reputation management

From the interviews, most mining companies care more on the damages of the reputation rather than the magnitude of the sanction. They think reputation is very important for the companies and very influential to the performance in the stock market. If the violation or sanction were disclosed, it would induce big loss of benefit and yield big negative influences to the company. Therefore, although both the probability and the severity of current sanction are very minor, wide publicity and strategic reputation management could be an effective approach to deter non-compliance. Some scholars also attach lots of importance on the role of reputation spillover effects. However, the publicity and exposure of violations are not widely used by enforcers because of internal and external pressures and considerations. The enforcers more incline to use conservative and informal responses like phone calls, site visits, warning letters, and notice of violations. But these informal responses seldom lead to more severe response or publicity if they are ignored. Therefore, the reputation management is not used enough to bring violators into compliance.

Failed to remove economic incentives to violate the law

Compliance yields little economic advantages. On the other hand, the cost of compliance is a considerate amount and the companies can save a massive time, money and efforts from skipping the permits application and neglecting the requirements of the permits. In addition, inadequate creating good social control and insufficient promotion and stimulation of compliance are also the main reasons of low compliance level.

Conclusion

Facing the more intensive construction activities and greater public interests in environmental issues, the improvement of the effectiveness of enforcement of WSCL will become more urgent and will face more challenges than ever before. Major findings in this research show the current enforcement need to be enhanced through the following nine aspects: 1) revise WSCL as soon as possible 2) enhance the stringency of detection and sanction 3) reputation management 4) close up the policy loop by establishing mechanisms of postmonitoring and auditing 5) create a reporting mechanism 6) set up proper economically stimulating policies for compliance performance bonds 7) increase the cooperation with other sectors and gain support from judicial system 8) education and training programs for officials 9) public participate.

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SPATIAL AND TEMPORAL MONITORING OF DESALINIZATION PROCESS IN IRRIGATED SOILS IN NIGER CONSIDERING SUBSURFACE GEOPHYSICAL SURVEY

Issifou Adam[1 2], Didier Michot[1], Christian Walter[1], Yadji Guero[2]

[1]UMR 1069 Sol-AgroHydrosystèmes-Spatialisation (SAS), Agrocampus-Ouest / INRA, 65 rue de St Brieuc - CS 84215, 35042 Rennes Cedex, France. E-mail : iadam@agrocampus-ouest.fr tel:+33 (0)2-23-48-54-38 fax: +33 (0)2-23-48-54-3
[2]Université Abdou Moumouni Dioffo Niamey, Faculté d'Agronomie Laboratoire Science du Sol BP 10960 – Niamey (NIGER)
Tél. : 20.31.52.37 – Fax : 20.31.66.12 E-mail : fagrony@refer

Summary
Located in dry zone, Niger has often recourse irrigation to do facing the hydric deficit limiting his farming. However the irrigation development had as consequence the degradation of soil by salinization. The general aims of this study is the spatial and temporal monitoring of dynamics of soil desalinization experiment in the valley of the river Niger The results showed a decrease in the values of the electric conductivity between the beginning and the end of experiment. The apparent electrical resistivity was increased of 2.95 ohms.m to 10,63 ohms.m. We estimated 14% (21 kg salts from initial stock of 148 kg salts) and 3% (21 kg from 616 kg salts) salts removal from the initial stock at 0-10 cm and 0-40 cm depths respectively.

Introduction
Soil degradation by salinity constitutes an obstacle in the development of agriculture in valley of river Niger. In the irrigated field we are facing a decline of crop yield due to increasing soil infertility. The spatial extension of the salinization phenomenon often leads to an abandonment of the soil under cultivation and consequently a decrease of agricultural area is observed.
Physico-chemical processes of soil salinization are well known (Cheverry, 1974; Szabolcs, 1989; Guéro, 2000). The difficulties in understanding salinization processes of irrigated soils reflect the deficit of knowledge, as an insufficient characterization of the ground water and soil surface interaction. Moreover, It is difficult to map exactly the spatial extension of the saline soils from the state of soil surface (salts efflorescence, surface crusts) or classic punctual measures (pH, electrical conductivity in saturated soil pastes). This difficulty is strengthened by the strong variability of salinity with time.

The present study aims at monitoring the spatial and temporal dynamics of soil desalinization experiment in the valley of the river Niger. In a field desalinization experiment, we try to map a strong spatial resolution of the soil salinity.

Materials and methods

Study site

The study site is located in the irrigated paddy fields of Kollo at 50 km from Niamey. The area of the paddy fields is 380 ha. The climate is soudano-sahelian. The mean temperature ranges from 40°C in April to 25°C in December. The annual rainfall average is near 700 mm but rainfalls are concentrated on 4 months from June to September. The irrigated paddy fields are cultivated during two rice cropping seasons per year (wet season and dry season) with rice plots of 0.25 ha. The rice yields are about 5 t per ha. The paddy fields are developed on vertic clayed soils with an acid pH ranging from 3.5 to 4.5. Gravity irrigation is practiced in these paddy fields.

Experimental device

A square experimental plot of 100 m^2 (10m x 10m) was defined in a high saline soil. Wood boards put into the soil at 80 cm depth form the boundary of the experimental plot. To limit water losses from the plot, wood boundaries were covered by some waterproof plastic tarpaulins. To avoid plot boundaries influence, data acquisition was performed on an area of 8m x 8m centrally located into the plot (Figure1)

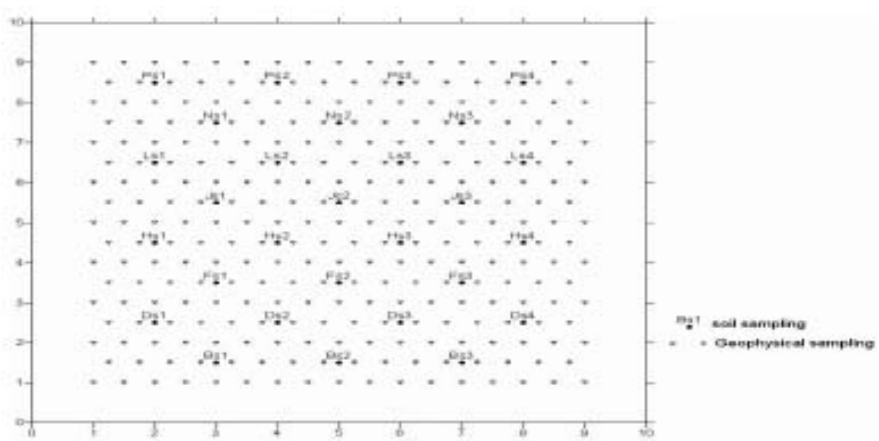

Figure 1. Geophysical and soil sampling strategies on the experimental map

Irrigation and water removal

This experiment was conducted from 13 July to 24 September, 2009. During this soil desalinization study, we made 12 irrigations of 60mm

water. The irrigation water was evacuated on successive day. After two consecutive irrigations, geophysical measurements and soil sampling was done from the experimental plot according the sampling map (Figure 1). 24 h after the second draining, we executed the measurements of apparent resistivity by Syscal R + in configuration Wenner (Ward, 1989) with two electrode spacing (a=10cm and a=30cm) in 281 knots of a bar in quinconce of 50 cm aside which constitute the center of the device. (Figure1). Soil sampling was done simultaneously with a 2 cm diameter gouge at 3 soil depths: 0-10 cm; 10 - 20 cm and 20 - 40 cm and 28 sampling points were arranged in quinconce rows with 2 m spacing (Figure 1). In the laboratory, electric conductivity 1/5 (soil/water) suspension and the dry residues were measured according to ISO 11265: 1994F.

Results and discussion

Hydrological assessment

Figure 2 shows the distribution of water input (irrigation and precipitation) and output (water removal and RET) during the whole duration of experiment monitoring. There is an irregularity between the irrigation and draining phase and essentially influenced by the precipitation. In 1107.8mm of water input, only 136.5 mm (12.32%) infiltrated and 971.3 mm evacuated by water removal and evaporation.

Salinity in drained water exceeded the salinity of irrigated water. The temporal variation was observed and the electric conductivity of drained waters decreased by 1.78 dS m^{-1} at the start of experiment and remained higher 0.65 dS m^{-1} at the end of experiment in comparison to irrigated water (Figure 3).

An evolution was observed in the mean values of electrical conductivity of soil and of apparent electrical conductivity (obtained by inversion of electrical resistivity). Globally we observed a decrease in the values of the electric conductivity between the beginning and the end of experiment. So the mean values decrease by 0.73 dS m^{-1}, 0.63 dS m^{-1} and 0.34 dS m^{-1} in 0-10 cm, 10-20 cm and 20-40 cm respectively (Figure 4). We estimated 14% (21kg salts from initial stock of 148 kg salts) and 3% (21kg from 616 kg salts) salts removal from the initial stock at 0-10 cm and 0-40 cm depths respectively. Moreover, the salinity was increased with the soil depth and variation was marked in 0-10 cm soil depth. The electrical conductivity map showed the spatial variability in EC (Figure 6) and temporal decrease in salinity was observed with depth (Figure 4B).

Spatial variability was shown in electrical resistivity map with spacing of 10cm interelectrode. The electrical resistivity increased with time (Figure 5). Soil electrical resistivity was influenced by many factors like water

contents, texture, salinity, temperature and soil aggregation (Keller and Frischknecht, 1966; Michot, 2003). In our study, variation of electrical resistivity was highly influenced salinity because soil moisture was relatively remained constant throughout the experiment.

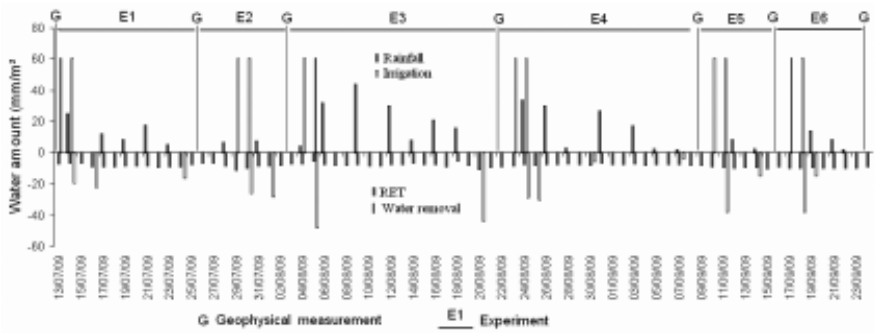

Figure 2. Distribution of irrigation and drained water.

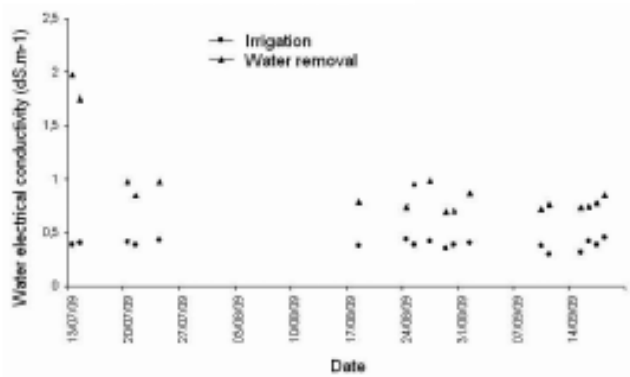

Figure 3. Evolution of water salinity.

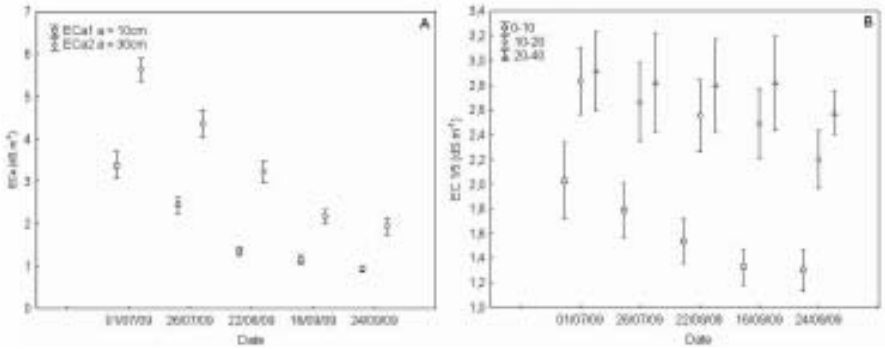

Figure 4. Evolution of apparent electrical conductivity (A) and soil electrical conductivity (B)

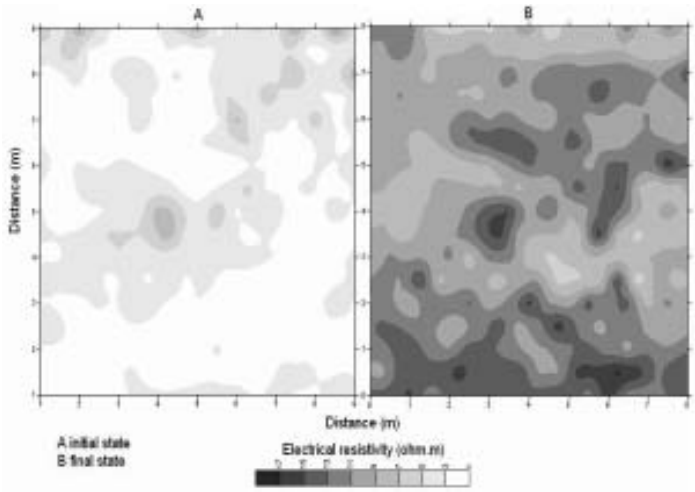

Figure 5. Apparent Electrical resistivity mapping using a wenner array (a = 10cm)

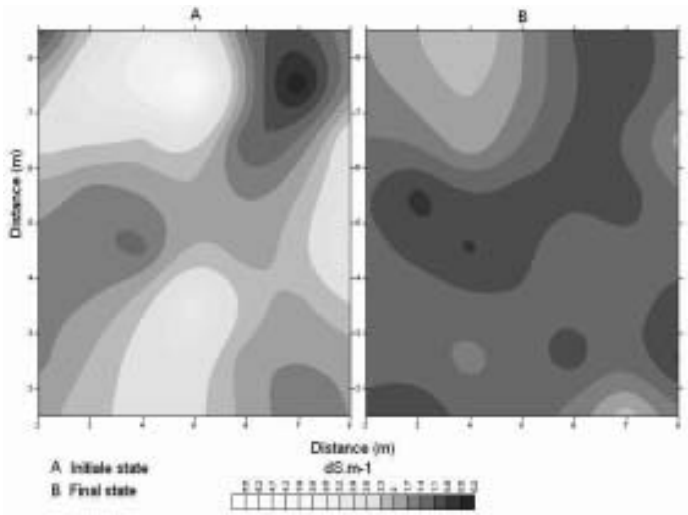

Figure 6 Soil electrical conductivity mapping for 10 cm depth.

Conclusion

Results of this study reflect that it is possible to monitor the desalinization by geophysical survey. This experiment showed spatial variability of salinity in the irrigated soil. The most effect of irrigation was observed in the first 10cm of soil depth, where 21 kg of salt were removed on 148 kg which represents 14% of the initial stock. This exportation had for consequence a increase of the mean value of the apparent electrical resistivity of 2.95 ohms m to 10.63 ohms m in appropriateness with the decreases of the values electrical conductivity 1/5 and apparent electrical conductivity.

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EROSIÓN DE SUELOS EN AMÉRICA LATINA Y EL CARIBE

Manuel Casanova[1], Gerd Dercon[2], Felipe Zapata[3]

[1]Universidad de Chile. Departamento de Ingeniería y Suelos (mcasanov@uchile.cl).
[2]Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, Department of Nuclear Sciences and Applications, International Atomic Energy Agency Wagramerstrasse 5. A-1400, Vienna - Austria. (G.Dercon@iaea.org).
[3]Consultor. Programa Conjunto FAO/IAEA, Wagramerstrasse 5. A-1400, Viena -Austria. (zapatafel@hotmail.com).

Abstract
Soil degradation by accelerated erosion is a serious problem for sustainable development especially in developing countries of the tropics and subtropics. In Latin America and the Caribbean its extent and severity as well as its economic and environmental impacts are in continuous debate, with uncertain magnitude for the 21st century due to additional pressures such as global climate change. Moreover, estimates of the land area affected in the region are tentative and subjective, with field measurements often technique-dependent. Then, this contribution is intended to provide an overview of available information on soil degradation by erosion for the region.
Key words: Soil erosion, sedimentation,

Introducción

La erosión natural de suelos y la sedimentación producida, son procesos que contribuyen a dar forma al paisaje debido principalmente a la acción en el tiempo de agentes, como el agua y viento. Sin embargo la dinámica de estos procesos puede ser acelerada y generar grandes pérdidas del recurso, por actividades antrópicas como la deforestación, sobre-pastoreo, uso inadecuado de tierras (sobre todo las marginales) así como el manejo inapropiado del suelo (Van Oost *et al*., 2006; UNEP, 2007).

La erosión acelerada es la forma de degradación más visible y severa del suelo, resultando ser una amenaza seria para una intensificación sostenible de la producción agrícola. Constituye un gran problema para el manejo sustentable de las cuencas hidrográficas y la conservación de sus recursos naturales básicos (Lal, 2000; Vanacker *et al*., 2003; Walling, 2002).

La erosión da lugar, indistintamente, a una ruptura del equilibrio en las propiedades del suelo (Casanova *et al.*, 2006), traduciéndose no solo en una reducción de la capacidad actual y/o futura del suelo (para producir flujos de bienes y servicios sustentables en el tiempo) sino además amenaza la sobrevivencia del hombre sobre el planeta

(Lal, 2009). Recientes estudios (UNEP, 2007) concluyen que el uso no sostenible de los suelos y los impactos del cambio climático son los factores principales que impulsan la degradación de las tierras (desertificación, escasez de agua, ruptura de los ciclos biogeoquímicos, empobrecimiento tanto físico, químico como biológico de los suelos). Los efectos acumulativos de estos procesos/cambios, afectan negativamente la seguridad alimentaria y la salud de la población, la biodiversidad, los procesos de fijación/captura/almacenamiento de carbono en los ecosistemas terrestres (OECD, 2004; Dercon *et al*., 2003; Dercon, 2006; Lal *et al.*, 2006; Lal, 2007; Schmitter *et al*., 2010). En general dan lugar a un pobre crecimiento económico (Pimentel, 2006; UNEP, 2007), pues limitan las opciones de subsistencia de las comunidades rurales marginales, ocasionando malestar social y migraciones rurales.

En particular, la degradación erosiva del suelo tiene efectos adversos a corto y largo plazo sobre la productividad de las tierras, causando pérdidas económicas apreciadas incluso a nivel de predial. Si bien sus efectos a largo plazo son atribuidos a la disminución de la calidad del suelo (Lal *et al.*, 2004), la erosión del suelo y la sedimentación asociada, tienen efectos en el sitio mismo (*in situ*) pero también genera problemas fuera o ajenos a éste (*ex situ*); tal es el caso de la depositación de sedimentos aguas abajo entre predios cultivados, hacia planos de inundación y, en general, hacia cursos de agua. En consecuencia, los efectos de la erosión y depositación no solo afectan la calidad del suelo y las funciones/servicios de los ecosistemas naturales y agrícolas (Lal, 2001a), sino también tienen impactos tanto ecológicos (calidad del agua y aire) como socio-económicos (conflictos y pobreza).

La gran diversidad y complejidad de las ecoregiones de suelo en América Latina está determinada por las diferencias en el ambiente biogeofísico (suelos, clima, vegetación, relieve, condiciones de latitud y altitud) y por las características culturales y socio-económicas predominantes en los 41 países de la región. Los principales usos comprenden, en millones de hectáreas: 752 de tierras agrícolas (140 de cultivos anuales - 17 de cultivos permanentes - 595 de praderas permanentes) y 1.752 de bosques, sabanas y otros usos; pero en algunas zonas, los ecosistemas naturales han sido o están siendo convertidos sostenidamente en agro-ecosistemas. Todo esto plantea un gran desafío en la formulación de políticas y regulaciones para un uso y manejo sustentable de los recursos naturales, imprescindibles para satisfacer los requerimientos de una población cada vez más numerosa (Lal *et al.*, 2006).

El objetivo de esta revisión es brindar información actualizada a la

comunidad científica sobre la degradación del suelo y particularmente de los procesos de erosión y sedimentación. Los temas son tratados con un énfasis particular en la erosión del suelo y sus impactos en América Latina y el Caribe. Su enfoque fundamental se orienta a los siguientes temas:

a) proporcionar información sobre la magnitud de los problemas de erosión a nivel mundial y regional,
b) realizar una revisión resumida de los estudios de medición y/o estimación de la erosión del suelo, incluyendo un análisis de los métodos actualmente empleados para estos estudios, y
c) presentar algunas perspectivas futuras de estos estudios en la región.

Magnitud de la erosión a nivel global y regional

Estudios realizados durante las últimas décadas destacan la severidad de los procesos de erosión y su ocurrencia general, tanto a nivel global como regional. Sin embargo existe gran incertidumbre respecto a esta información y muchos estudios deben ser considerados solo como aproximaciones. A nivel de países en desarrollo no es posible concluir demasiado al respecto, dada la escasa información disponible y la dificultad de estimar las pérdidas *ex situ*. Las estimaciones de daños causados por erosión proporcionadas por Morgan (2005) se contraponen a lo informado por Lomborg (2001), quien argumenta que existe una frecuentemente mala e inadecuada utilización de los datos disponibles, atribuyendo a la erosión de suelos todos los problemas del hombre.

Se ha estimado que en las últimas cuatro a cinco décadas la disminución anual de la productividad ha sido sólo de 0,1 a 0,3% (Crosson and Anderson, 2000), con escaso o indirecto efecto sobre la seguridad alimentaria. No obstante, se debe tener claro que estas cifras son globales y que existen ciertas zonas críticas (hotspots) donde la degradación constituye una amenaza considerable a la seguridad alimentaria para una gran cantidad de personas de escasos recursos económicos, para la actividad económica local y para importantes productos y servicios ambientales. Entre otras, se destacan las áreas regadas del norte de México y las laderas de las porciones subhúmedas y semiáridas de América Central (Scheer y Yadav, 1996).

No obstante esta incertidumbre y la falta de metodologías estandardizadas para evaluar los impactos adversos de la erosión sobre la productividad (Lal *et al.*, 2004), éstos han sido estimados a nivel mundial en un monto anual de US $ 400 billones (Pimentel *et al.*, 1995; Bernard and Iivari, 2000).

Por otra parte, la extrapolación global de tasas de erosión sobre la base de datos escasos, tomados con metodologías diversas y no estandarizadas, puede conducir a graves errores; es más, enfatiza que información errónea e irreal puede ser peor que no disponer de ella, debido a que puede conducir a juicios equivocados y costosos en materia de políticas de conservación de suelos. Vanacker *et al*. (2000) y De Vente *et al.* (2007) enfatizan que la producción de sedimentos medida a una escala (parcela, ladera, cuenca, región) no puede ser simplemente extrapolada a otro nivel de escala. Así, salvo que los datos sean confiables, abundantes y respaldados por métodos científicos, esta información cualitativa no debe ser generalizada, y debe ser usada con precaución.

La erosión hídrica es predominantemente el principal proceso de degradación de suelo en las tierras secas (*drylands) de* precipitaciones escasas y de alta variabilidad, con altas temperaturas y estacionalmente elevadas tasas de evapotranspiración. Existen informes sobre la severa degradación erosiva en las islas del Caribe debido a la eliminación de los bosques tropicales que proporcionan cobertura vegetal y protección a los suelos (Lugo *et al.,* 1981). En América Central las tierras cultivadas con el sistema de corte y quema en zonas de las laderas inclinadas contribuyen sustancialmente a la erosión de sus suelos derivados de cenizas volcánicas (Walle and Sims,1999). La situación en América del Sur es muy variable, donde la degradación erosiva refleja los cambios de uso y manejo de las tierras así como los efectos de factores climáticos y geomorfológicos (Coppus *et al*., 2003). En esta subregión, la información es escasa pero en las tierras secas de las zonas andinas (Colombia, Venezuela, Ecuador, Perú y Bolivia) la erosión es severa, y se ve incrementada con la creciente aridez y fuertes temporales en la estación de lluvias. La fuerte sedimentación del río Paraná que drena partes de Brasil, Paraguay, Uruguay y Argentina es testimonio de la considerable erosión en sus cuencas. En cuanto a la erosión eólica, sería severa para las zonas arenosas de oeste de Argentina y en general para la Patagonia (Dregne, 2002).

Las tasas de erosión de suelo quedan de manifiesto a través de la descarga mundial total de sedimentos al mar; así, de los 15 billones de Mg estimados: 7,6 proceden de Asia, 2,4 de América Latina, 2,1 de América del Norte, 1,7 de África y 1,2 de otras partes del mundo (Lal, 2001b).

GLASOD (Global Assessment of Human-Induced Soil Degradation) puede considerarse como la primera aproximación para una evaluación de la degradación del suelo a nivel global (Oldeman *et al.*, 1990; Oldeman *et al,* 1991; Sonneveld and Dent, 2009). Datos de

Scherr (1999), relativos a las áreas afectadas por erosión a este nivel se muestran en el Cuadro 1, donde las últimas dos columnas se refieren sólo a zonas que están degradadas moderada, fuerte o extremadamente.

Cuadro 1. Superficie mundial regional afectada por procesos erosión.

	Área con erosión por agua				Área con erosión por viento						
Región	L	M	F & E	Total	L	M	F & E	Total	Área erosionada	Área con erosión seria	TSA*
	(millones de ha)										(%)
África	58	67	102	227(+)	88	89	9	186(+)	413	267	16
Asia	124	242	73	441(+)	132	75	15	222(+)	663	405	15
América del S.	46	65	12	123(+)	26	16	...	42(-)	165	93	8
Centroamérica	1	22	23	46(+)	246	4	1	5(-)	51	50	25
América del N.	14	46	...	60(±)	3	31	1	35(-)	96	78	7
Europa	21	81	12	114(+)	3	38	1	42(±)	156	132	17
Oceanía	79	3	222	83(+)	16	...	27	16(+)	99	3	3
Mundo	343	526	223	1.094(+)	269	254	26	548(+)	1.642	1.029	12

(+): tendencia a aumentar (-): tendencia a disminuir (+): estables (...): cantidades despreciables L = ligera M= moderada F & E= fuerte y extrema (TSA): Área con erosión seria respecto al total utilizado.

Aun cuando se trata de un estudio general, se aprecia la magnitud alcanzada por la degradación en el mundo, con el agravante de una tendencia a aumentar tanto en los procesos erosivos hídricos como en los eólicos. A este mismo nivel, se estima que casi 1.100 y 550 millones de hectáreas han sido afectadas, respectivamente (Lal, 2000; WRI, 1992-1993; Oldeman, 1994). Más aún, sobre el 75% de la superficie mundial afectada por erosión hídrica (la eólica es menos extensiva) se localiza en los países en vías de desarrollo de África, Asia y América Latina.

En particular para América del Sur, un estudio del Departamento de Agricultura de EUA (USDA-NRCS, 1999) sobre riesgos de erosión hídrica y eólica inducida por el hombre, muestra que espacialmente éstos son altos a muy altos tanto en los bordes costeros como en las zonas montañosas.

Bai *et al.* (2008), empleando índices de vegetación basados en imágenes de sensores remotos, informan que para el período 1981-2003 la zona degradada alcanzó a un 24% de la superficie sólida del planeta (un valor que contrasta con el 15% señalado por GLASOD), precisando que entre las zonas más afectadas se encuentran las Pampas. Este territorio constituye un extenso plano de aproximadamente 52 Mha que abarca el centro de Argentina y se extiende tanto hacia Uruguay como Brasil. Originalmente se encontraba cubierto de praderas y constituido principalmente de Mollisoles de elevada fertilidad. Si bien se emplea para la producción de granos y ganado, su superficie degradada estaría contribuyendo en casi un 3% a la degradación global.

El Cuadro 2 presenta estadísticas sobre las áreas degradadas en los países de América Latina, tomadas de estos mismos autores.
Recientemente, para las zonas altas tropicales (países asociados a la Cordillera de los Andes, y zonas montañosas de América Central y el Caribe) Nyssen *et al.* (2009) estima que los procesos de erosión hídrica dominan sobre los eólicos, presentando grados de moderados a muy severos (Cuadro 3), pero además muestra una clara relación entre degradación y densidad de población, considerando que su contribución a la degradación del planeta debe ser importante al ocupar más del 50% de la superficie tropical elevada mundial

Cuadro 2. Zonas degradadas en países Latinoamericanos, 1981–2003 (Bai *et al.*, 2008)

País	Area degradada (km^2)	Territorio afectado (%)	Contribución a la degradación global (%)	Pérdida total de Prod. Primaria Neta (Mg C/3 años)	Población total (%)	Personas afectadas
Argentina	902.438	32.62	3.13	23.556.380	36.95	14.455.276
Bolivia	60.339	5.49	0.18	1.656.319	16.39	1.518.038
Brazil	1.881.702	22.11	5.38	63.346.316	26.67	46.566.573
Chile	77.230	10.20	0.27	1.950.752	10.42	1.645.825
Colombia	291.295	25.58	0.82	17.999.691	36.02	16.309.420
Costa Rica	14.691	28.75	0.04	529.401	13.41	592.632
Cuba	32.430	29.25	0.10	755.493	28.31	3.050.836
R. Dominicana	18.507	37.98	0.05	560.541	43.43	3.843.087
Ecuador	40.136	14.15	0.10	2.401.056	16.13	2.199.904
El Salvador	5.585	26.54	0.02	234.650	16.76	1.139.730
Islas Malvinas	1.635	13.43	0.01	50.944	23.18	366
Guyana Francesa	24.947	27.41	0.06	1.033.318	14.36	25.745
Guatemala	55.884	51.32	0.16	2.866.596	30.46	3.936.416
Guyana	93.448	43.47	0.26	230.119	26.49	196.445
Haití	11.821	42.60	0.03	360.262	34.56	2.823.765
Honduras	30.145	26.89	0.08	1.450.818	23.36	1.673.952
México	487.804	24.73	1.47	23.871.310	34.30	36.234.761
Nicaragua	47.223	36.47	0.13	2.060.424	29.26	1.684.227
Paraguay	66.704	16.40	0.20	1.659.006	66.97	4.071.629
Perú	197.211	15.34	0.57	11.414.777	10.69	3.001.345
Puerto Rico	436	4.79	0.00	19.231	2.91	111.458
Suriname	50.503	30.93	0.13	2.102.421	10.13	38.529
Trinidad & Tobago	675	13.16	0.00	113.407	5.51	65.120
Uruguay	87.566	49.69	0.29	1.874.537	33.03	1.058.877
Venezuela	207.916	22.80	0.59	520.023	8.26	2.156.456
Total	**4.658.271**		**14.07**	**162.648.795.80**		**148.431.415**
Promedio		**26.08**			**23.93**	
Mundo	**35.958.184**	**23.54**	**100**	**955221418.5**	**23.89**	**1.537.676.146**

Cuadro 3. Erosión de suelo en zonas altas tropicales de Latinoamérica y el Caribe.

Región tropical de montaña	Subregión	Área (1000 km^2)		Población (10^6)		Densidad población (km^{-2})		Países con >40% población de montaña	Degradación erosiva
		>1000 msnm	>2500 msnm	>1000 msnm	>2500 msnm	>1000 msnm	>2500 msnm		
América Central y el Caribe	**Sierra Madre, Cordillera de Salamanca y Sierra Maestre**	85	5	9	1	107	200	**Guatemala, Costa Rica, El Salvador, Honduras**	Hídrica (3-4)
América del Sur	**Los Andes**	2033	1114	38	21	19	19	**Bolivia, Colombia, Perú, Ecuador**	Hídrica (2-4) Eólica (2-4)
Total mundial		4561	1634	151	38	33	23		

Con respecto a las tierras secas, Zika and Erb (2009) señalan que su degradación muestra variaciones importantes, dependiendo de su definición. No obstante, estiman que para América Latina y el Caribe abarcaría del orden de 140.000 y 840.000 km^2, para zonas cultivadas y de pastoreo/praderas, respectivamente; casi un 14% de la superficie de las tierras secas degradadas a nivel mundial.

Finalmente, Harden and Hyman (2007) en una extensa revisión, señalan que a pesar del carácter generalizado de la erosión del suelo, gran parte de América del Sur sigue siendo rica en tierras agrícolas y recursos de agua dulce. La producción agrícola sigue en aumento y la agricultura sigue siendo un sector importante de las economías nacionales. En los Andes, tanto las tasas de erosión naturales como las tasas de erosión antrópicas son relativamente altas; por cuanto, las actividades humanas en estos ambientes frágiles, sustentadas con un elevado consumo de energía, requieren de esfuerzos especiales para evitar la aceleración de estos procesos naturales. A excepción de las tierras recién abiertas a la agricultura (zonas amazónicas de Brasil y el este de países andinos como Perú, Bolivia, Ecuador), se considera que gran parte de la erosión de los suelos ocurrió con anterioridad al Descubrimiento de América, pero se aceleró después de este evento.

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EVALUACIÓN DE LA EROSIÓN DE SUELO: MÉTODOS TRADICIONALES

Manuel Casanova[1], Gerd Dercon[2], Felipe Zapata[3] ,

[1]Universidad de Chile. Departamento de Ingeniería y Suelos. (mcasanov@uchile.cl).
[2]Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, Department of Nuclear Sciences and Applications, International Atomic Energy Agency Wagramerstrasse 5. A-1400, Vienna - Austria. (G.Dercon@iaea.org).
[3]Consultor. Programa Conjunto FAO/IAEA, Wagramerstrasse 5. A-1400, Viena - Austria. (zapatafel@hotmail.com).

Abstract

Soil erosion (man induced) is a systematic processes that threatens the entire solid portion of the planet, but is especially relevant for lands under agricultural and forestry use. Because these losses are not usually obvious, often receive little attention, but it is clear that means a serious long-term economic decline, by directly affecting the productivity of crops and trees. Any value of soil erosion rate without experimental evidence should be considered only as a comparative indicator with respect to other study areas with same conditions and using the same methodology. Therefore, soil erosion evaluation is a fundamental knowledge to allow decision making on the territory, to reach levels of detail that would enable the proper use and management of soils as a function of soil loss tolerance. Finally, it is concluded that it is high time for action, i.e. to pass from rhetoric to practice in soil conservation with sustainable soil use and management programs, including monitoring, impact evaluation, assessment experiments (participative, innovative and adapted to local reality), natural resources inventory (base lines and databases), reliable data generation, and above all a solid and comprehensive training of all the actors involved. Although considerable progress in erosion modelling has been made, model validation for main soils and ecoregions is often lacking. This contribution is intended to provide an overview of available information on traditional methods used for the quantification of accelerated soil erosion

Key words: erosion assessment, measurement and research methods.

Introducción

Cuando se realizan estudios de erosión del suelo se plantean varias preguntas básicas « ¿***dónde y porqué está ocurriendo***?, ¿***quién o qué es responsable de su ocurrencia***?, ¿***cuán serio es el problema***?, ¿***a quién afecta***?, ¿***cuál(es) debería(n) ser la(s)***

respuesta(s)?, ¿***se puede prevenir***? y ¿***cuál es el costo***?» de manera que para poder responder al menos a aquellas interrogantes de mayor relevancia, es indispensable contar con los medios/ instrumentos necesarios para su cuantificación. En otras palabras, se necesita disponer de metodologías adecuadas para conocer y comprender los procesos que ocurren, así como también identificar los factores principales que determinan dichos procesos.

Es sabido que los estudios de erosión del suelo toman mucho tiempo además de demandar gran cantidad de recursos económicos y humanos, por cuanto se deben limitar a experimentos bien diseñados y utilizando metodologías estandardizadas, de tal manera que los datos obtenidos sean comparables y representativos de las áreas en estudio (Lal, 1994; Zapata *et al.*, 1995).

Necesidades de estudios en erosión de suelos

El principio fundamental de la Conservación de Suelos y Aguas es *la conservación y mejoramiento de la calidad del suelo y el agua debe ser una preocupación común de toda la humanidad*. Por lo tanto la responsabilidad de la humanidad para mantener y mejorar la productividad del suelo - adoptando medidas eficaces para impedir la degradación del suelo, preservar y mejorar la calidad de los recursos de tierra e hídricos - para así satisfacer las necesidades de la agricultura, la sociedad y la naturaleza, es inherente a este principio.

Los países tienen la necesidad de conservar sus recursos naturales como capital de inversión para su desarrollo, así como de evitar los efectos negativos de su degradación y mantener la sustentabilidad del ambiente (UNEP, 2007; WASWC, 2008). La mayoría de ellos son signatarios de acuerdos/convenciones internacionales, comprometiéndose a desarrollar acciones y políticas de protección ambiental (Convenio para combatir la Desertificación, Convenio para conservar la Biodiversidad, Convenio Marco sobre el Cambio Climático, entre otros).

Los gobiernos se han comprometido a ejecutar programas de inventario de los recursos naturales y su estado de degradación en el territorio, a formular políticas y un marco legal, así como también a proporcionar incentivos/subsidios, para prevenir/controlar la erosión acelerada del suelo y sus impactos negativos.

Sin embargo, los medios disponibles (financieros, humanos e institucionales) son generalmente inferiores a los requeridos para dichos propósitos. Como consecuencia, se hace imprescindible demostrar a los gobiernos los beneficios que tendrán ante inversiones públicas adicionales, y asegurar que dichos esfuerzos se enfoquen hacia aquellas áreas más vulnerables a la degradación.

No obstante, cuando se dispone de ayuda financiera internacional, los aportes se concentran en iniciativas de desarrollo de una cuenca hidrográfica específica, o en proyectos de conservación de suelo de un área determinada; en tales condiciones, si bien se evalúan los efectos directos de corto plazo, no se hace lo mismo con los beneficios indirectos que ocurren más allá de la duración del proyecto (Sheng, 2007).

Consecuentemente, existe una fuerte necesidad de contar con programas de evaluación de la erosión del suelo (magnitud, extensión, riesgos y tasas) y de monitoreo de las tendencias/cambios con el tiempo, considerando sus efectos/impactos sobre la productividad agrícola y el ambiente en general (Prosser *et al.*, 2004). El creciente interés por estudiar y comprender los efectos/impactos asociados con la pérdida acelerada del suelo y, en general, su interacción con la degradación de las tierras ha generado la necesidad urgente de realizar estudios para obtener datos cuantitativos confiables sobre la magnitud y tasas de la erosión de suelo en los diversos agro-ecosistemas del mundo (Boardman, 2006). A pesar de la abundancia de literatura sobre los problemas globales, regionales y nacionales de erosión del suelo, es escasa esta información específica a nivel de cuencas hidrográficas. No obstante, existe consenso entre los investigadores (Lal, 1994; Walling, 2002; OECD 2003 & 2004) que es fundamental obtener dicha información para:

a) evaluar la magnitud o severidad de los problemas de erosión y sus efectos en la productividad del suelo;
b) lograr una mejor comprensión de los factores involucrados, los controles y dinámica a través del tiempo;
c) validar modelos existentes y crear otros nuevos de predicción del riesgo de erosión;
d) seleccionar prácticas efectivas de conservación y estrategias mejoradas de uso y manejo de suelos;
e) entender y manejar la sedimentación en áreas de depositación y en la contaminación de cauces;
f) realizar una mejor evaluación de los impactos económicos y ambientales;
g) proporcionar lineamientos y desarrollar políticas científicamente correctas sobre el uso y manejo de suelos.

Métodos de medición o estimación de la erosión de suelos

La adquisición de datos reales de pérdidas de suelo es un asunto complejo, que involucra problemas técnicos difíciles de resolver. Los datos provenientes de mediciones experimentales deben ser interpretados de acuerdo al método usado para obtenerlos y dependen

de la escala espacial de medición. Tanto métodos como escala de medición deben ser definidos acorde a los objetivos que se buscan. Muy a menudo los datos disponibles de erosión de suelo para un área no reflejan con precisión las tasas reales, de forma que deben interpretarse comparando tratamientos o micro-ambientes entre parcelas. La validez de la medición depende de la conformidad de los métodos acorde a los objetivos planteados, una regla básica en todos los proyectos y publicaciones, para evitar errores de tantos estudios previos.

Los métodos clásicos tales como el reconocimiento de campo, las parcelas y el uso de trazadores reúnen algunas de estas condiciones pero tienen varias limitaciones importantes: representatividad de los datos obtenidos, su resolución espacial, los costos involucrados y su bajo potencial para proporcionar información a largo plazo y los patrones espaciales de erosión asociados a extensas áreas (Loughran, 1989; Higgitt, 1991). Además, avances en el desarrollo y uso de modelos de distribución espacial, además de las aplicaciones de los sistemas de información geográfica y de la geoestadística a la modelación de la erosión, han destacado la necesidad de contar con datos de erosión/sedimentación espacialmente distribuidos dentro del paisaje, en función de la topografía y el uso/manejo de las tierras (Walling, 2002). Por lo tanto un método ideal para evaluar la erosión del suelo debería reunir las siguientes condiciones (Walling and Quine, 1993):

a) Tener acceso inmediato a la información.
b) Estimar tasas a largo plazo, de erosión y sedimentación, integradas por todos los procesos.
c) Diferenciar los procesos dominantes de erosión.
d) Identificar los patrones espaciales de redistribución del suelo a largo plazo.
e) Estimar las tasas netas de pérdidas de suelo.
f) Tener aplicación potencial a diferentes escalas: laderas/cuencas.

Aparte de lo anterior, parece necesario contar con métodos para evaluar las tasas de sedimentación en zonas de acumulación, llanuras de inundación, y represas/embalses de agua; además de métodos para evaluar la relación entre la redistribución del suelo y la calidad del suelo**.** En esta perspectiva, los métodos actuales para la evaluación de la erosión del suelo se pueden clasificar en:

a) determinación (semi) cuantitativa o cualitativa en terreno.
b) modelación/predicción.
c) experimentos en laboratorio o en condiciones de campo.
d) mediciones en condiciones naturales o simuladas de lluvia/viento.
e) medición en el sitio o empleando imágenes de sensores remotos.
f) métodos convencionales o técnicas nucleares.

Independiente de la forma que se les clasifique, la selección del método a usar depende de los objetivos, de la escala del estudio y de la disponibilidad de recursos (Lal, 1994). No obstante, se debe tener presente que a veces será necesario emplear más de uno de ellos, con propósitos de verificar o calibrar sus resultados.

Reconocimiento de campo o inspección de la erosión en el terreno*:* Cada proceso erosivo produce ciertos rasgos o signos característicos y visibles en los suelos afectados, que pueden ser empleados como indicadores de erosión. En este sentido, los especialistas pueden identificar estos rasgos durante la inspección de terreno o visita de campo e inferir a partir de éstos la magnitud de la erosión.

El método más simple para evaluar las pérdidas en canalículos y cárcavas es a través de la determinación de varias secciones transversales a estas evidencias de flujo canalizado. El promedio de las áreas de dos secciones sucesivas multiplicado por la distancia que las separa, corresponde al volumen de material removido; así, conociendo o estimando la densidad aparente del suelo, es posible obtener la masa de suelo perdido en el área afectada por ambos tipos de erosión. Ciertamente que el método ignora la contribución de la erosión inter-canalículos y presenta las dificultades para identificar los límites del canalículo, por cuanto se considera que sobreestima este tipo de erosión en un 10 a 30% (Morgan, 2005). Un método volumétrico, como el indicado anteriormente, puede ser aplicado también para estimar sedimentación en reservorios o cuerpos de agua desde una cuenca de drenaje; así, empleando batimetría, es posible obtener los volúmenes acumulados, a partir del mapa altiplanimétrico del fondo del reservorio.

Algunos ejemplos de rasgos, no tan evidentes como cárcavas y canalículos, son la presencia de pedestales (bajo fragmentos gruesos/ plantas), sellado del suelo, curvatura de troncos y cicatrices en el suelo por deslizamientos, acumulaciones de sedimentos en cercos y, raíces expuestas de árboles. Con relación a este último método, Gärtner (2007) precisa que es posible reconstruir el tamaño y ‘posición de las raíces al momento de quedar expuestas; consecuentemente, es factible calcular el espesor del suelo erosionado, permitiendo una reconstrucción detallada de las tasas de erosión.

Stocking and Murnaghan (2001) abordan muchas de las metodologías anteriores, con detalles bastante prácticos para efectuar las estimaciones y, en particular, muestran cómo las combinaciones de diferentes indicadores pueden dar una evidencia concluyente de la severidad de diferentes tipos de degradación.

***Clavos y perfilómetros*:** El uso de clavos o varillas de acero (erosion pins) insertos en terreno pueden proporcionar un punto de referencia contra el cual tanto erosión como depositación pueden ser estimadas empleando reglas de precisión o micrómetros. En Chile son empleados desde hace varios años (Pizarro y Cuitiño, 1999; Cartes *et al.,* 2009) en suelos desde la Precordillera Andina hasta la Cordillera de la Costa, para evaluar erosión de flujo precanalizado aunque potencialmente permiten monitorear también el avance de cárcavas. Se recomienda que las varillas sean muy delgadas, asociadas a arandelas holgadas, no establecerlas muy superficiales o a ras de suelo, que sean monitoreadas al menos cada 6 meses, que sean establecidas en hileras cortas (o grupos) y que se ubiquen perpendiculares al máximo gradiente de pendiente.

Los perfilómetros o rugosímetros consisten en marcos apoyados en puntos de referencia permanentes, constituidos de varias barras o varillas verticales deslizantes que se apoyan en la superficie del suelo, de manera que es posible controlar los cambios en ésta sin interferir en su forma o en los procesos; si bien se recomiendan para superficie pequeñas y también para evaluar secciones de cárcavas o canalículos, su eficiencia se ha visto incrementada con el empleo complementario de cámaras digitales para realizar el seguimiento. Sin embargo, se recomienda que para no superar el 10% de error, las secciones transversales definidas no estén distanciadas a más de 5 m (Casalí *et al*., 2006).

El Cuadro 1 presenta las principales ventajas y limitaciones de los estudios en terreno, clavos y perfilómetros, a ser consideradas en el marco de estudios de erosión.

***Parcelas de erosión*:** Este método proporciona datos sobre la cantidad de suelo que es extraída de un área determinada y delimitada (confinada), de pendiente linear y con un cierto tipo de cobertura. Ha sido uno de los métodos más empleado para estudios de procesos básicos en conservación de suelos (Rodríguez *et al*., 2009; Casanova *et al*., 2007; Joel *et al*., 2002; Casanova *et al*., 2000; Pérez y López, 2000). Se les puede clasificar como experimental y de observación, en el primer caso el investigador controla al menos un factor que afecta la erosión (cobertura, uso, manejo, etc.), en tanto que las de observación comprenden estudios de la pérdida de suelo en condiciones naturales. Ya que las parcelas son de área conocida, la pérdida de suelo puede ser expresada en unidades ML^{-2} y tiempo, lo cual asume que la pérdida es uniforme en la parcela e implica que es independiente del tamaño y forma de ella. En rigor, las parcelas delimitadas, no pueden por tanto ser empleadas para medir la pérdida en condiciones naturales.

Cuadro 1. Principales ventajas y limitaciones de los estudios de erosión del suelo en el terreno, clavos y perfilómetros.

Ventajas
Se pueden identificar y medir las pérdidas de suelo ocurridas y, cuando existe información adecuada de sensores remotos, es posible hacer evaluaciones retrospectivas para periodos de 10 a 20 años.
Mediante visitas de terreno repetidas y de largo plazo se pueden identificar la distribución espacial de las pérdidas.
Sirven de verificación de la información obtenida desde sensores remotos (imágenes de satélite y aerofotografías) y sistemas de información geográfica.
El método no requiere equipos complejos, pero sí capacitación del personal.
Si sus determinaciones en el tiempo son acumuladas en bancos de datos, son de gran utilidad y complemento en el refinamiento de modelos.
Limitaciones
La información obtenida sobre las pérdidas de suelo es fragmentaria. Las tasas de erosión calculadas representan solamente los rasgos visibles. No se tienen en cuenta varios tipos de erosión (de flujo precanalizado, por labranza, por cosecha, etc.).
Es muy difícil cuantificar con exactitud la tasa de depositación sobre la base del volumen de suelo removido, aun en casos de erosión hídrica dominante.
Es necesario realizar un monitoreo a largo plazo para obtener una consistente secuencia temporal de los patrones y tasas de erosión. Todo esto demanda más trabajo, eleva los costos y los datos no están disponibles cuando éstos son necesarios.
Muchos de ellos (pins, por ejemplo) no pueden ser usados para experimentos de largo plazo en áreas cultivadas y, pequeños cambios en la elevación de la superficie pueden ser indetectables por éstos.
Las manifestaciones o dispositivos pueden ser, alterados o sustraídos, por el ganado, fauna silvestre o población local.

El Cuadro 2 presenta las principales ventajas y limitaciones de las parcelas a ser consideradas en el marco de estudios de erosión y sedimentación. Boix-Fayos *et al*. (2006) han mostrado que los temas de escala, alteración y representación de las condiciones naturales (continuidad, conectividad y heterogeneidad de sistemas naturales) y la complejidad de las interacciones del ecosistema (conectividad, patrones y procesos que operan con las escalas) son claves cuando se trata de recolectar datos representativos de campo al usar parcelas de erosión. Todos estos asuntos se traslapan y relacionan entre sí en muchas formas, pero los conceptos de escala espacial y umbrales son básicos para todos ellos. Al respecto, el Cuadro 3 sintetiza las conclusiones y recomendaciones de estos autores, teniendo presente la situación actual y las necesidades futuras de investigación.

Cuadro 2. Principales ventajas y limitaciones de las parcelas de erosión.

Ventajas
Proporcionan datos de la escorrentía, erosión y sedimentos que pueden ser relacionados en detalle con las características del evento erosivo y con combinaciones específicas suelo-cultivo.
Sirven para establecer la relación entre la pérdida neta de suelo y el estado de fertilidad, para las combinaciones específicas suelo-cultivo.
Permite la identificación del impacto de los sistemas de cultivo y prácticas de manejo sobre las tasas netas de erosión
Permiten evaluar distintos de métodos protección de suelo a pequeña escala.

(Continuación cuadro 2)

A corto plazo proporcionan datos para medir la erosión en base a eventos y también pueden ser utilizados para monitoreo de la erosión a largo plazo.
Limitaciones
No es posible obtener información sobre la redistribución espacial del suelo dentro del área estudiada.
Algunas parcelas están confinadas, por lo tanto desconectadas del contexto topográfico y de los procesos que están operando en áreas adyacentes. Los resultados pueden no ser representativos de las áreas en estudio.
El uso de parcelas estandardizadas impide un replicación efectiva de un amplio rango de rasgos del paisaje y de los procesos que puedan ocurrir en el área en estudio.
Sus datos, difícilmente pueden ser extrapolados a condiciones de campo. Las discrepancias fluctúan en un factor de 2 a 10 y.
Para obtener datos de la efectiva erosión, el monitoreo debe hacerse a largo plazo debido a las condiciones cambiantes climáticas. Todo esto demanda más trabajo y costos, pero además los datos no están disponibles cuando son necesarios.
Su tamaño pequeño limita su potencial para estudios de cierto tipo de erosión (canalículos, cárcavas y movimientos de masa).

Con un enfoque en condiciones semiáridas mediterráneas, más recientemente Boix-Fayos *et al*. (2007) precisan al menos 3 fuentes principales de variabilidad detectadas en parcelas de analizadas, aunque estas limitaciones metodológicas probablemente se encuentran en otros tipos de ecosistema: sitios con bajas tasas de formación de suelo y con patrones irregulares y/o en bandas de vegetación, además de una elevada discontinuidad de las flujos de agua y sedimentos.

Cuanto más grande la parcela, más cercana es su respuesta a la realidad debido a una mejor representación de las conexiones entre los factores del sistema natural. Parcelas muy grandes reducen algunos problemas de las parcelas pequeñas, como la interrupción artificial del sistema hidrológico, bajos flujos de energía debido a las distancias cortas y la inducción de una respuesta rápida a la escorrentía debido a una disminución artificial de los tiempos de concentración para flujos continuos. En contraste, parcelas pequeñas son muy apropiadas para caracterizar rápidamente la respuesta hidrológica y erosiva de micro-ambientes diferentes, así como para estudiar el efecto de los componentes y características superficiales del suelo. Sin embargo, las parcelas pequeñas tienen ventajas prácticas, tales como bajos costos de mantención y fácil manejo, por cuanto son más fáciles de replicar. Una buena comprensión de las ventajas y desventajas de cada tipo/tamaño de parcela y su influencia en los resultados, es fundamental para seleccionar el tipo más adecuado, en función de los objetivos de cada estudio específico.

Trazadores físicos: Muchos estudios (Govers *et al*., 1994; Van Oost *et al*., 2006) han mostrado que la erosión también ocurre como consecuencia de la labranza. Para medir este tipo de transporte de suelos, el uso de trazadores físicos se ha vuelto una práctica bastante común (Turkelboom *et al*., 1997; Dercon *et al*., 2007), como

complemento al uso de parcelas de erosión. Al respecto, se han utilizado cubos metálicos o fragmentos gruesos coloreados, los que si bien permiten una sola y rápida medición del transporte de suelo durante las operaciones de labranza, proporcionan información sobre la tasa de erosión durante una labor de labranza a la vez. Implementados para distintos rangos de gradiente de pendiente, pueden ser empleados para evaluar la erosión causada por labranza manual, mecanizada o por tracción animal.

Cuadro 3. Resumen de ventajas y limitaciones de las parcelas de erosión, con relación a las características del ecosistema (Boix-Fayos *et al.*, 2006).

Características		Ventajas	Limitación	Alternativa a de parcelas o cierto tipo de éstas, en terreno.
Problemas de escala	Temporal	Datos detallados de eventos	Dificultades para mantener seguimientos de largo plazo en terreno	Imágenes de sensores remotos multi-temporales Estudios en reservorios temporales (lagunas, represas) Estudios con trazadores (^{137}Cs, ^{7}Be, etc.)
				Caracterización comparativa del suelo, entre áreas protegidas y otras no protegidas
	Espacial	Mediciones directas en condiciones naturales	Medición de diferentes procesos dependiendo de la escala	Imágenes de sensores remotos a diferentes resoluciones espaciales
				Metodología de unidades de respuesta
		Abarcando diferentes tipos de micro-ambientes	Dificultades de ampliación de escala	Aproximación de paso múltiple
				Aproximaciones anidadas
Alteración de condiciones naturales		Comparación entre diferentes tratamientos de suelo	Alteración introducida por los límites de la parcela (parcelas cerradas)	Mediciones de parcelas abiertas para evitar efecto límite
		Determinación directa de áreas de contribución (parcelas cerradas)		Mediciones en parcelas abiertas para evitar agotamiento de sedimentos
			Agotamiento de material desprendible (parcelas cerradas)	
		Control de variables dentro de la parcela		
Representación de condiciones naturales	Continuidad y conectividad de los sistemas	Mediciones directas de condiciones del mundo real y procesos *in situ*	Dificultades de establecer una gran cantidad de muestras para una real representación cuando se usan parcelas grandes	Mediciones en parcelas abiertas localizadas en la base de las laderas para evitar desconexión de sectores y así de flujos de de agua y sedimentos
	Heterogeneidad y variabilidad de los sistemas	Posibilidad de una gran cantidad de parcelas en condiciones naturales	Extrapolación de datos uniformes dentro paisajes no uniformes	Uso de parcelas replicadas con el mismo patrón de distribución de vegetación y otros componentes de la superficie del suelo
Complejidad de interacciones del sistema	Conectividad del sistema	Facilita la comprensión de factores individuales en procesos naturales (especialmente por uso de parcelas pequeñas que representan microambientes diferentes)	Dificultad para controlar todos los factores en el experimento de campo	Mediciones en parcelas abiertas localizadas en la base de las laderas para evitar desconexión de sectores y así de flujos de agua y sedimentos
	Patrones espaciales de áreas desnudas y cubiertas de vegetación	Facilita la comprensión de las interacciones entre factores, cuando se usan parcelas grandes	Dificultad para obtener una buena representación de los patrones espaciales y temporales	Uso de técnicas de sensores remotos a diferentes resoluciones espaciales
	Procesos a través de las escalas			Uso de un diseño experimental de parcelas anidadas para estudiar procesos en un rango de escalas

***Modelos en erosión*:** A pesar de la gran cantidad de modelos existentes, que varían en complejidad y objetivos, no existe uno válido para todo tipo de situaciones y debe considerarse que se encuentran en un proceso de continuo desarrollo. En consecuencias, es necesaria una evaluación sistemática de los existentes, empleando bancos de datos comunes.

En América Latina, el modelo más empleado hasta principios de este siglo ha sido básicamente la USLE (Andrade y Rodríguez, 2002; Clérici y García-Prechac, 2001; Honorato *et al.*, 2001), la Ecuación Universal de Pérdidas de Suelo. Recientemente, ha sido empleado WEPP (Water Erosion Prediction Project) por varios investigadores (Zehetner and Millar, 2006; Romero *et al.* (2007). En particular Stolpe (2005), comparó los modelos RUSLE, EPIC y WEPP en la zona centro-sur Chile, concluyendo que este último resulta en una más adecuada parametrización y le recomienda para dicha zona.

Cuadro 4. Características de los modelos empleados en erosión de suelos

Modelo	Tipo	Escala espacial	Escala temporal	Requerimientos	Información generada
AGNPS	Co	Cuenca peq.	Evento/Continuo	Alto	Escorrentía superficial (ES), tasa máxima de erosión (TME), producción de sedimentos (PS)
ANSWERS	Físico	Cuenca peq.	Evento/Continuo	Alto	ES, TME, PS
CREAMS	Físico	Parcela/campo	Evento/Continuo	Alto	Erosión (E), depositación (D)
EMSS	Co	Cuenca	Continuo	Bajo	ES, concentración de sedimentos (CS)
HSPF	Co	Cuenca	Continuo	Alto	ES, flujo, CS
IHACRES-WQ	Emp./Co	Cuenca	Continuo	Bajo	ES, sedimentos (S)
IQQM	Co	Cuenca	Continuo	Moderado	CS
LASCAM	Co	Cuenca	Continuo	Alto	ES, S
SWAT	Co	Cuenca	Continuo	Alto	ES, TME, PS
AGWA	Co/Físico	Cuenca	Continuo	Alto	ES, TME, PS
GUEST	Físico	Parcela/campo	Continuo	Alto	ES, CS
KINEROS2	Físico	Ladera/Cuenca	Evento	Alto	ES, TME, S
LISEM	Físico	Cuenca peq.	Evento	Alto	ES, S
EUROSEM	Físico	Cuenca peq.	Evento	Alto	ES, E, S
PERFECT	Físico	Parcela/campo	Continuo	Alto	ES, E
SEDNET	Co/Emp.	Cuenca	Anual/continuo	Alto	Sedimentos suspendidos (SS), ES y erosión de riberas
T0POG	Físico	Ladera		Alto	Riesgo de erosión
USLE	Emp.	Ladera	Anual	Alto	E
RUSLE	Emp.	Ladera	Anual	Alto	E
RUSLE-3D	Emp./Co	Cuenca	Anual	Moderado	E
USPED	Emp./Co	Cuenca	Evento/ Anual	Moderado	E/D
EROSION-3D	Físico	Cuenca	Evento	Alto	ES, E, S
MMMF	Emp./Co	Ladera/Cuenca	Anual	Moderado	ES, E
THORNES	Co/Emp.	Ladera/Cuenca	Anual	Moderado	ES, E
EPIC	Físico	Ladera/Cuenca	Continuo	Alto	E
WATEM	Co	Cuenca	Anual	Moderado	E
WEPP	Físico	Ladera/Cuenca	Continuo	Alto	ES, producción de sedimentos (PS), E
MIKE-11	Físico	Cuenca	Continuo	Alto	PS, ES
SHETRAN	Físico	Cuenca	Evento	Alto	ES, TME, PS
SEAGIS	Emp./Co	Cuenca	Anual	Alto	E, PS,
PESERA	Físico	Ladera/región	Continuo	Alto	ES, E, S
SPL	Emp./Co	Cuenca/río	Anual	Moderado	Erosión fluvial, incisión de ríos
	Co: conceptual		**Emp.: empírico**		

Para aquellos más comúnmente empleados en estudios de erosión, el Cuadro 5 incluye sus aplicaciones principales; en tanto que el Cuadro 6, presenta en forma resumida las principales ventajas y limitaciones a ser consideradas en éstos, en el marco de estudios de erosión y sedimentación.

Cuadro 5. Áreas de aplicación para modelos de erosión del suelo más comunes (Auerswald, 2008).

Modelo	USLE/RUSLE	WEPP	EPIC	AGNPS	EUROSEM
Frecuencia de uso[1]	51%	16%	13%	5%	4%
Escala temporal					
• Minuto					+
• Evento individual	(+)	+		+	+
• Anual		+	(+)		
• Largo plazo	+	+	+		
Escala espacial					
• Predio	+	+	+		+
• Cuenca	(+)	+		+	+
Uso del suelo					
• Agricultura	+	+	+	+	+
• Praderas / Forestal / Sitios de construcción	+	+		+	
• Estructuras de control de erosión	+	+		+	
Tipos de erosión					
• Cárcavas / Cárcavas efímeras		+	+	+	+
• Canalículos e intercanalículos.	+	+	+	+	+
• Derretimiento de nieves	(+)	+			+
• Por riego		+			
• Eólica			+		
Sedimentación			+		+
Pérdida de nutrientes/pesticidas			+	+	
Movimiento de agua (escorrentía, infiltración, percolación)		+	+	+	+
Generador de clima		+	+		
Crecimiento vegetal		(+)	+		
Evaluación económica			+		

[1] modelos en artículos científicos entre 2000 y 2003 en base a 15 modelos comunes
(+) aplicabilidad restringida.

Sensores remotos (SR): En los estudios de erosión de suelo, los datos de alta resolución (1 m) tales como fotografías aéreas son frecuentes para áreas entre 2.000 y 10.000 ha, mientras que aquellos de baja resolución (15 m) se emplean para áreas > 10.000 ha. Vrieling (2006) resume las características principales de los satélites empleados en la investigación de la erosión de suelos (Cuadro 7). A partir de estos datos es posible realizar una interpretación visual de cárcavas y otras superficies erosionadas, basada en la desviación de las propiedades espectrales, o bien se hace automáticamente utilizando la técnica de máxima verosimilitud. Otra opción de uso de los SR en conservación de suelos es por la vía de relaciones empíricas entre erosión y reflexión, lo que asume implícitamente una vinculación entre la cubierta vegetal y la erosión (Mathieu *et al.*, 2007). En relación a los efectos fuera del sitio (*ex situ*) afectado por erosión, los SR tienen una indudable aplicación en el ámbito de calidad de aguas, pues les es posible detectar la carga de sedimentos disueltos.

Cuadro 6. Ventajas y limitaciones de la modelación de la erosión del suelo

Ventajas
Se utilizan para estimar tasas de erosión en áreas donde no existe dicha información.
Se pueden utilizar para predecir las tasas futuras de erosión bajo escenarios de cambio climático, uso de la tierra y/o empleo de tecnologías de conservación.
Sirven para hacer una evaluación de los riesgos de erosión definiendo las áreas críticas, donde las tasas de erosión exceden límites permisibles (tolerancia).
Limitaciones
Su aplicación está limitada a los ambientes (lluvia, condiciones hidrológicas y del paisaje), escala y usos de la tierra para los cuales han sido desarrollados y calibrados. Su empleo en otras condiciones puede producir resultados completamente erróneos.
La aplicación correcta de los modelos implica: i) un chequeo de la validez del modelo para las nuevas condiciones de uso, ii) la disponibilidad de un banco de datos confiables, iii) el refinamiento/mejoramiento de los parámetros empleados en el modelo iv) la verificación/ calibración de los resultados del modelo con observaciones de terreno a largo plazo y otros métodos. Al respecto existen muy pocos estudios completos por lo que la calidad de los resultados obtenidos es incierta.
Cuando son aplicables, los resultados deben ser considerados en primera instancia más bien como una clasificación de los riesgos por la erosión, que una estimación de las tasas de la erosión.
Su complejidad y dificultad de uso, costos de desarrollo, disponibilidad de datos, calibración, valor para los usuarios finales, desempeño y cambios de escala a partir de predicciones en pequeña escala.
En particular, los modelos espacialmente distribuidos, requieren de mayor información con alta resolución espacial. Esto puede dar lugar a que los costos de recolección de datos excedan los beneficios del modelo.

Cuadro 7. Características de satélites empleados en investigación de erosión (Vrieling, 2006).

Satélite	Sensor	Tiempo de operación	Resolución espacial (m)	Cantidad de bandas espectrales	Dominio espectral
Landsat-1,2,3	MSS	1972 – 1983	80	4	VNIR
Landsat-4,5	TM	1982 – 1999	30	6	VNIR, SWIR
			120	1	TIR
Landsat-7	ETM	1999 –	15	1	VNIR
			30	6	VNIR, SWIR
			60	1	TIR
SPOT-1,2,3	HRV	1986 –	10	1	VNIR
			20	3	
SPOT-4	HRVIR	1998 –	10	1	VIS
			20	4	VNIR, SWIR
IRS-1A,1B	LISS-1	1988 – 1999	72,50	4	VNIR
	LISS-2		36,25	4	
IRS-1C,1D	PAN	1995 –	5,80	1	
	LISS-3		23,50	3	
			70	1	SWIR
Terra	ASTER	1999 –	15	3	VNIR
			30	6	SWIR
			90	5	TIR
NOAA/ TIROS	AVHRR	1978 –	1.100	5	VNIR, SWIR, TIR
IKONOS	Pancromático	1999 –	1	1	VNIR
	Multiespectral		4	4	
QuickBird	Pancromático	2001 –	0,61	1	
	Multiespectral		2,44	4	

VNIR: Visible e infrarojo cercano SWIR: infrarojo de onda corta TIR: infrarojo térmico

Para cárcavas grandes y que abarcan grandes extensiones, la fotografía aérea es una técnica bastante apropiada, a pesar de la dificultad de interpretar sus límites consistentemente; si se consigue delimitar claramente los bordes de la cárcava, es posible comparar su forma para distintas fechas, consecuentemente su avance ya sea en la cabecera o en sus flancos. Más recientemente, algunos autores (Betts *et al*., 2003; Baily *et al.,* 2003), en base a fotografía aéreas a gran escala (1:10.000) han construido modelos de elevación de alta resolución digital (DEMs), los que pueden presentar la precisión de las técnicas tradicionales de fotogrametría analítica, pero son mucho más rápidos en generar resultados.

Perspectivas de los estudios de erosión y sedimentación.

Los procesos e interacciones entre las fuentes de suelo/sedimentos, su transporte en el paisaje y acumulación en sumideros son sumamente complejos. Los mecanismos de transporte son claves para comprender el movimiento y destino de muchos nutrientes (ejem: N y P) y residuos de agroquímicos asociados (Nario *et al.,* 2009; Mc Dowell and Sharpley, 2003; Mc Dowell *et al.*, 2001), así como la dinámica del C a nivel de cuencas (Lal, 2007; Schmitter *et al.*, 2010). La acumulación de estas sustancias puede disminuir la productividad agrícola, impulsar la eutrofización y la degradación ambiental. Por lo tanto, es necesario conocer y comprender estos procesos para identificar zonas críticas de erosión (y producción de sedimentos) en la cuenca, de forma de planificar y ejecutar prácticas efectivas de control.

Se considera que a pesar de los avances en las técnicas de medición, el constante mejoramiento de modelos de estimación y el empleo de tecnología de vanguardia en los estudios de erosión, persisten ciertos obstáculos de conocimiento para que la conservación de suelos pueda resolver los problemas que genera este tipo de degradación de los suelos. En este sentido la Conservación de Precisión (Delgado and Berry, 2008; Schumacher *et al*., 2005) ha sido recientemente propuesta como una herramienta que se orienta a superar varios de estos obstáculos.

Es sabido que los suelos degradados no responden a cualquier aporte adicional de insumos agrícolas, a menos que su calidad física, química y biológica sea restaurada. Esta restauración hacia niveles al menos cercanos a los originales, está supeditada al concepto de resiliencia del suelo, es decir, la capacidad regenerativa inherente al suelo, que relacionada a su manejo permitiría revertir la degradación del suelo. Sin embargo, actualmente solo se tiene una claridad parcial de este concepto extremadamente fundamental para determinar si una práctica de manejo debe ser aceptada o rechazada (Casanova, 2000).

Por otra parte, considerando que la erosión de suelos comprende el desprendimiento de partículas, su transporte y posterior depositación a una tasa superior a la tasa de formación de suelos, se cuenta con escasa información a nivel local de esta última. Para el diseño adecuado de las medidas de control de erosión resulta fundamental contar con la tolerancia del suelo a ésta pero, a pesar de los esfuerzos por abordarla científicamente, tampoco se cuenta con esta información a nivel local. En síntesis, para cumplir con las tareas pendientes de evaluación de la erosión es imperativo tomar acciones y los programas de uso y *manejo sustentable* de tierras deberían pasar de la retórica a la práctica debiendo incluir el seguimiento, evaluación del impacto, la experimentación de evaluación y control (consensuada o participativa, adaptada a la realidad local y de tecnologías innovadoras), inventario de los recursos (líneas bases y banco de datos), la generación de información confiable y, sobre todo, una formación y entrenamiento sólidos y completos de los actores involucrados.

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EVALUACIÓN DE LA EROSIÓN DE SUELO: MÉTODOS ISOTÓPICOS

Felipe Zapata[1] , Gerd Dercon[2], Manuel Casanova[3]

[1]Universidad de Chile. Departamento de Ingeniería y Suelos. (mcasanov@uchile.cl).
[2]Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, Department of Nuclear Sciences and Applications, International Atomic Energy Agency Wagramerstrasse 5. A-1400, Vienna - Austria. (G.Dercon@iaea.org).
[3]Consultor. Programa Conjunto FAO/IAEA, Wagramerstrasse 5. A-1400, Viena - Austria. (zapatafel@hotmail.com).

Abstract
Search for alternative methods to supplement the information provided by the traditional methods of measuring erosion and meet the new requirements, have directed attention to the use of nuclear techniques. Different radionuclides (radioisotopes) are used as tracers of soil motion. In these studies, both the source and the amount of soil loss can be determined by marking artificial soil particles with an appropriate radionuclide. Moreover, double marking techniques allow the detection of two sizes of particles or contribution from two sources. This contribution is intended to provide an overview of available information on isotopic tracers used for the quantification of accelerated soil erosion.
Key words: isotopic tracers, erosion assessment.

Introducción
Diversos radionúclidos artificiales, principalmente emisores de rayos gamma (^{59}Fe, ^{46}Sc, ^{110}Ag, ^{198}Au, ^{134}Cs, ^{51}Cr etc.), han sido utilizados como trazadores en estudios de campo de la erosión del suelo. Sin embargo la mayoría de aplicaciones en estudios de erosión está relacionada con el empleo de los radionúclidos ambientales como ^{137}Cs, ^{210}Pb, ^{7}Be, ^{240}Pu, ^{14}C, ^{32}Si, ^{26}Al y ^{36}Cl, los cuales han mostrado gran potencial para evaluar la erosión y la sedimentación (IAEA, 1995; IAEA, 1998). Algunos de ellos son naturales y pueden ser producidos por los rayos cósmicos en la atmósfera (^{7}Be, ^{14}C, ^{32}Si, ^{26}Al y ^{36}Cl) o son miembros de la serie de desintegración natural de los radionúclidos primordiales ^{238}U, ^{235}U y ^{232}Th (por ejemplo, ^{210}Pb). Otros (^{134}Cs, ^{137}Cs, $^{239-240}$Pu y ^{241}Am) son artificiales y han sido liberados al ambiente como lluvia radioactiva, como resultado de las pruebas de armas nucleares en la atmósfera o a partir de reactores nucleares.
Cuando radionúclidos tales como ^{137}Cs, ^{210}Pb y ^{7}Be llegan a la superficie del suelo, éstos son adsorbidos rápida y fuertemente a los

sitios de intercambio de los coloides y resultan básicamente no-intercambiables en la mayor parte de los ambientes. En vista que los procesos biológicos y químicos casi no tienen influencia sobre el intercambio de los radionúclidos adsorbidos, su movimiento está mayormente determinado por procesos físicos. Así, para obtener un inventario de los radionúclidos, se recolectan muestras de suelo/ sedimento en puntos seleccionados del área en estudio siguiendo un protocolo y diseño de muestreo establecido. La medición exacta de las actividades de estos radionúclidos en las muestras es relativamente fácil, pues se emplean protocolos estandardizados para asegurar la calidad de los resultados, se utiliza instrumentación moderna (Espectrometría Gamma de Germanio de Alta Pureza, detector HPGeγ y la información se obtiene electrónicamente mediante logiciales especiales. No obstante, la realización de ejercicios de inter-comparación, es fundamental para conocer y mejorar la ejecución analítica de los laboratorios (Shakashiro and Mabit, 2009).

Los inventarios de radionúclidos ambientales como ^{7}Be, ^{137}Cs, y ^{210}Pb proporcionan información básica para estimar las tasas promedio de redistribución del suelo a corto plazo (< 30 días), mediano plazo (~40 años) y largo plazo (~100 años) respectivamente, utilizando modelos de conversión (Ritchie and McHenry, 1990, Walling and Quine, 1995, Zapata *et al.*, 2002). Además, dichos valores pueden ser graficados utilizando modelos digitales de elevación (DEMs) para apreciar los patrones de redistribución del suelo en el área estudiada.

Una revisión reciente de las ventajas comparativas y limitaciones de dichos tres radionúclidos (Cuadro 1) ha sido realizada por Mabit *et al.* (2008).

Cuadro 1. Comparación de radionuclidos para documentar redistribución y sedimentación.

	^{137}Cs	^{210}Pbex	^{7}Be
Origen	Antrópico	Geogénico natural	Cosmogénico natural
Energía emitida	662 keV	46,5 keV	477,6 keV
Vida media	30,2 años	22,3 años	53,3 días
Duración	50 años	100 años	< 6 meses
Escala temporal	Mediano plazo	Largo plazo	Corto plazo
Muestreo	Simple	Simple	Muestreo a incrementos finos de profundidad
Área de studio	Parcela a grandes cuencas	Parcela a cuencas	Escala local, parcela a predios
Equipamiento	Detector normal HPGe	Detector de amplio rango de energía HPGe	Detector normal HPGe
Medición en laboratorio	Fácil	Más difícil	Fácil
Medición *in situ*	Fácil	Limitada y no fiable	Al menos el doble de tiempo que ^{137}Cs
Datación de sedimentos	Posible	Posible	Posible

Avances en la aplicación de las técnicas nucleares

La planificación de dos redes internacionales de investigación por el Organismo Internacional de Energía Atómica (IAEA, 1995; Zapata *et al.*, 1995; Pennock and Zapata, 1995; IAEA, 1998) y su ejecución a nivel mundial con 25 grupos de trabajo, han contribuido a refinar la técnica. En particular, el desarrollo de protocolos armonizados se ha orientado a que pueda ser empleada como una herramienta universal en la cuantificación de la redistribución de suelo en una gran variedad de ecosistemas naturales (Zapata, 2002; Zapata and Nguyen, 2009). Su eficacia y valor ha sido demostrada (Queralt *et al.*, 2000; Zapata, 2003; Zapata, 2004) en un amplio rango de ambientes del mundo. Una selección de las aplicaciones de estas técnicas, en estudios de erosión/sedimentación, se presenta en el Cuadro 2.

Además, se ha compilado (Ritchie and Ritchie, 2009) una bibliografía (Internet), con casi 4.000 referencias hasta el año 2007, sobre uso del ^{137}Cs y otros radionúclidos en estudios de erosión/depositación de sedimentos. Ello ha facilitado la aplicación más amplia de la técnica, en particular para evaluar la eficiencia de tecnologías de conservación en el control o mitigación de la erosión del suelo y otros procesos de degradación asociados (Zapata, 2001, 2007). Más recientemente se han realizado estudios que incluyen el uso combinado de radionúclidos, lo que ha permitido la determinación de tasas integradas de erosión a diversas escalas de tiempo, además de patrones de redistribución de suelo en respuesta a diversas condiciones locales o a diferentes prácticas de conservación (Zapata and Li Yong, 2007).

El Programa Conjunto FAO/OIEA a través de proyectos de investigación y de cooperación técnica, más otros mecanismos, ha venido promoviendo un mayor desarrollo y aplicación de estas técnicas para controlar la degradación de los suelos, particularmente en estudios de erosión/sedimentación (Nguyen *et al.*, 2008; Zapata and Nguyen, 2009).

En el contexto de los impactos de la agricultura sobre la sustentabilidad ambiental, se han remarcado los efectos fuera del sitio causados por los sedimentos (y agroquímicos asociados) en la degradación de los recursos hídricos (calidad del agua), además de una gran variedad de otros problemas ambientales en muchas partes del mundo (Horowitz and Walling, 2005). Se pronostica que dichos impactos serán mayores en el futuro debido al cambio climático global.

En la actualidad, se ha establecido una red de investigación para desarrollar la aplicación conjunta de las técnicas de radionúclidos, modelación, sistemas de información geográfica y otras técnicas relacionadas para lograr una determinación cuantitativa del movimiento, transporte y almacenamiento de los sedimentos dentro

Cuadro 2. Selección de aplicaciones de las técnicas de radionúclidos ambientales en estudios de erosión/sedimentación (Zapata and Nguyen, 2009).

Asunto/tópico	Lugar	Referencias
Relación entre la predistribución del suelo y los factores topográficos	Canadá / Brasil / China Argentina / Eslovaquia	Pennock, 2000; 2003 ; Bacchi *et al.*, 2000; Bujan *et al.*, 2000; 2003; Fulajtar, 2000; 2003; Li Yong *et al.*, 2000
Relación entre parámetros de calidad de suelo y erosión deducida de la redistribución de ^{137}Cs.	Canadá /Brasil / China / Eslovaquia / Grecia	Pennock, 1998, 2000; Bacchi *et al.*, 2000; Li Yong *et al.*, 2000; Fulajtar, 2000; Theocharopoulos *et al.*, 2000.
Influencia de la labranza sobre la redistribución de suelo.	Canadá / Bélgica / China Chile /Canadá	Lobb *et al.*, 1995; Gowers *et al.*, 1996; Zhang *et al.*, 2003; Li Yong & Lindstrom, 2001; Schuller *et al.*, 2003, 2004, 2007; Li S. *et al.*, 2007
Identificación de fuentes de sedimentos en suspensión en cuencas.	Francia / Australia / Reino Unido	Sogon *et al.*, 1999; Wallbrink *et al.*, 1999; Walling, 2005.
Caracterización de erosión superficial a partir de perfiles de ^{137}Cs en sedimentos de lagos/reservorios.	China	Zhang & Walling, 2005
Control de la erosión/sedimentación para regenerar poblaciones de peces en ríos.	Canadá	Bernard & Lavardiere, 2000
Relación entre la redistribución de suelo (^{137}Cs)y los patrones de distribución de carbono orgánico del suelo.	Canadá / EUA / China	Pennock & Frick, 2001; McCarty & Ritchie, 2002; Ritchie & McCarty, 2003; Venteris *et al.*, 2004; Li Yong *et al.*, 2006, 2007
Producción de sedimentos y P-adsorbido a sedimentos según procesos de erosión y clases de uso de la tierra en una cuenca de uso múltiple.	Australia	Wallbrink *et al.*, 2003
Impactos de cosecha forestal en redistribución del suelo	Australia / Chile	Wallbrink *et al.*, 2002; Schuller *et al.*, 2006
Estudio de reconocimiento de erosión de suelo, Programa Nacional de Cuidado de Tierras.	Australia	Loughran *et al.*, 1992 ; Loughran & Elliott, 1996 ; Loughran (personal communication).
Comparación de métodos USLE, y ^{137}Cs para evaluar erosión de flujo precanalizado, canalículos y cárcavas.	Rusia	Belyaev *et al.*, 2005.
Estudios de erosión en cárcavas	Rumania / Rusia / China	Ionita & Margineanu, 2000; Belyaev *et al.*, 2004; Li Yong *et al.*, 2003
Caracterización espacial de los datos de redistribución del suelo empleando SIG	Canadá	Mabit *et al.*, 2007.
Relación entre la redistribución del suelo y el destino de los plaguicidas en paisajes agrícolas	Austria / Canadá / América Latina	IAEA, 2002; Farenhorst *et al.*, 2008 Ferris, personal communication
Mediciones de las pérdidas de erosión de suelo en diversos ambientes.	Marruecos / Japón / Italia Vietnam / Brasil / Turquía	Nouira *et al.*, 2003 ; Onda *et al.*, 2003, 2007 ; Fukuyama *et al.*, 2005; Phan Son Hai *et al.*, 2006; Guimaraes *et al.*, 2003 ; Porto *et al.*, 2003a; 2003b; Hadyakupoglu *et al.*, 2006
Aplicaciones de metodologías específicas y combinadas de radionúclidos ambientales	Australia / Italia / Reino Unido/ /Chile / China.	Burch *et al.*, 1988; Blake *et al.*, 2002; Porto *et al.*, 2006; Sepúlveda *et al.*, 2008; Walling *et al.*, 2003b ; Yang *et al.*, 2006; Zhang *et al.*, 2006 ; Zheng *et al.*, 2007
Validación de modelos de erosión/ sedimentación, espacialmente distribuidos	Reino Unido	Walling *et al.*, 2003a
Refinamiento de actuales modelos de conversión de inventarios de radionuclidos	Chile / China	Schuller *et al.*, 2000; Zhang *et al.*, 2000
Comparación de tasas de erosión obtenidas con ^{137}Cs y estimados por modelos de erosión	Brasil / Rusia	Bacchi *et al.*, 2003; Golosov, 2003
Estudios de erosión eólica	Reino Unido / EUA	Chappel *et al.*, 1998; Chappel & Warren, 2003; van Pelt *et al.*, 2007
Estudios de conservación de precisión	EUA	Schumacher *et al.*, 2005
Impactos de incendios en la redistribución de suelo y materia orgánica (nutrientes)	Australia	Wallbrink *et al.*, 2005

de las vertientes a diferentes escalas de tiempo (Walling *et al.*, 1998; Walling *et al.,* 2006; Walling, 2005; Le Cloarec *et al.*, 2007; Nguyen, 2008). Además, técnicas recientemente desarrolladas, basadas en la abundancia natural de isótopos estables de compuestos específicos (^{13}C y ^{15}N), serán empleadas como huellas digitales para identificar las fuentes de los sedimentos (Gibbs, 2005, 2006 y 2008). Tales aplicaciones ayudarán también a la identificación y localización de áreas de alto riesgo, para formular los lineamientos de una gestión sostenible de los recursos naturales (OECD, 2003 y 2004).

Otros estudios están orientados a contribuir al uso y manejo sostenible de tierras y aguas, en los países Miembros del OIEA, mediante el empleo de las técnicas nucleares y otras relacionadas. El Programa de Cooperación Técnica del OIEA proporciona asistencia técnica en términos de equipo, capacitación y designación de expertos para medir la erosión/sedimentación bajo diferentes ecosistemas, a fin de identificar tecnologías eficaces para controlar la degradación y para evaluar sus impactos adversos, tanto en la calidad/productividad del suelo como en la contaminación de los recursos hídricos. Este Programa viene ejecutando proyectos nacionales en varios países del mundo y también redes regionales; tal es el caso de Asia, durante el periodo 2002-2008 (IAEA, 2002; Nguyen *et al.*, 2008).

Como se ha señalado, particularmente en la zona andina y tropical, existen grandes extensiones degradadas por erosión a causa del uso inadecuado de las tierras y el manejo descuidado de sus suelos. Estos problemas han sido identificados como de alta prioridad en el Perfil Estratégico Regional de ARCAL (Acuerdo Regional de Cooperación para la promoción de la Ciencia y Tecnología nucleares en América Latina y el Caribe) para el periodo 2007-2013 (IAEA-ARCAL, 2007). En este sentido, el OIEA inició un proyecto regional que tiene como meta realizar urgentemente inventarios del grado de degradación de las tierras, determinar indicadores de calidad del suelo, evaluar los riesgos de la degradación y las probables consecuencias ambientales en los principales ecosistemas terrestres de la Región. Estos estudios, en los cuales participan 15 países de la región (Argentina, Bolivia, Brasil, Chile, Cuba, República Dominicana, El Salvador, Haití, Jamaica, México, Nicaragua, Perú, Uruguay, Venezuela) y coordinado por Argentina, incluirán la medición directa de tasas de erosión del suelo mediante radionúclidos y la aplicación de modelos en zonas representativas de los principales ecosistemas. Con ello se dispondrá de información necesaria para evaluar el riesgo potencial de los recursos, para así formular políticas y lineamientos acorde a la realidad social y económica de los países de la región.

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EL SISTEMA DE INCENTIVOS PARA LA RECUPERACION DE SUELOS DEGRADADOS, ARTICULACIÓN PÚBLICO-PRIVADA PARA MEJORAR LA SUSTENTABILIDAD DE LOS SUELOS.

Germán Ruiz[1] C., Elias Araya[1], Pilar mesa[1]

Servicio Agrícola y Ganadero, Chile.

Introducción

El Desarrollo Sustentable a nivel mundial tiene el desafío de resolver el problema de la degradación de los suelos. Chile, que tiene en la agricultura un pilar fundamental de su economía, no escapa a esta realidad la cual se ha visto acentuada en las últimas décadas por la intensividad del uso de las tierras y de prácticas inadecuadas de manejo del suelo, así como también por la sobreexplotación de este recurso.

Sobre las consecuencias o efectos concretos de la degradación de los suelos en la población objeto, se debe señalar que, como se ha dicho, ésta disminuye la potencialidad productiva de los suelos, limitando por consiguiente la rentabilidad de los sistemas agroproductivos, haciéndolos no sustentables y por consiguiente, deteriorando la calidad de vida de la población rural.

El Sistema de Incentivos para la Recuperación de Suelos Degradados (SIRSD) de Chile, junto a otros instrumentos de fomento[1], ha sido la iniciativa de mayor envergadura de las últimas décadas en inversión pública y articulación con el sector privado, destinada a recuperar el recurso suelo. Durante los últimos 12 años, considerando desde el año 1996 hasta el 2009, se han intervenido más de 2,7 millones de hectáreas y se ha beneficiado a más de 420.000 planes de manejo, con más de $ 260.000 millones entregados en bonificaciones efectivas, equivalentes a US$ 415 millones[2].

El recurso suelo

El suelo es uno de los recursos naturales más escaso y deteriorado del país. Los procesos de degradación y pérdidas de suelos, en lo que a cifras se refiere, son de alta significancia para el país, es así

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[1] DL 701. Ley de Fomento Forestal y Ley N° 18.450 de Riego y Drenaje.

[2] La cifra de superficie corresponde a hectáreas intervenidas, es decir, considera la aplicación de más de un programa específico en una misma superficie.
La cifra de agricultores también considera la participación de un agricultor en más de una oportunidad y está conformada por 45.000 beneficiarios del SAG y 335.000 de INDAP.
Los recursos en $ están actualizados por IPC a noviembre de 2008, los que se convirtieron a dólares a un valor de $ 640 por dólar (valor del dólar observado al 14 de noviembre de 2008).

como el 78% de la superficie de suelos productivos de Chile, presenta grados de erosión que van desde moderado a muy grave (CIREN-Chile, 1979). Del mismo modo, en el Tercer Informe Nacional[3], 2006 preparado por CONAF se señala que dos tercios del territorio nacional, equivalentes a 48,3 millones de hectáreas enfrentan en la actualidad procesos de desertificación. Con estos antecedentes, resulta evidente que los procesos de erosión y de desertificación en Chile son los problemas ambientales de mayor relevancia.

El Gobierno de Chile, en conocimiento de esta realidad, ha tomado el compromiso a través del Ministerio de Agricultura, a fin de impulsar medidas orientadas a mitigar las consecuencias de estos procesos, las cuales se suman a las propias acciones que en forma creciente adoptan los productores para dar sustentabilidad a sus recursos productivos.

Historia y evolución del SIRSD

Las primeras experiencias precursoras del SIRSD se remontan al año 1993, con la implementación del ***Programa de Bonificación de Fertilizantes para Praderas Naturalizadas de la Zona Austral***. Su sustento técnico se basaba en investigaciones del Instituto Nacional de Investigaciones Agrarias (INIA) y de experiencias en Nueva Zelanda, país en donde durante varios años se aplicaron subsidios a la fertilización y mejoramiento de suelos y praderas, lo que para este país *a posteriori* significó una de sus principales ventajas competitivas.

El Sistema de Incentivos para la Recuperación de Suelos Degradados» (SIRSD) en su versión inicial, se concibió como un medio para compensar el impacto negativo de la apertura comercial a las importaciones de carne, leche y granos de los países del MERCOSUR y se materializó como una de las 48 medidas ministeriales denominada «Bonificación al Establecimiento y Mejoramiento de Praderas en las regiones del Bío Bío, de la Araucanía y de Los Lagos[4]», establecida por el MINAGRI en 1995, tomando como base las experiencias de un programa de fertilización de praderas en la Región de Aysén, iniciado en 1993[5]. Esta medida formaba parte de un conjunto de iniciativas de apoyo a aquellos rubros y productores que podrían verse afectados por la asociación de Chile al MERCOSUR y por la rebaja de aranceles.

La implementación de esta iniciativa se fundamentó, además, en la constatación de que los suelos de las regiones del Maule hasta Los Lagos presentaban un fuerte déficit de fósforo disponible para las

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[3] CONAF-Chile, 2006

[4] Hoy separada en Región de los Ríos y de Los Lagos.

[5] Programa de Fertilización de Praderas fertilización de las praderas en las explotaciones de la región bonificando parte del valor de compra de fertilizantes.

plantas, asociado a un exceso de acidez, factores que limitaban seriamente el desarrollo de cultivos y praderas y por ende una baja competitividad sobre todo, de los rubros tradicionales.

Carácter del incentivo

El incentivo es un beneficio hasta un máximo anual de 160 UTM al valor del 1° de enero del año, al cual el usuario tiene pleno derecho una vez concluidas las labores correspondientes, las que debe confirmar por la vía de una declaración jurada y que a su vez se hayan comprobado y/o certificado la correcta ejecución de ellas, conforme a lo establecido técnicamente y en la época apropiada en el respectivo Plan de Manejo que dió origen a la asignación del incentivo, en el caso del SAG por la vía de concursos públicos de carácter regional, provincial o territorial, y en el caso de INDAP, por la vía de asignación mayoritariamente por «ventanilla».

Este Programa es de responsabilidad del Ministerio de Agricultura y se ejecuta en todo el territorio nacional, a través de dos instituciones estatales. Por una parte, el Servicio Agrícola y Ganadero (SAG), cubriendo el segmento de productores pequeños, medianos y grandes, vía concursos públicos. Por otra parte, el Instituto de Desarrollo Agropecuario (INDAP), sólo para productores pequeños y a través de la demanda directa de sus usuarios.

Es importante destacar que este objetivo no incorporaba explícitamente el carácter de fomento productivo que si alcanzó a finales de su implementación. Las urgencias ambientales, implícitas en los compromisos con la Organización Mundial del Comercio, dieron paso a la necesidad de ajustar el Sistema para incorporar programas específicos de conservación y rehabilitación de suelos. Estos aspectos permitieron una evaluación positiva del programa por hechos que trascienden el aspecto sólo productivo; todo asociado muy justificadamente a la conservación de los recursos naturales.

Objetivo del Programa

El objetivo general del programa es detener o revertir la pérdida sostenida de la fertilidad natural de los suelos de uso agropecuario. A través de este instrumento de fomento, el Servicio Agrícola y Ganadero (SAG) y el Instituto de Desarrollo Agropecuario (INDAP) asignan recursos destinados a la entrega incentivos a los productores (as), con el objeto de que éstos (as) puedan ejecutar un conjunto de prácticas tendientes a mejorar y/o preservar la calidad del recurso suelo. Los (as) productores (as) podrán mediante diagnóstico previo al predio, seleccionar las mejores prácticas propuestas por un técnico agrícola y/o profesional Ingeniero Agrónomo, a detener o revertir los procesos de

degradación de suelos, permitiendo que los productores (as) agropecuarios (as) del país puedan acceder a recursos estatales que se destinen a promover la conservación, el manejo sustentable y la recuperación de sus suelos.
Los Directores Regionales de INDAP y de SAG, por resoluciones fundadas en los recursos asignados y en las necesidades específicas de sus respectivas regiones, podrán, para las temporadas correspondientes, otorgar prioridad y asignar financiamiento al desarrollo de sólo algunos de los programas específicos señalados precedentemente o a determinadas prácticas de algunos de esos programas, pudiendo focalizarlos a áreas agropecuarias específicas, a localidades determinadas, a suelos que registren avanzados niveles de degradación o con otros criterios técnicos.

Funcionamiento del Programa.
Este Programa se desarrolla en todo el territorio nacional y en él tienen una importante participación tanto el sector público como el privado. El sector público a través del Servicio Agrícola y Ganadero (SAG) y del Instituto de Desarrollo Agropecuario (INDAP), bajo la coordinación de la Subsecretaría de Agricultura y de la Oficina de Estudios y Políticas Agrarias (ODEPA), ejecutan este Programa. INDAP asigna los incentivos a los pequeños productores, según lo establecido en la Ley 18.910 orgánica de INDAP, y el SAG atiende a todo tipo de agricultores, excepto a aquellos pequeños propietarios que en el mismo año, hayan obtenido el beneficio a través de INDAP[6].
El sector privado participa en este Programa a través de operadores (profesionales y técnicos del agro), que confeccionan los planes de manejo y toman las muestras de suelos para los análisis de fertilidad requeridos por los programas específicos de fertilización fosfatada, de aplicación de enmiendas calcáreas y establecimiento de cubiertas herbáceas permanentes, para la definición de dichos planes; los laboratorios acreditados que realizan los análisis de suelos y los agricultores, que son los beneficiarios directos.
La instancia de participación que en cada región coordina la ejecución del Programa es el Comité Técnico Regional (CTR) del SIRSD y en éste se encuentran representados actores públicos (SEREMI, SAG, INDAP, INIA y CONAF) y privados (asociaciones gremiales de productores, académicos y otros). Este Comité tiene por objeto coordinar y focalizar el Programa en la región, velar porque éste se ejecute en coherencia con la política agraria diseñada por el MINAGRI y proponer las bases técnicas y administrativas de los concursos del SAG.

[6] En el priemr trimestre de 2009, un dictamen de la Contraloría General de la República inhibe al Servicio Agrícola y Gandero de otorgar los beneficios de este programa a productores/as que califiquen como usuarios de INDAP.

El Programa en base a antecedentes regionales y nacionales fue identificando diferentes situaciones de degradación de tierras y en virtud de ellas fue definiendo programas específicos, los que fueron evolucionando desde sus inicios en el año 1995/96. Es así como hoy, contempla los siguientes programas específicos:

Componentes del sistema de incentivos

El «Sistema de Incentivos» está integrado por seis programas específicos, los que se describen a continuación:

Programa de establecimiento y regeneración de praderas

Está orientado a estimular el establecimiento o regeneración de cubierta vegetal permanente en suelos degradados mediante un incentivo de hasta un 50%. Es un instrumento de corto plazo con efectos hasta en los dos primeros años, los que pueden permanecer hasta el tercer año.

Programa de Conservación de Suelos

Este programa estimula evitar las pérdidas de suelos mediante el uso de prácticas tales como: cero o mínima labranza, incorporación de rastrojos, utilización de curvas de nivel, labranzas en contorno, establecimiento de coberturas forestales en suelos con erosión severa o que correspondan a ecosistemas frágiles de cordillera o precordillera y para protecciones de riberas de ríos y otros cauces de aguas, zanjas de infiltración, aplicación de materia orgánica o «compost», nivelación, labores que contribuyan a incorporar una mayor cantidad de agua disponible en el perfil de suelo apto para el uso agropecuario, exclusión de uso de áreas de protección u otros, para lo cual se otorga un incentivo de hasta el 80% de los costos netos, determinados en la tabla anual de costos, por efectos de aplicación de tales métodos de conservación de suelos.

Programa de Fertilización Fosfatada.

Este programa incentiva el uso de fertilización fosfatada de corrección, destinada a recuperar los niveles de fertilidad natural en suelos deficitarios, definida ésta en 20 mg de fósforo por kilo de suelo (20 ppm),según el método P-Olsen. Se bonifica hasta el 80% de los costos netos (sin IVA).

La fertilización fosfatada para producción, es decir aquella que será extraída por el cultivo y que deberá estar disponible en el suelo para alcanzar los rendimientos deseados, por sobre el nivel de 20 ppm de fósforo establecido como meta de corrección, es de responsabilidad del productor.

Programa de Enmiendas Calcáreas.
A través de él, estimula la incorporación al suelo de las dosis de cal necesarias para cambiar el nivel de pH hasta un valor de 5,8 o para reducir la saturación de aluminio a niveles inferiores al 5%, considerando la capacidad de intercambio de cationes efectiva según análisis de suelo. Se bonifica hasta el 80 % de los costos netos.

Programa de Rehabilitación de Suelos
A través de él se promueve la eliminación total o parcial de troncos muertos, matorrales sin valor forrajero y otros impedimentos físicos o químicos en suelos de uso agropecuario, mediante un incentivo de hasta el 50% de los costos netos de tales labores.

Programa de Rotación de Cultivos.
Está orientado a incentivar la rotación de cultivos por la vía de bonificar hasta en un 50% el costo neto de los cultivos que forman parte de la misma, determinados en la tabla anual de costos.

Participantes del Programa
Los participantes en optar al incentivo han sido preferentemente, pequeños y medianos productores. Estos pueden ser propietarios, arrendatarios, comunidades sucesoriales.
Todo postulante, deberá presentar ante el SAG o ante INDAP, según corresponda, un plan de manejo que deberá ser aprobado por tales servicios.
Para acceder al Programa, los productores deben presentar planes de manejo elaborados por operadores (profesionales y técnicos privados) que deben acreditarse ante el SAG o INDAP, para lo cual deben estar en posesión de un título profesional o técnico, cuyo plan de estudios contemple asignaturas académicas de reconocimiento y fertilidad de suelos, establecimiento de praderas o de protección de recursos naturales de uso agropecuario. Los operadores acreditados, asumirán la responsabilidad de los contenidos técnicos de los mismos.

Resultados.
Diversas evaluaciones realizadas sobre el Programa han destacado la alta significancia que éste ha tenido en el ámbito nacional y regional al ir sentando las bases para desarrollar la complementariedad entre desarrollo económico y la sustentabilidad del patrimonio natural. Sin duda que este es un aspecto que debe ser reforzado en adelante, a través de un mayor intercambio entre los agentes públicos y privados, para lo cual debe incentivarse la participación de los principales actores en los Comité Técnicos Regionales(CTR).

IMPACT OF LAND DEGRADATION ON FOOD SECURITY ANDSOCIO-ECONOMIC CONDITIONS IN THE DRIER ZONES OF INDIA

K. Shadananan Nair

Nansen Environmental Research Centre-IndiaGopal Residency II Floor, Thottekkat Road, Kochi œ 682011, Kerala, IndiaKerala, IndiaTel: +91-484-2383351, Fax: +91-484-2353124, E-mail; nair59@yahoo.com

Summary

Land degradation is a challenge to food and water securities, with far reaching consequences in the rural life in India, especially in the drier zones. Setbacks in agriculture affect rural employment opportunities. Soil erosion by wind and water causes landslides and floods in hill areas, threatening the existence of tribal communities. Intensive agriculture and unscientific irrigation leads to water logging and soil salination and alkanization in farms. Waste outflow from urban centres and domestic areas, salinity intrusion due to groundwater overdraft in coastal zones, overgrazing, deforestation, industrial development etc. result in widespread degradation of rich soil. In the arid western zone of India, wind erosion increases desertification, whereas in the plains, erosion due to floods and eutrophication due to agricultural runoff are evident. The agricultural revolution made India self-sufficient in food, but resulted in losing fertility of rich farming lands and contaminated the soil and water with fertilizers and pesticides. Sand quarrying, and landfilling of wetlands and paddy fields for industrial and residential purposes add to the already shrinking agricultural area. Demands for food in India will be tremendous in near future, as the population is expected to stabilise only by the year 2050 at 1.5 Billion, 50% more the present level. Feeding such a large population is a real challenge and efficient soil management has a key role to do in it. Unfortunately, the administrative and legal measures for soil protection in India fail because of political interference and slow and corrupt government machinery. Present paper is a comprehensive assessment of the issues associated with soil degradation and sustainable soil management in the drier zones of India. Suggestions for better management have been provided, considering the social, economic, political and environmental conditions.

Introduction

Sustainable management of land is a challenging issue in developing countries like India with a fast rising population and weak economy,

and with an inefficient administrative mechanism to implement effective protection measures. Controlling the soil degradation is important in achieving food security, sustainable forestry, and agricultural and rural developments. Indian economy is largely agriculture dependent and life of more than half of the population, especially the rural poor is some way related to it. Most of the land area in the country shows evidence of degradation, thus affecting the productive resource base of the economy. Out of the total geographical area of 329 million hectares, 175 million hectares are considered degraded. Arid and semi arid agricultural area comprise a large share of this. One sixth of the area of country is drought prone. India has a vast area of drylands potentially threatened by desertification.

Materials and methods

Drier zones of India have been delineated using the method introduced by Thornthwaite (1948) and later modified by Thornthwaite & Mather (1955) and by Subrahmanyam (1982). Aridity is the condition of extreme dryness, which eventually turns to desertification when conditions become favourable. It is a combined effect of irregularity in temporal and spatial distribution of rainfall, heterogeneous land topography and high anthropogenic pressure and local and global climate anomalies can play a decisive role in the spreading of aridity. It is determined as the ratio of a region's potential annual evaporation and transpiration, as determined by its receipt of solar radiation, to its average annual precipitation. Trends in aridity in these zones have been assessed. Necessary data of temperature and rainfall for the period 1901-2000 have been procured from the India Meteorological Department and the CDIAC, USA. Other relevant information on population and geography has been collected from various published records of the Government of India. A comprehensive assessment of the issues associated with soil degradation and sustainable soil management in the selected zones of India has been carried out. Suggestions for better management have been provided, considering the social, economic, political and environmental conditions

Results and Discussion Dry climates dominate almost half of the area of the country. Most of the interior parts are semiarid and the northwest is arid. Though the climate conditions showed wide variations in certain occasions, no significant trend in aridity was observed. However, changes in rainfall seasonality that influence the soil moisture condition may affect the soil characteristics in future.

In the arid western zone of India, wind erosion increases desertification, whereas in the interior plains, erosion due to floods and eutrophication due to agricultural runoff are evident. Vast areas

of interior India are rich agricultural lands. Intensive agriculture and unscientific irrigation leads to water logging and soil salination and alkanization in farms. The agricultural revolution helped India to overcome the food crisis during the post-independent period, but resulted in losing fertility of rich farming lands and contaminated the soil and water with fertilizers and pesticides. Today, sand quarrying, and landfilling of wetlands and paddy fields for industrial and residential purposes add to the already shrinking agricultural area. Waste outflow from urban centres and domestic areas, salinity intrusion due to groundwater overdraft in coastal zones, overgrazing, deforestation, industrial development etc. result in widespread degradation of rich soil.

Demands for food in India will be tremendous in near future, as the population is expected to stabilise only by the year 2050 at 1.5 Billion, 50% more the present level. Feeding such a large population is a real challenge and efficient soil management has a key role to do in it. Agriculture being the livelihood of millions, any setback in it will have far reaching consequences in the socio-economic conditions in all sectors of India. Globalisation and industrial development in recent years have already proved their impact. There are rules and regulations for environmental protection. Unfortunately, the administrative and legal measures for soil protection in India fail because of political interference and slow and corrupt government machinery.

To achieve success in soil conservation there is need of a holistic approach paying attention to policy, institutions and operations framework. A comprehensive policy should comprise land, water, forest, population and socio-economic factors. It should also include awareness, and schemes for the participation of public and NGOs. The Government strategy towards preventing soil degradation may include survey and investigation of problem through remote sensing techniques, bio-mass production in reclaimed land, micro level planning and transfer of technology. The country needs to develop a climate adaptation mechanism, as the possible extremes in rainfall and temperature are likely to affect the soil condition. India is included in the list of countries having dry lands that are potentially threatened by desertification.

There should be a strong and impartial political will to implement the policy guidelines.

Conclusions

Though there is no significant trend in aridity, changes in rainfall seasonality associated with global climate anomalies may affect the soil characteristics in future. In addition to climate related factors such

as wind, droughts and floods, human induced factors such as such as unscientific farming, sand quarrying landfilling of wetlands and paddy fields for industrial and residential purposes add to the degradation of land. Trends in urbanization, overdraft of groundwater that increases salinity, overgrazing, deforestation, industrial development etc. result in widespread degradation of rich soil. The country needs to develop an appropriate policy for land and water, a climate change adaptation mechanism, and an efficient mechanism for their implementation. Control of further degradation of land is vital, as the country is heading towards a food crisis.

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CUANTIFICACIÓN DE LA EROSIÓN DE SUELOS Y BALANCE HÍDRICO EN CULTIVO DE CAÑA DE AZUCAR Y PRADERAS EN LATOSOLOS, ESTADO DE SÃO PAULO-BRASIL

Cristian Youlton[1]; Edson Wendland[2].

[1]Doutorando em Ciências da Engenharia Hidráulica e Saneamento. Escola de Engenharia de São Carlos – Universidade de São Paulo (EESC/ USP). cristian.youlton@usp.br
[2]Professor Doutor do Departamento de Hidráulica e Saneamento. Escola de Engenharia de São Carlos – Universidade de São Paulo (EESC/ USP). ew@sc.usp.br

Introducción

Los cultivos extensivos más importantes en el Estado de São Paulo, Brasil, son las praderas y la caña de azúcar. La superficie cultivada con caña de azúcar para producción de bioetanol se expande mientras la actividad pecuaria extensiva es la que cede mayor superficie. Esta expansión continuará, considerando el aumento de la demanda de biocombustibles en Brasil y en el mundo. Esta expansión produce efectos ambientales negativos, como erosión de suelos descubiertos e intensamente arados para el establecimiento y renovación del cultivo, y entre la colecta anual hasta el nuevo crecimiento. Las partículas erosionadas producen turbidez en los cuerpos de agua, transportan agroquímicos contaminantes y producen el embancamiento de los cuerpos de agua.

En el Estado de São Paulo se han realizado pocas mediciones y estimativas de erosión en el cultivo de caña de azúcar. El Cuadro 1 presenta un resumen de los estudios existentes.

Cuadro 1. Mediciones de erosión en caña de azúcar, Estado de São Paulo

Municipio	Cultivo	Erosión ($t\ ha^{-1}\ año^{-1}$)	Metodología	Autor
Catanduva-SP	Caña 0% rastrojo	5,81	Simulación de lluvias	Martins Filho *et al.*, 2009
	Caña 50% rastrojo	1,93		
	Caña 100% rastrojo	0,77		
Piracicaba-SP	Caña	31	WEPP	Sparovek & Schnug, 2001
Piracicaba-SP	Caña	58	USLE	Weill & Sparovek, 2008
Estado SP	Pradera	10-0,19	USLE	Drugowich *et al.*, 2009
Cunha-SP	Pradera	28	USLE	Silva *et al.*, 2005

Las investigaciones de erosión en el cultivo de caña de azúcar y praderas en el estado de São Paulo fueron realizadas bajo diferentes condiciones de lluvias y suelos, por lo que sus resultados no son comparables entre si. Los modelos no fueron calibrados con valores

de erosión colectados en campo, o los datos existentes son mediciones puntuales de simulaciones que no consideran las variaciones interanuales. Como resultado, no existe consenso sobre las dimensiones del problema erosivo. Además de las pérdidas de suelo, la substitución de cultivos modifica el balance hídrico del suelo, especialmente por la interceptación del follaje y la demanda hídrica específica de cada cultivo. El balance hídrico, basado en la metodología de continuidad de masas, está dado por:

$$ETP = PP - IC - \text{”}W - Es - Per$$

donde

ETP: evapotranspiración, PP: precipitación, IC: interceptación del follaje, ”W: agua almacenada en el suelo, Es: escorrentía, Per: percolación.

Para el cultivo de caña de azúcar en Brasil, existen pocos estudios realizados para determinar su balance hídrico, y ningún estudio ha determinado los cambios causados por la substitución de praderas. El Cuadro 2 presenta un resumen de los estudios realizados.

Cuadro 2. Estudios de balance hídrico a caña de azúcar en Brasil.

Municipio	Cultivo	Medición	Meses	Resultado	Autor
Piracicaba-SP	Caña con/sin rastrojo con/ sin quema	***PP***-Es-Per-ΔW	Nov-Mar	Sin diferencia estadística	Timm *et al.*, 2002
Jaboticabal-SP/ Pirassununga-SP	Caña con diferentes dosis N	***PP***-Per-***ΔW***-ETC	Sep-Jul	Sin diferencia estadística	Brito *et al.*, 2009
Campinas-SP	Caña de azúcar	***PP-IC***	Feb-Dic	40% de PP total es interceptada por el follaje	Castilho, 2000

Negrita y cursive: indica los parámetros medidos directamente.

En relación al balance hídrico, los estudios realizados no consideraron la fracción de lluvia interceptada por el follaje, no cuantificaron la percolación con mediciones directas en el suelo, como también no compararon caña de azúcar y praderas. Los objetivos del proyecto son: 1) Determinar experimentalmente la erosión de suelos en caña de azúcar y praderas. 2) Cuantificar los componentes del balance hídrico para los citados cultivos.

Metodología

Para determinar la pérdida de suelos en el cultivo de caña de azúcar y praderas, se construirán parcelas de escorrentía 20x10 m. Al final de la parcela existe un sistema colector con tapa para evitar el ingreso directo de lluvia, y un conjunto de estanques y divisores para retener la escorrentía y sedimentos, según la Figura 1. Los cultivos a evaluar

en las parcelas serán caña de azúcar para producción de etanol y pradera para el pastoreo de ganado bovino, simulando los manejos representativos de plantaciones comerciales, con tres repeticiones para cada cultivo. La plantación de caña de azúcar será realizada especialmente para el presente estudio, en un sector de pradera extensiva de la Hacienda Canchim, en convenio con la Empresa de Pesquisa Agropecuaria, Centro Pecuario Sudeste. Para evaluar el balance hídrico, las diferentes variables serán monitoreados con la metodología descrita en Cuadro 3.

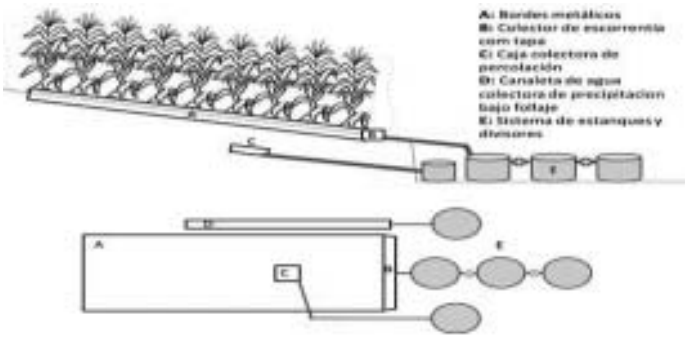

Figura 1. Parcelas de erosión.

Cuadro 3. Variables de medición.

Variable	Metodología
Evapotranspiración (ETP)	Ecuación Penman-Monteith (estación meteorológica)
Precipitación (PPtotal)	Pluviógrafo
Interceptación del follaje (IC)	PPtotal – PPsolo (canaletas de agua bajo el rastrojo)
Agua almacenada en el suelo (ÄW)	Tensiómetros para cada cultivo
Escorrentía (Es)	Parcelas de escorrentía
Percolación (Per)	Cajas metálicas 1 m bajo el nivel del suelo

La pendiente del área es de 12%, ya que según el Zoneamiento Agroecológico da Caña de azúcar, ese es el valor máximo permitido para cosecha mecánica del cultivo. Semanalmente serán colectadas muestras de escorrentía y erosión desde el sistema de tanques, determinando en laboratorio el peso seco de las muestras. Para evaluar si los cultivos producen alguna variación en el nivel freático, y determinar si tiene correlación con las mediciones de percolación, seran construidos dos pozos profundos con un dispositivo de monitoreo automático (*diver*). La investigación será desarrollada durante 2 años, monitoreando la erosión y balance hídrico desde la preparación de suelos hasta la primera cosecha de caña de azúcar. Los resultados obtenidos permitirá calibrar el

modelo WEPP y evaluar si la expansión del cultivo de caña de azúcar para producción de etanol es efectivamente una alternativa sustentable de biocombustibles bajo las condiciones del Estado de São Paulo, Brasil.

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ISOLATION AND CHARACTERIZATION OF *Bradyrhizobium* sp. ISOLATED FROM *Lupinus albescens* H. et Arn

Manoeli Lupatini[1]; Marcos Roberto Dobler Stroschein[1]; Flávio Luiz Foletto Eltz[1]; Zaida Inês Antoniolli[1]; Luciano Kaiser Vargas[2]; Adriana Giongo[3]; Mateus Padoin Pontelli[1]

[1] Department of Soil, Universidade Federal de Santa Maria, Avenue Roraima, 1000, Camobi, CEP 97105-900, Santa Maria, Rio Grande do Sul, Brazil, tl: 55- 3220-8157, fax: 55-3220-8256, e-mail: mlupatini@gmail.com
[2] Fundação Estadual de Pesquisa Agropecuária – FEPAGRO, Street Gonçalves Dias 570, Menino Deus, CEP 90130-060, Porto Alegre, Rio Grande do Sul, Brazil, tl: 51-3288-8000, fax: 51-3233-7607, e-mail: fepagro@fepagro.rs.gov.br(3 Department of Genetics, Universidade Federal do Rio Grande do Sul, Avenue Bento Gonçalves, 9500, CEP 91501-970, Porto Alegre, Rio Grande do Sul, Brazil, tl: 51-3331-66730, fax: 51-3331-92011, e-mail: giongo77@hotmail.com

Summary

Legume species belonging to the genus Lupinus are annual herb plants. The majority of them are indigenous to the Americas. They are known for nitrogen-fixing symbioses with soil bacteria collectively called rhizobia. The aim of this work was to characterize a rhizobium strain isolated from Lupinus albescens using phenotypic, symbiotic and molecular approaches. Strain UFSM LA 1.3 was tested in vitro according to several parameters: colony size, color and growing rate; acid or alkaline reaction in yeast mannitol media supplemented with bromothymol blue; gum production. Molecular characterization was evaluated by PCR technique using primers BOX A1-R and ITS sequencing. Sequence analysis of the 16S-23S rDNA intergenic region (ITS) fragments showed genetic similarity with Bradyrhizobium sp. The polymorphism observed by BOX-PCR have shown that strain differs from the reference strain SEMIA 928 and SEMIA 938. The symbiotic efficiency of UFSM LA 1.3 was 94.6% compared to the mineral nitrogen fertilized control.

Introduction

The Southwest region of Rio Grande do Sul State, Brazil, presents about 5.2% of the area occupied by sandy soils. *Lupinus albescens* H. et Arn, an wild specie, has been used in the recovery of sandy soils of RS due to its high rusticity, strong adaptability to sandy regions and biological nitrogen fixation when associated to rhizobia (Rovedder, 2007).

Microsymbionts from *Lupinus* spp. have been little characterized, but some species have been isolated from different lupin such as *Bradyrhizobium*, *Rhizobium* and *Ochrobactrum* (Trujilo *et al.,* 2005).

Besides rhizobia can be distinguished with cultural and morphological characteristics and the molecular biology techniques are used as complementary studies of strain characterization. Primers known as BOX (enterobacterial repetitive sequences) can create highly characteristic patterns when separated in agarose gels, providing good discrimination on strain level (Vargas *et al*., 2007).
Sequences of 16S rDNA are highly conserved among bacteria and a high sequence variation in the internally transcribed spacer (ITS) region has been observed in bradyrhizobia strains what makes ITS region a very informative tool of *Bradyrhizobium* taxonomic (Willems *et al.,* 2001). The objectives of this work to characterize a *L. albescens* isolate by phenotypic and molecular methods and to evaluate its symbiotic efficiency in a greenhouse essay.

Material and methods

L. albescens plants were collected in an experimental area located at Alegrete, RS, Brazil (29°39'58"S, 55°23'43"W) in a degraded area under sandy erosion processes. The region climate is classified by Köppen as Cfa, humid subtropical without dry season, with a raining fall about 1,400 mm per year (Rovedder, 2007). Soil of the experimental area is a Quartzipsamments (Soil Survey Staff, 1998) with pH of 4,5, 94,7% sand, 4,8% of clay and 0,8% of organic matter. Rhizobia were isolated form fresh root nodules on YEM medium (Somasegaran & Hoben, 1994). One strain, UFSM LA 1.3 was chosen for analysis in this study. *Bradyrhizobium* sp. strains SEMIA 928 and SEMIA 938 were used as type strains able to nodulate and fix nitrogen in lupin plants. It were obtained from the Biological Nitrogen Fixation Center/Fundação Estadual de Pesquisa Agropecuária (Fepagro), RS, Brazil.
UFSM LA 1.3 was tested for Gram reaction, cell shape, colony size, growing rate, pH range in YEM medium with bromothymol blue; presence of gummy substances and colony color (Somasegaran & Hoben 1994).
The strain UFSM LA 1.3 was cultivated in YEM broth during 7 days at 28°C and DNA isolation was carried out by CTAB modified method (Doyle & Doyle, 1991). rep-PCR reactions and ITS region sequencing were carried out according to Fernandes *et al.* (2003). The bands were analyzed by Gelpro-3.2 program using the algorithm UPGMA. The UFSM LA 1.3 sequence was added to the GenBank - NCBI (accession number EU367996). Partial nucleotide sequences of the ITS 16S-23S rDNA from strains of *Bradyrhizobium* sp. were accessed and utilized in a cladogram construction. The selected sequences were aligned by ClustalW algorithm and the phylogenetics relationships were accessed using Neighbor-joining method carried out by MEGA 4.0 (Tamura *et al*., 2007).

Evaluation of the capacity and symbiotic efficiency of rhizobial strain UFSM LA 1.3 and reference strain SEMIA 938 was performed in a greenhouse essay. Seeds of *L. albescens* were transferred into plastic pots containing a mixture of sterilized vermiculite and sand (2:1). After 48h pots were inoculated with bacterial culture grown in YEM broth. Plants were maintained in a greenhouse and were supplied with N-free plant nutrient solution once a week (Sarruge, 1975). Positive control received a solution of 400mg of ammonium nitrate per pot during all the experiment as N source. After 55 days plants were harvested and dried at 65°C and analyzed for nitrogen accumulation (Tedesco *et al*., 1995). The number of nodules, nodule dry weight, and dry matters were also measured. Statistical significance was determined by using the analysis of Scott-Knott test, with 5% error probability, estimated by the software Sisvar 4.6.

Results and discussion

One bacterial strain was selected among all bacteria isolated. Genotypic characterization of this strain was assessed by electrophoretic profiles of amplification products using rep-PCR and ITS sequencing.

When submitted to BOX-PCR analysis strain UFSM LA 1.3 showed a very particular band profile comparing with reference strains SEMIA 928 and 938. The reference strains SEMIA 928 and SEMIA 938 presented low polymorphism using this technique and could represent the same strain; only SEMIA 938 was kept for greenhouse experiments. UFSM LA 1.3 DNA amplification presented nine different bands with sizes ranging between 4888 and 192bp. This pattern was unique for this strain and it has been not observed in any other. Rhizobium sp. strain presents seven bands well defined with the size of 4507, 3643, 3320, 2791, 1335, 1053 and 192 bp. Two groups were formed with 60% molecular similarity, where the UFSM LA 1.3 isolated presented an 80% similarity with reference strains SEMIA 938 and 928 (Figure 1).

An 846bp fragment of the ITS sequence 16S-23S rDNA was obtained. Constructing the phylogeny with the aligned UFSM LA 1.3 sequence and sequences obtained from GenBank showed that the lupine isolate was closely related *Bradyrhizobium* sp. ORS 199 (95% homology) and *Bradyrhizobium* sp. ORS 3257 (92% homology) (Figure 2). Studies on bradyrhizobia species isolated from *Lupinus* spp. (Jarabo-Lorenzo *et al.*, 2003), indicated that the *Bradyrhizobium* strains nodulating this legume represents a very huge heterogeneous and their phylogenetic relationships is far from being solved.

Based in the experiments performed for phenotypic characterization strain UFSM LA 1.3 presented a slow colony growing rate with generation time of 10-14h forming convex, cream color, single, circular and mucoid colonies, reaching diameter of 1-2mm after seven days of incubation at 28°C on YEM agar. It presented basic reaction in YEMA media supplemented with bromothymol blue and low gum production. *Bradyrhizobium* genus presents these characteristics with exception of the cream color not frequently observed in this genus although it has already been described to *Bradyrhizobium* strains isolated from *Macroptylium atropurpureum* in Amazonia (Lima *et al*., 2005).

Strain UFSM LA 1.3 produced approximately 40% more aerial dry matter than SEMIA 938 without N supply (Table 1). Strain SEMIA 938 did not differed to the negative control treatment. Total nitrogen of the aerial matter of *L. albescens* demonstrated that strain UFSM LA 1.3 was similar to the positive control supplemented with nitrogen, presenting a concentration of 3.19% and a relative symbiotic efficiency of 94.2%. However, SEMIA 938 showed similar results to the control without nitrogen, with a nitrogen concentration of 2.42% with absence of nodule formation. It demonstrated that strain SEMIA 938 is not an efficient *L. albescens* symbiont.

Nodule formation processes depend and vary in function of plant genotype and strains involved, as well as environmental factors. In this way, soil and climatic conditions found in the Pampa region could have contributed to the rhizobia natural selection of symbiotic strains to *L. albescens*.

Conclusions

The UFSM LA 1.3 isolated demonstrated a high efficiency in the biological nitrogen fixation for *Lupinus albescens*, and showed phenotypic and molecular characteristics that allow locating this isolated in the *Bradyrhizobium* genus. The isolated presented low phylogenic relationship with described species for this genus until now, probably belonging to new *Bradyrhizobium* specie found in soil and climatic conditions under sandy soils and in *Lupinus albescens* plants, which microbial diversity is not well known.

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Table 1 - Plant response to inoculation with strains UFSM LA 1.3 and SEMIA 938.

Treatment	Dry matter (mg plant^{-1})	Nitrogen content (%)	Number of nodules	Relative symbiotic efficiency
UFSM LA 1.3	135 a*	3.19 a	4	94.2 a
SEMIA 938	80 b	2.42 b	0	4.6 b
Control + N	118 a	3.24 a	0	100.0 a
Control – N	95 b	2.38 b	0	0.0 b
Variation coefficient (%)	12.45	11.19		8.7

*Values in the same column followed by the same letter did not differ statistically at P=0.05 (Scott-Knott test).

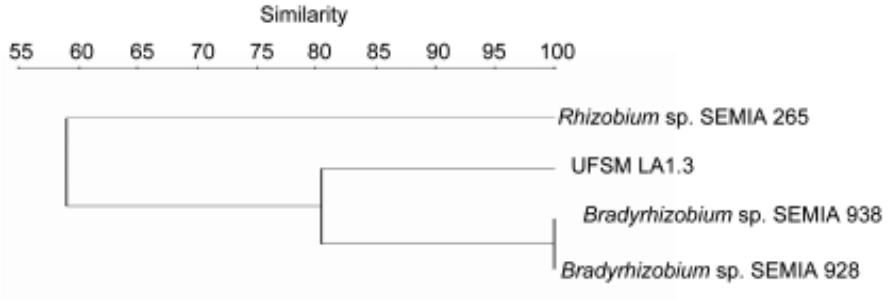

Figure 1 - Dendrogram built with UPGMA method and the Simpson coefficient based on BOX-PCR products obtained of strain UFSM LA 1.3 and other three rhizobia strains

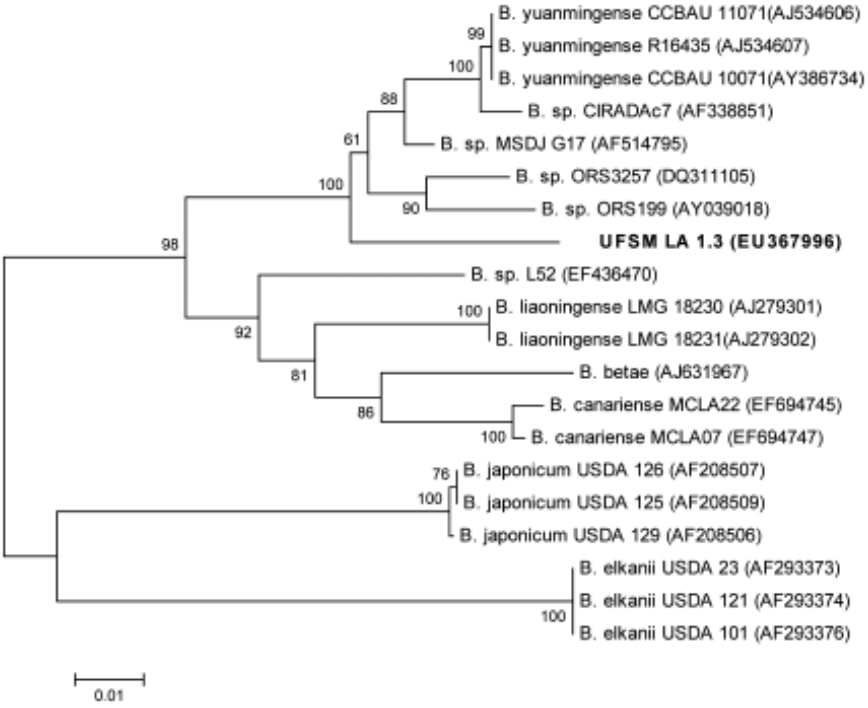

Figure 2 - Phylogenic tree based in the analysis Neighbor-joining of the ITS region 16S-23S rDNA of UFSM LA 1.3 and correlate bradyrhizobia. The number in the ramifications represents the bootstrap value. () código de acesso ao GenBank.

EFECTO DE DOS APLICACIONES DE LODO PROVENIENTE DE LA INDUSTRIA DE CELULOSA EN UN ANDISOL DEL SUR DE CHILE: ENSAYO DE LIXIVIACIÓN EN COLUMNAS

Gallardo, F.[1]; Flores, M.J.[1]; Peña, V.[1]; Diez, M.C.[2]

[1]Departamento de Ciencias Químicas y Recursos Naturales, Universidad de La Frontera
[2] Departamento de Ingeniería Química, Universidad de La Frontera. Av. Francisco Salazar 01145, Temuco. fgallar@ufro.cl

Resumen

La aplicación de lodos secundarios provenientes del tratamiento de aguas residuales de una planta de celulosa, se ha relacionado con mejorar las propiedades físico-químicas y biológicas de los suelos. Los lodos secundarios, se caracterizan por presentar altos contenidos de materia orgánica (M.O), macro nutrientes (N, P, K) y micro nutrientes (Cu, Fe, Zn). De esta manera estudios revelan la aplicación de este tipo de residuos como reemplazo de fertilizantes químicos. Asimismo, la contaminación de aguas superficiales y subterráneas por actividades agrícolas es un problema al cual se le ha puesto énfasis en los últimos años. Con el objetivo de estudiar el efecto de la aplicación de lodo de celulosa sobre la calidad de las aguas superficiales y subterráneas, se realizó un montaje de 12 columnas, las cuales corresponden a un tubo cilíndrico de PVC de 14 cm de diámetro y 60 cm de largo empacada con mezcla suelo-lodo. El ensayo correspondió a 2 aplicaciones de lodo, con dosis de 0, 10, 20 y 30 ton/ha realizadas cada tres meses. Cada tratamiento se realizó en triplicado. Las columnas fueron regadas con agua destilada asumiendo las precipitaciones de la región de la Araucanía. El análisis de lixiviados consistió en mediciones de pH, conductividad, DQO, nitrato y contenidos de Zn y Mn. La aplicación de distintas dosis de lodo en los suelos no produjo cambios significativos en el pH de las muestras analizadas. Los niveles de conductividad aumentaron al incrementar la dosis de lodo, lo cual fue más evidente luego de la segunda aplicación. En general, la aplicación de lodo aumentó los niveles de DQO y nitrato, esto debido al alto contenido de M.O y Nitrógeno del lodo. No se detectó la presencia de Zn y Mn en las muestras analizadas. Los resultados obtenidos se encuentran dentro del rango establecido según la normativa chilena para agua de riego. En base a lo anterior, se concluye que la aplicación de lodos en suelos de interés agrícola no produciría efectos negativos sobre la calidad de las aguas subterráneas.

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Introducción

El tratamiento de aguas residuales proveniente de una planta de tratamiento de RILes de la industria de celulosa Kraft, trae como consecuencia la generación de grandes cantidades de lodo biológico. La aplicación de lodos secundarios provenientes del tratamiento de aguas residuales de una planta de celulosa, se ha relacionado con mejorar las propiedades físico-químicas y biológicas de los suelos. Los lodos secundarios, se caracterizan por presentar altos contenidos de materia orgánica (M.O), macro nutrientes (N, P, K) y micro nutrientes (Cu, Ni, Zn) por lo que son útiles como reemplazo de fertilizantes químicos (Gallardo *et al*., 2010). La disposición de estos lodos como mejorador de suelo para fines agrícolas es una alternativa para evitar su acumulación y de esta manera contribuir a la recuperación de suelos degradados Asimismo, la contaminación de aguas superficiales y subterráneas por actividades agrícolas es un problema al cual se le ha puesto énfasis en los últimos años. De esta forma, el objetivo del presente trabajo fue estudiar el efecto de la aplicación sucesiva de lodo de celulosa sobre la calidad de las aguas superficiales y subterráneas.

Materiales y métodos

En condiciones controladas se realizó un montaje de 12 columnas, cada columna correspondió a un tubo cilíndrico de PVC de 14 cm de diámetro y 60 cm de largo empacada con mezcla suelo-lodo. El suelo utilizado para este estudio fue un Andisol, procedente de la serie Freire (pH, 5.4; MO, 10 %; P, 17,5 mg/kg; N, 19,2 mg/kg), extraído desde el centro experimental Maquehue de la Universidad de La Frontera, localizado en Freire Región de La Araucanía (Chile).

Asimismo, el lodo biológico proveniente del tratamiento RILes (lodo secundario) de una planta de celulosa kraft (pH, 6,9; MO, 76%; P, 313,1 mg/kg; N, 586,2 mg/kg) fue secado y aplicado a las columnas con dosis de 0, 10, 20 y 30 ton/ha cada 90 días. El ensayo contempló 2 aplicaciones sucesivas de lodo y cada tratamiento se realizó en triplicado. En la parte inferior de cada columna se dispuso de un sistema de aislamiento y protección con el fin de evitar los movimientos de partículas dentro de la unidad, además se montó de un sistema para la recolección de las muestras de lixiviado. Las columnas fueron regadas con agua destilada diariamente asumiendo las precipitaciones de la región de la Araucanía.

Los lixiviados fueron colectados mensualmente, filtrados (0,45 µm)

y almacenados en botellas plásticas para su posterior análisis. El contenido de nitrato y amonio fue determinado mediante destilación Kjeldahl (Keeney and Nelson, 1982), la conductividad y pH por potenciometría, se determinó la demanda química de oxígeno (DQO) utilizando el método colorimétrico (Clasificación APHA 5220 D). Para la determinación de metales se utilizó la metodología de espectrofotometría de absorción atómica con llama (NCh2313-10.Of96).

Los datos se analizaron con el programa estadístico SPSS versión 17. Se determinaron los valores medios y el error típico de la media. El análisis estadístico se realizó mediante ANOVA de una vía. La separación de grupos se determinó a través de la prueba Tukey ($P<0,05$).

Resultados

La Figura 1 presenta el efecto de dos aplicaciones sucesivas de lodo sobre el pH y conductividad de los lixiviados colectados. El pH de los lixiviados colectados de la primera aplicación de lodo osciló entre 5,0 y 5,5. Al prolongar el tiempo de muestreo junto a una segunda aplicación de lodo, el pH aumentó manteniendo un valor promedio de 6,0. Estos valores se encuentran dentro del límite para agua de riego según la NCh 1333.Of78 (5,5 – 9,0).

Los valores de conductividad mostraron resultados similares para las dos aplicaciones realizadas, aumentando progresivamente de 131 µS/cm a 191 µS/cm al incrementar la dosis de lodo. Esta variación indicó un movimiento de electrolitos solubles a través de los sustratos al incrementar la dosis. Sin embargo, los valores obtenidos se encuentran dentro del rango usual de conductividad para aguas de riego (0-3 dS m^{-1}) reportado por la Organización de Naciones Unidas para la agricultura y alimentación (FAO) el año 1985 (Santibañez *et al.,* 2007).

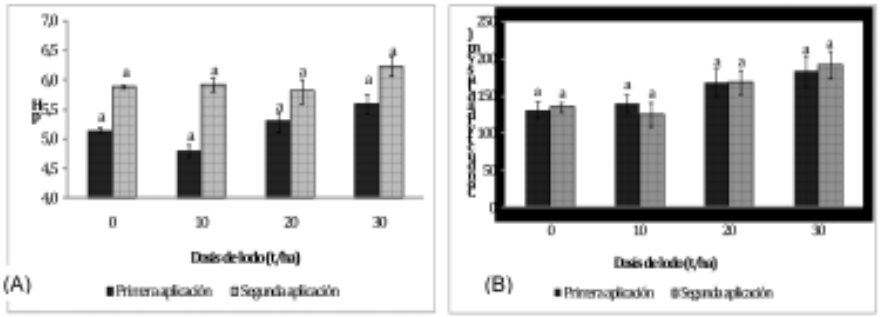

Figura 1. Efecto de dos aplicaciones sucesivas de lodo sobre el (A) pH y (B) conductividad de los lixiviados colectados

La productividad y calidad de la pradera mejora con la aplicación de fertilizantes nitrogenados. Sin embargo, un manejo inadecuado puede incrementar las pérdidas de nitrógeno (N) por lixiviación y volatilización, contaminando el medio ambiente (Nuñez, 2008). La lixiviación de N es el proceso a través del cual las diferentes formas nitrogenadas, orgánicas e inorgánicas aplicadas artificialmente o existentes en el suelo, son movilizadas más allá de la zona de las raíces de las plantas, por efecto del movimiento de percolación de las aguas (tanto por flujo de masa como por difusión) (Silva *et al.,* 1987). Según lo propuesto por Nuñez. (2008), la lixiviación dependerá además de las formas de nitrógeno en el suelo y de los cambios en los minerales presentes (NO_3^- + NH_4^+). La Figura 2 presenta las concentraciones de nitrato y amonio obtenidas de las muestras colectadas. Para la primera aplicación de lodo, no se encontraron diferencias significativas en el contenido de nitrato entre tratamientos, sin embargo al incrementar el tiempo de muestreo junto a una segunda aplicación de lodo, la concentración de nitrato aumento progresivamente oscilando valores entre 12 y 20 mg/L. Estos valores se encuentra dentro del rango establecido según la normativa para agua de riego según la FAO (5-30 mg/L) (Santibáñez *et al*., 2004). Por su parte, la concentración de amonio no superó los 10 mg/L, resultados similares fueron encontrados por Nuñez. (2008), al estudiar las pérdidas de nitrógeno por lixiviación en una pradera pastoreada en un Andisol, Serie Freire.

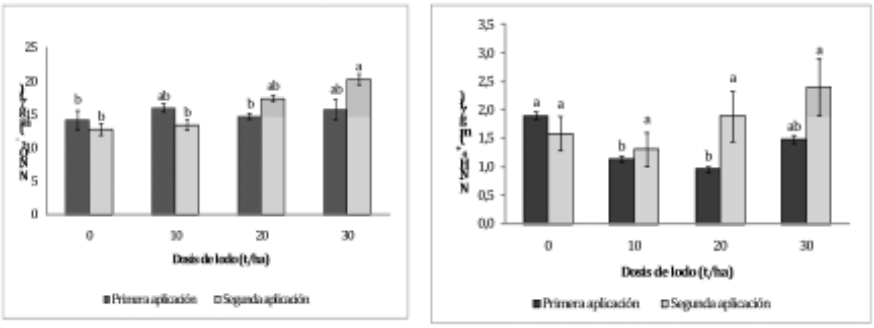

Figura 2. Efecto de dos aplicaciones sucesivas de lodo sobre el contenido de (A) Nitrato y (B) amonio de los lixiviados colectados

La carga orgánica de los lixiviados, medida en términos de DQO, es otro factor importante para determinar la calidad del agua y su contaminación potencial. Altos valores de DQO indican un nivel bajo de calidad del agua (Aluko *et al*., 2003). La aplicación de distintas dosis de lodo podría producir percolación de materia orgánica en las aguas residuales. Los mayores niveles de DQO fueron obtenidos en

los lixiviados colectados desde los tratamientos con mayor dosis de lodo aplicada. Sin embargo, las concentraciones obtenidas se encuentran dentro del rango permisible según la unión europea (125 mg DQO/L).

Por otro lado, se analizó el contenido de zinc y manganeso de las muestras colectadas, sin embargo no se detectó la presencia de estos elementos en las muestras colectadas.

Cuadro 1. Efecto de dos aplicaciones sucesivas de lodo sobre la demanda química de oxígeno.

DQO (mg/L)	*Dosis de lodo (ton/ha)*			
	0	**10**	**20**	**30**
Primera Aplicación	4,6 ± 0,6 c	6,4 ± 1,0 c	13,2 ± 0,8 b	12,4 ± 0,8 b
Segunda Aplicación	4,5 ± 1,0 c	15,7 ± 2,6 ab	18,7 ± 1,0 a	13,0 ± 1,7 b

Conclusión

En base a los resultados presentados es posible concluir que dos aplicaciones sucesivas de lodo proveniente de la industria de celulosa sobre suelos de interés agrícola no producirían efectos negativos sobre la calidad de las aguas subterráneas.

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OPTIMIZATION OF CARBON SEQUESTRATION USING SILVOPASTORAL SYSTEMS WITH PONDEROSA PINE AND CLOVER ON DEGRADED ANDISOLS IN THE CHILEAN PATAGONIA

Dube, Francis[1]; Zagal, Erick[2]; Stolpe, Neal[2], Thevathasan, Naresh[3]; Gordon, Andrew[3]; Espinosa, Miguel[1]

[1]Departamento de Silvicultura, Facultad de Ciencias Forestales, Universidad de Concepción, Victoria 631, Casilla 160C, Chile. Tel.: (+56) 41 2204848 Contact: fdube@udec.cl and mespinos@udec.cl
[2]Departamento de Suelos Y Recursos Naturales, Facultad de Agronomía, Universidad de Concepción, Vicente Méndez 595, Casilla 537, Chillan, Chile. Tel.: (+56) 42 208853 Contact: ezagal@udec.cl and nstolpe@udec.cl
[3]Department of Environmental Sciences, University of Guelph, Guelph, Ontario, N1G 2W1, Canada.
Tel.: (+1) 519 8244120 Contact: nthevath@uoguelph.ca and agordon@udec.cl

Abstract
This study aimed to investigate the potential to sequester C in a Ponderosa pine-based silvopastoral system (SPS), a plantation (PPP) and a natural prairie (PST) in the Chilean Patagonia. The C contents in grass and tree biomass in SPS exceeded that of PST and PPP, respectively. Determination of SOC and N at 0-40 cm depths shows that SPS had the highest contents, and there was more C in soil than corresponding plant biomass. C pools were 224, 199 and 177 t C ha^{-1} in SPS, PPP and PST, respectively, and net C flux was +1.8, +2.5 and –2.3 t C ha^{-1} y^{-1} for SPS, PPP and PST. The silvopastoral system is an interesting alternative for C sequestration, erosion control and plant growth. A land area of 481 km^2 under SPS would permit to offset all C losses from cattle-raising activities in the Chilean Patagonia.
Key words: C pools and fluxes, volcanic soils, leguminous pasture.

Introduction
Several studies have shown that agroforestry systems have greater C sequestration potential than sole cropping systems, prairies, and forest plantations. Still, few of them have measured *in situ* C inputs and outputs, which are all important when modeling C balance at the system level. The study performed by Peichl *et al.* (2006) is the only one known until now that compares the C fluxes and pools in monocropping and intercropping systems. In Patagonia, ranchers increasingly face more difficulties to maintain cattle-raising productivity, a traditional activity that is often the only source of income. However, there is a limited scientific research on Chilean agroforestry

systems that could be used to model C balances, and especially on degraded volcanic soils. This study is likely to be the first to investigate C sequestration potentials in agroecosystems of the Chilean Patagonia, and determine which land-use is the most promising to mitigate climate change.

Materials and methods

The site was located in the San Gabriel Agroforestry Unit established in 2002 by INFOR, at S 45°25' and W 72°00'. Within the module, the land-uses are: 1) natural prairie with traditional cattle grazing (PST), 2) 18-year-old *Pinus ponderosa* plantations (PPP), 3) silvopastoral systems arranged in strips (SPS). The annual precipitation is 1000-1500 mm. Mean temperatures are 12-14°C in summer and 2-3°C in winter. During summer, strong west winds provoke the loss of soil organic matter. Destructive sampling was performed to determine the weight of different tree and pasture components. C contents were obtained with a Fisons CHNS-O Elemental Analyzer. Litter traps were used to collect litterfall and determine their distribution. Litterbags were used to measure decomposition of organic material in contact with the soil. Soil samples were taken at 0-5, 5-20, 20-40 cm depths in order to determine C content. Soil respiration in closed chambers was measured following the soda-lime technique. The C% in leachates was measured using lysimeters at 80 cm depth. The soil moisture (20 cm depth), soil surface temperature (5 cm depth) and air temperature (+5 cm) were measured using Decagon Devices Data Loggers. All treatments were analyzed with the General Lineal Model procedure of SAS v.9.0 (SAS Institute, NC) for completely randomized designs. Analysis of variance was conducted with Tukey's HSD and Student's *t*-test, where applicable.

Results

The C content was higher in every component of SPS, but significant differences were found only for Twigs, Needles and Cones, Total aboveground, and Total tree (Table 1). C contents decreased in the order Roots > Trunks > Branches > Twigs > Needles > Cones. For PPP and SPS, respectively, 64 and 69% of total tree C were stored as aboveground biomass, whereas 36 and 31% were stored within roots. On a hectare basis, there was no significant difference between treatments regarding the amount of C stored in branches, twigs, needles and cones, besides the double-tree density in PPP.

Table 1. Carbon content of distinct tree components from a pine-based silvopastoral system arranged in strip (SPS) and a plantation (PPP) in the Chilean Patagonia (average ± standard deviation).

Tree components	kg tree^{-1}		kg ha^{-1}	
	PPP	SPS	PPP	SPS
Trunk	19.2 ± 4.8 a	23.0 ± 4.9 a	15350 ± 3829 a	9216 ± 1947 b
Branches	9.1 ± 5.9 a	12.6 ± 3.4 a	7291 ± 4755 a	5054 ± 1379 a
Twigs	2.3 ± 1.2 a	3.7 ± 1.1 b	1832 ± 952 a	1478 ± 436 a
Needles	7.6 ± 1.6 a	13.4 ± 4.1 b	6066 ± 1288 a	5341 ± 1636 a
Cones	0.2 ± 0.1 a	0.4 ± 0.04 b	144 ± 80 a	157 ± 15 a
Roots	21.3 ± 2.4 a	23.4 ± 4.8 a	17057 ± 1922 a	9372 ± 1912 b
Total aboveground	38.4 ± 13.2 a	53.1 ± 12.7 b	30683 ± 10577 a	21247 ± 5086 b
Total belowground	21.3 ± 2.4 a	23.4 ± 4.8 a	17057 ± 1922 a	9372 ± 1912 b
TOTAL	59.7 ± 15.5 a	76.5 ± 17.3 b	47740 ± 12379 a	30619 ± 6902 b

Values with the same lower case letter within a tree component and between treatments (PPP and SPS) for every group (kg tree^{-1} or kg ha^{-1}) are not significantly different (Student's t test, **P<0.01).

Table 2. Soil organic C and total N(%) and contents (Mg ha^{-1}) at distinct depths in a natural pasture (PST), a pine plantation (PPP) and a silvopastoral system arranged in strip (SPS) (average ± standard deviation).

Treatment	Soil depth (cm)	SOC (%)	N (%)	SOC (Mg ha^{-1})
PST	0-5	10.77 ± 0.7 A a	0.86 ± 0.15 A a	48.49 ± 3.34 A a
	5-20	5.62 ± 0.08 A b	0.38 ± 0.00 A b	75.85 ± 1.06 A b
	20-40	2.92 ± 0.50 A c	0.19 ± 0.01 A c	52.57 ± 9.08 A a
	0-20	6.92 ± 0.15 A	0.50 ± 0.04 A	124.5 ± 2.74 A
	0-40	4.92 ± 0.28 A	0.35 ± 0.01 A	177.1 ± 10.1 A
PPP	0-5	6.25 ± 0.08 B a	0.49 ± 0.01 B a	28.12 ± 0.37 B a
	5-20	3.89 ± 0.05 B b	0.28 ± 0.02 B b	52.49 ± 0.70 B b
	20-40	3.81 ± 0.43 A b	0.26 ± 0.05 A b	68.65 ± 7.70 A c
	0-20	4.48 ± 0.03 B	0.34 ± 0.02 B	80.61 ± 0.55 B
	0-40	4.15 ± 0.20 B	0.30 ± 0.02 B	149.3 ± 7.34 B
SPS	0-5	10.68 ± 0.4 A a	0.86 ± 0.03 A a	48.04 ± 1.57 A a
	5-20	6.51 ± 0.15 C b	0.49 ± 0.01 C b	87.94 ± 1.98 C b
	20-40	3.20 ± 0.21 A c	0.21 ± 0.00 A c	57.54 ± 3.73 A c
	0-20	7.57 ± 0.10 C	0.58 ± 0.01 C	136.2 ± 1.86 C
	0-40	5.38 ± 0.13 A	0.40 ± 0.01 C	193.8 ± 4.61 A

Values with the same higher case letter within a column and within a same depth among treatments are not significantly different (Student's *t* test, ***P*<0.01). Values with the same lower case letter within a column and within a same treatment are not significantly different (Tukey's HSD test, **P*<0.05).

When comparing litterfall in PPP and SPS, a significant difference was found only for needle fall in the second measurement period, being 60% higher in PPP. With respect to litterfall distribution within SPS, approximately 54% of the total fell within the tree strip, 40% within 3 m of the east side of the tree row and 6% within 3 m of the west side. Soil C was significantly different at 0-5, 5-20 and 20-40 cm depths in all treatments, except at 5-20 and 20-40 cm depths in PPP (Table 2). Among treatments, C% was similar at 0-5 cm depth in PST and SPS, but almost twice as high as PPP. At 0-40 cm depth, C% also decreased in the order SPS > PST > PPP. SOC reached a peak at 2.5 m on either sides of the strip, being higher eastward. Among

treatments, SOC was similar in the upper 5 cm in PST and SPS, but almost double and significantly different than in PPP. At 0-40 cm depth, SOC also decreased in the order SPS > PST > PPP, showing that land-uses affected substantially SOC stocks. There was a 69% increase resulting from the conversion of PPP to SPS but a 35% decrease from PST to PPP. Compared to PPP, soil respiration was similar within the tree strip and at 1 m from the strip in SPS, whereas at 7.5 m it was similar to PST (Table 3). Among agroecosystems, annual soil respiration was significantly higher in PST and lower in PPP. At distinct locations within SPS, soil respiration was not significantly different in the tree strip and at 1 from it, but significantly higher at a distance of 7.5 m. Leached C% was highest in PPP, and slightly higher in PST than SPS. Within SPS, C% was also slightly higher in the tree strip than at 1 m away, being the highest at 10.5 m from the strip, which is also the middle of the pasture alley, although none of the differences were significant.

Table 3. Total soil respiration (t CO_2 ha^{-1} y^{-1}) and C (%) of leached soil solution over two field seasons, between November 2007 and 2009 (average ± standard deviation).

Treatment	Soil respiration (t CO_2 ha^{-1} y^{-1})	C in leachates (%)
PST	18.75 ± 0.29 A	0.0049 ± 0.0020 AB
PPP	15.63 ± 0.39 B	0.0056 ± 0.0024 A
SPS (mean)	16.94 ± 0.58 C	0.0044 ± 0.0008 B
SPS (in strip)	15.27 ± 0.53 a	0.0044 ± 0.0011 a
SPS (1m from strip)	15.98 ± 0.53 a	0.0040 ± 0.0011 a
SPS (7.5m from strip)	18.84 ± 0.68 b	n/a
SPS (10.5m from strip)	n/a	0.0048 ± 0.0016 a

Values with the same higher case letter within a column and among treatments (PST, PPP and SPS) are not significantly different (Student's t test, **P<0.01). Values with the same lower case letter within a column and between locations in SPS (in strip, 1, and 7.5 or 10.5m from strip) are not significantly different (Tukey's HSD test, *P<0.05).

Discussion

It is clear that trees in SPS are using more efficiently the site resources (water, nutrients, light, etc.) and have their growth enhanced by the additional soil N provided by the leguminous pasture, resulting in larger amounts of C being sequestered. There is a favorable microclimate in SPS, and a synergy resulting from the positive interaction of active aerial and subterranean C cycles of the tree and grass components. Bigger trees in SPS compensate for the lower density, without forgetting additional C sequestered in grass roots and soil pools, thereby making SPS the best alternative of all. The predominant winds blowing eastward across the year were responsible for the low litterfall input within 3 m west. On the other hand, other studies have shown increases of soil C following conversion of plantations to intercropping systems (Bambrick et al., 2010) and decreases after afforestation of pastures with first-

rotation pine plantations (Dube et al., 2009). The larger SOC% at 2.5 m until the middle of the alley in SPS could be attributed to the better growth and yield of pasture in contrast with PST, resulting in more N being fixed by clover and stored in soil at 0-20 cm depth and therefore, more C being accreted. Also, the remaining stumps and coarse roots left in the alleys after converting the plantation to SPS, and the regular inputs of lignin-rich litter from the trees represent a source of recalcitrant C that may contribute to significant gains in SOC.

For every agroecosystem and distinct locations within SPS, there was a significant negative correlation between respiration and soil moisture, and highly significant positive correlations between respiration and air/soil temperature. The regular litterfall and shade provided by the tree cover in SPS strip and PPP resulted in lower mean annual air and soil temperature, contributing to decrease total soil respiration. On the other hand, the high C% in leachates at 10.5 m from the tree strip within SPS could be attributed to the presence of root exudates, decomposing stumps and structural/coarse roots since the conversion of the plantation into SPS. This could also explain why leached C is higher in PPP, taking also in consideration the half tree density in SPS, and why dissolved C follows the same pattern within and at 1 m from the tree strip in SPS.

C storage in agroecosystems pools, including trees and aboveground grass biomass, reached 224, 199 and 177 t C ha^{-1} within SPS, PPP and PST, respectively. Eighteen years after the establishment of SPS and PPP, their C pools are 27 and 12% higher, respectively, than the natural prairie C pool, and six years after the conversion of the plantation into the silvopastoral system, the SPS C pool has increased 13%. Carbon fluxes in agroecosystems over a two-year measurement period, including assimilation by trees and grass, decomposition of woody detritus, soil respiration, C leaching and atmospheric depositions, animal consumption, feces input and fertilizer applications, when applicable, reached +1.8, +2.5 and –2.3 t C ha^{-1} y^{-1} for SPS, PPP and PST, respectively. The C fluxes of SPS and PPP remained positive, which shows their potential as true C sinks, whereas the negative flux for PST indicates a net C source to the atmosphere. Based on the results of this study, the land area required in the Chilean Patagonia using SPS would be only 481 km^2 in order to become C neutral, while this value climbs to a total of 1678 km^2 if a natural prairie approach is used.

Conclusion

Well-designed silvopastoral systems can be effective CO_2 sinks, especially with the use of perennial crops and fast growing tree

species that increase soil sinks in the short term. In Patagonia, the adoption of silvopastoral systems is a sustainable practice that satisfies socio-economic needs of rural population, optimize land productivity, control erosion, preserve C and N pools, and contribute to reduce atmospheric CO_2.

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FITOTOXICIDAD EN SUELOS AFECTADOS POR LLUVIA ÁCIDA CERCANOS A UNA FUNDICIÓN DE COBRE

Iván González Labra[1], María Adriana Carrasco[1], Juan Pablo Fuentes[2]

[1] Departamento de Ingeniería y Suelos, Facultad de Ciencias Agronómicas, Universidad de Chile. Av. Santa Rosa Nº 11315, La Pintana, Santiago. i.gonzalez.labra@gmail.com
[2] Departamento de Silvicultura, Facultad de Ciencias Forestales, Universidad de Chile. Av. Santa Rosa Nº 11315, La Pintana, Santiago.

Resumen

Más del 50% de las exportaciones de nuestro país provienen de la minería del cobre. Pese a los beneficios económicos que la minería aporta al país hay una serie de perjuicios ambientales. Uno de los efectos adversos que la minería del cobre genera al ambiente es la lluvia ácida, la que se genera al reaccionar los gases provenientes de las fundiciones con la humedad del aire. Al caer esta lluvia acidifica todos los ecosistemas donde se deposita. En el caso de los suelos, al acidificarse aumentan los contenidos de aluminio intercambiable, el que es altamente fitotóxico. Con el objetivo de evaluar fitotoxicidad por aluminio intercambiable en suelos afectados por lluvia ácida y si ésta tiene relación con la distancia de la fuente contaminante de gases generadores del fenómeno y con la profundidad de muestreo, se realizaron tres bioensayos de germinación. Para ello se prepararon extractos de suelo muestreado a cuatro distancias crecientes de la fundición de cobre de Caletones (D1 = 2,8 km; D2 = 3,9 km; D3 = 6,6 km; y D4 = 7,2 km) y a tres profundidades (p1 = 0-5 cm; p2 = 5-10 cm; y p3 = 10-20 cm), dando doce tratamientos, los que contaron con cuatro repeticiones cada uno. En ellos se incubaron por 120 horas semillas de avena (*Avena sativa* L. cv. Nehuén), cebada (*Hordeum vulgare* L. cv. Libra) y lechuga (*Lactuca sativa* L. *var. capitata* cv. Cuatro Estaciones). Posteriormente se determinó para cada especie y tratamiento el Porcentaje Relativo de Germinación (PRG), Crecimiento Radical Relativo (CRR), Índice de Germinación (IG) y la Biomasa Radical (BR) en base a materia seca radical*semilla germinada^{-1}.

Independiente de la especie vegetal utilizada, el IG mostró tener mayor correlación con el contenido de aluminio intercambiable del suelo (R^2 entre 0,92 y 0,95, ajustándose a una curva logarítmica), lo cual hace recomendable su uso en desmedro del PRG (R^2 entre 0,29 y 0,47), CRR (R^2 entre 0,88 y 0,95) y BR (R^2 entre 0,16 y 0,45) Las tres especies mostraron que los niveles de fitotoxicidad por aluminio de los suelos presentan diferencias significativas ($p < 0,05$) en cuanto a la distancia de la fundición y la profundidad de muestreo,

presentándose valores de IG significativamente mayores en los suelos más lejanos y en los más profundos.
En cebada se observó una mayor correlación entre los valores de IG y los contenidos de aluminio intercambiable del suelo (R^2 = 0,95), por lo que se hace recomendable su uso para determinar fitotoxicidad por aluminio en suelos ácidos.
Palabras clave: lluvia ácida, aluminio intercambiable, fitotoxicidad por aluminio, bioensayo de germinación, *Avena sativa* L. cv. Nehuén, *Hordeum vulgare* L. cv. Libra, *Lactuca sativa* L. *var. capitat*a cv. Cuatro Estaciones, porcentaje relativo de germinación, crecimiento radical relativo, índice de germinación, biomasa radical.

Introducción

Durante años los suelos circundantes a la fundición de cobre de Caletones, Región del Libertador Bernardo O´Higgins, Chile (34º06´ S; 70º27´ W), han estado expuestos a los efectos de la lluvia ácida, esta última provocada por las constantes emisiones de dióxido de azufre y dióxido nitroso desde la fundición a la atmósfera. La contaminación producida durante casi un siglo por la actividad de la fundición ha generado altos niveles de aluminio intercambiable.
El aluminio es el catión dominante en los sitios de intercambio de los coloides en suelos ácidos (Bohn *et al.*, 2001). La toxicidad del aluminio generalmente es el problema más común y severo de los suelos de pH menor de 5,5 afectando tanto a plantas, mesofauna y microorganismos edáficos (Sadzawka, 2006). El aluminio no tiene una función biológica específica en las plantas, sin embargo afecta el normal desarrollo vegetal cuando se encuentra biodisponible (Poschenrieder *et al.*, 2008). Afecta principalmente a las plantas mediante la inhibición en el crecimiento de las raíces, en la elongación radical y en la cantidad y longitud de las raíces laterales, altamente absorbentes (Delhaize y Ryan, 1995; Barceló y Poschenrieder, 2002), lo que coincide con una disminución de la división celular (Frantzios *et al.,* 2001). Los síntomas pueden aparecer después de unos pocos minutos u horas desde que las plantas son expuestas a soluciones con concentraciones micromolares de aluminio (Ma *et al.,* 2002).
Es por lo anterior que los objetivos de este trabajo son: a) evaluar el posible efecto fitotóxico del aluminio intercambiable de los suelos cercanos a la fundición de Caletones; b) establecer si existe relación entre fitotoxicidad y distancia a la fuente de emisión y profundidad de muestreo y c) determinar cuál de las tres especies utilizadas (avena, lechuga, cebada) es el mejor bio-indicador para evaluar fitotoxicidad por aluminio intercambiable en suelos ácidos

Materiales y Métodos

En el estudio se utilizaron semillas de avena cv. Nehuén, cebada cv. Libra y lechuga cv. Cuatro Estaciones, además de las muestras de suelos de cuatro sitios circundantes a la fundición de cobre de Caletones. Las muestras fueron colectadas en cuatro sitios, considerando distancias crecientes a la fundición de cobre Caletones. Los sitios muestreados fueron Caletones (D1), Barahona Robinia (D2), Barahona Embalse (D3) y Los Cóndores (D4), ubicados a 2,8; 3,9; 6,6; y 7,2 km de distancia de la fuente de emisión, respectivamente. En cada sitio de muestreo se extrajeron nueve muestras compuestas a tres profundidades (p1 = 0-5 cm; p2 = 5-10 cm; y p3 = 10-20 cm). En términos de taxonomía de suelos, los suelos muestreados pueden ser clasificados dentro del orden de los Inceptisols, ya que poseen un desarrollo incipiente de un horizonte B. Son suelos con alta pedregosidad, con un régimen de temperatura térmico y un régimen de humedad xérico.

Se considerará un diseño factorial con dos factores, D*p; en el que D es distancia a la fundición (4) y p es profundidad de muestreo (3), lo que da un total de 12 tratamientos, con los cuales se realizaron tres bioensayos de germinación (uno con cada especie). El detalle de los tratamientos se muestra en el Cuadro 1.

Cuadro 1: Localización y concentración de aluminio intercambiable de cada tratamiento.

Tratamiento	Distancia a la Fundición (km)	Profundidad de muestreo (cm)	Al intercambiable ($cmol_+ kg^{-1}$)	Localidad
T1	D1	P1	10,3	Caletones
T2	D1	P2	7,8	Caletones
T3	D1	P3	0,96	Caletones
T4	D2	P1	10,7	Barahona Robina
T5	D2	P2	10,2	Barahona Robina
T6	D2	P3	7,7	Barahona Robina
T7	D3	P1	12,4	Barahona Embalse
T8	D3	P2	11,2	Barahona Embalse
T9	D3	P3	6,0	Barahona Embalse
T10	D4	P1	0,27	Los Cóndores
T11	D4	P2	0,13	Los Cóndores
T12	D4	P3	0,02	Los Cóndores

Para cada tratamiento se prepararon extractos en una relación de 1:5, colocando 10 g de suelo seco y tamizado a 2 mm en una vaso plástico de 150 mL, al cual se le agregarán 50 mL de agua destilada (Zuconni *et al.,* 1981). . Se tomó una alícuota de 10 mL de cada extracto, que se colocó en una cápsula de Petri con papel filtro Whatmann Nº 3. Sobre el papel ya embebido del extracto se colocaron, con la ayuda de una

pinza, diez semillas de una misma especie con una separación tal que permitiera la elongación de la radícula. Se utilizó un testigo para cada ensayo usando agua destilada y la misma cantidad de semillas que en cada tratamiento. Luego las cápsulas fueron tapadas y se colocaron dentro de bolsas de polietileno para evitar la perdida de humedad durante la incubación. El proceso de incubación fue de 120 horas, tiempo en el cual las semillas estuvieron a oscuras a una temperatura de 25 ± 1ºC. Una vez finalizado el período de incubación se determinó el índice de germinación (IG). Este parámetro, sugerido por Tiquia *et al*. (1996), tiene como principal ventaja que permite evaluar la toxicidad aguda, que afecta a la germinación, y la toxicidad baja, que afecta el crecimiento de la radícula. El IG se determinó a través de sus componentes, el porcentaje relativo de germinación (PGR) y el crecimiento de la radícula relativo (CRR). Una vez obtenidos el PRG, CRR y IG, se procedió a determinar la Biomasa Radical (BR). Para este procedimiento se tomó el total de las radículas de cada placa de Petri y se colocaron en una estufa a una temperatura de 70ºC durante 24 horas (Sadzawka *et al.*, 2004). Luego de este tiempo fueron pesadas en una balanza con presión de ± 0,1 mg, determinando con ello la BR en base materia seca radícula*placa^{-1} y finalmente la BR en base materia seca radícula* semilla germinada^{-1}. Para determinar diferencias significativas respecto a la distancia de la fundición y profundidad de muestreo se realizó un análisis de varianza (ANDEVA) con una significancia de un 5%. Debido a que ninguna transformación permitió normalizar los valores del CRR se realizó la prueba no paramétrica de Kruskal-Wallis con una significancia de un 5% para determinar diferencias significativas. En el caso de encontrarse diferencias estadísticamente significativas se realizó la prueba de comparaciones múltiples de Tukey.

Resultados y Discusión

De los cuatro parámetros de fitotoxicidad, el que mejor se correlaciones con los niveles de Al^{+3} del suelo es el IG, para las tres especies, siendo la cebada la que presenta la mayor correlación (R^2 = 0,946), como lo muestra la Figura 1. Lo anterior concuerda con los estudios de Zuconni *et al*. (1981), Tiquia (1996) y Varnero *et al*. (2007), ya que este parámetro permite evaluar la toxicidad aguda que afecta la germinación con la toxicidad baja que afecta el crecimiento radical. Se vio que el aluminio afecta principalmente el crecimiento radical tal como Dehaize y Ryan (1995), Kollmeier *et al.* (2000) y Abdalla (2008), por sobre la germinación. Los valores PGR presentan baja correlación ($R^2 < 0,5$), mientras que el CRR presenta valores altos, pero menores que IG ($0,75 < R^2 < 0,90$).

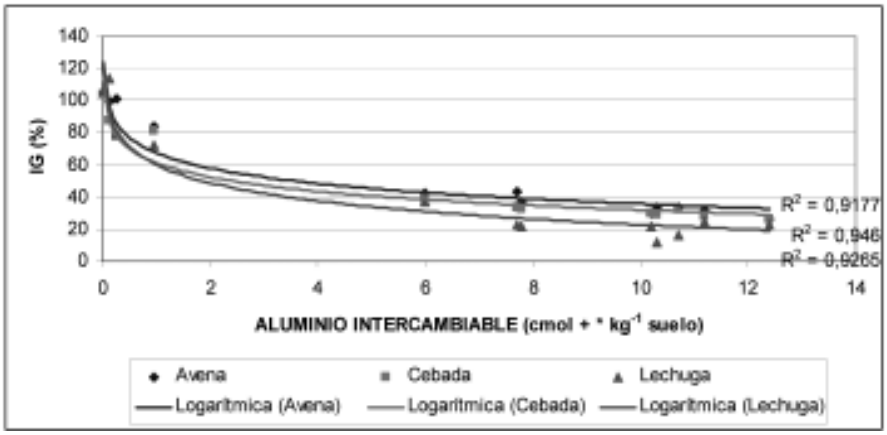

Figura 1: Correlación entre Al^{+3} y valores IG.

La biomasa radical tiene baja correlación con los contenidos de aluminio del suelo (R^2 entre 0,16 y 0,45). Esto se debería a que al modificarse la arquitectura radical (Clarkson, 1969; citado por Poschnreider *et al.,* 2008) y al engrosarse las raíces por los efectos del aluminio (Alam *et al.*, 1979; citado por Feixa, 2001), la biomasa radical no sufre grandes cambios.

Las tres especies mostraron que hay diferencias significativas ($p < 0,05$) en cuanto a los valores IG obtenidos en distancia y en profundidad (figuras 2, 3 y 4). Se observa que los suelos más lejanos a la fundición presentan los valores más altos. En cuanto a la profundidad los suelos más profundos son los que presentan los valores más altos. Se observó también que de las tres especies, la cebada es que presenta la correlación más alta entre los niveles de aluminio intercambiable y los valores IG. Según Zuconni *et al* (1981) valores IG inferiores al 50% indican alta fitotoxicidad, esto es lo que se ve en los suelos más cercanos a la fundición, lo cual indica como la actividad minera afecta el hábitat para el normal desarrollo vegetal.

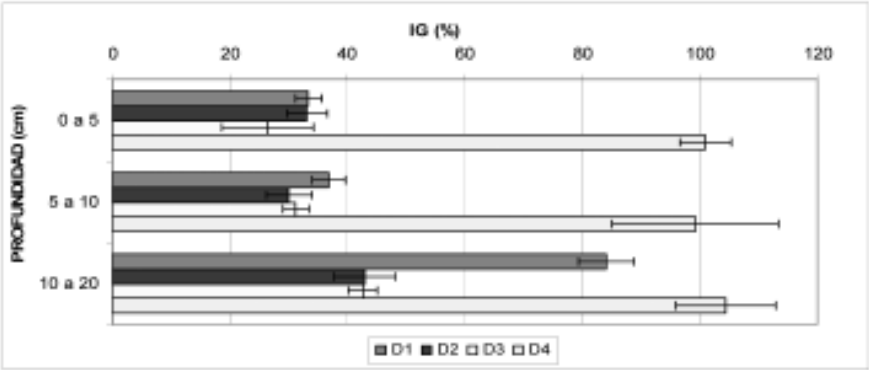

Figura 2: Valores IG respecto a la distancia de la fundición y la profundidad de muestreo para avena. Las barras de error representan ± 1 error estándar.

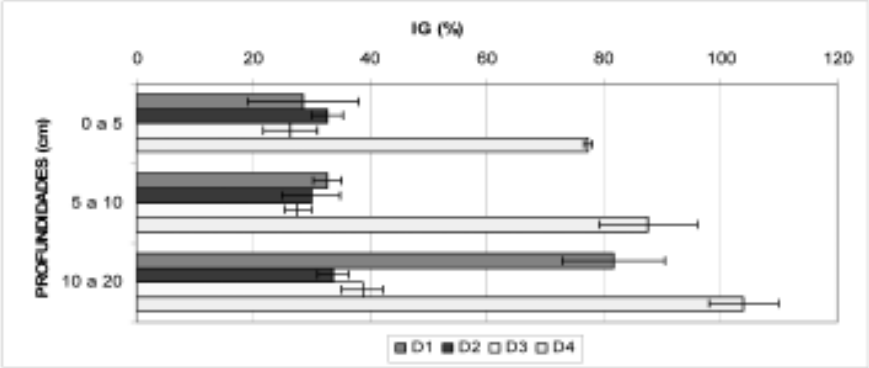

Figura 3: Valores IG respecto a la distancia a la fundición y profundidad de muestreo para cebada. Las barras de error representan ± 1 error estándar.

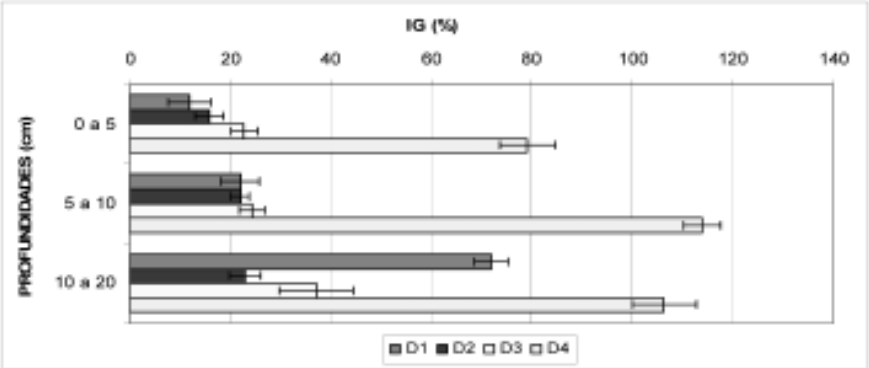

Figura 4: Valores IG respecto a la distancia de la fundición y la profundidad de muestreo para lechuga. Las barras de error representan ± 1 error estándar.

Conclusiones

Hay efecto fitotóxico por parte del aluminio intercambiable en los suelos cercanos a la fundición de cobre de Caletones.

Hay relación entre la distancia a la fundición y la profundidad de muestreo con los niveles de fitotoxicidad, siendo estos menores en suelos más alejados y en suelos más profundos.

La cebada es la especie que mostró tener mayor correlación entre sus valores IG y los niveles de aluminio del suelo, por lo que se considera como el mejor bio-indicador de fitotoxicidad para este caso.

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DRIVING FORCES OF SOIL FORMATION
A GLOBAL APPROACH

Winfried E.H. Blum

Institute of Soil Research, University of Natural Resources and Applied Life Sciences
Vienna, Peter Jordan Str. 82, Austria, Europe,
Tel: +43-1-47654-3101; Fax: +43-1-47654-3130, winfried.blum@boku.ac.at

Summary
Four different forms of energy are involved in soil formation: gravity, orogenic energy, solar energy and anthropogenic energy. The specific influence of these forces is important for understanding soil development and protection under different physio-geographic and environmental conditions.

Introduction
Soils are providing goods and services of paramount importance for sustaining human societies and the environment (Blum 2005; Frossard *et al.* 2006; Costanza *et al*. 1997).
In view of the world wide losses of soil, e.g. through sealing, erosion and further impacts, information about the time scale of soil formation becomes increasingly important (European Commission 2006). Until today, we have measurements and assessments regarding soil losses, e.g. through erosion, but no solid data about the pace of soil formation. Therefore, the question arises: How much soil is formed with time, under different climatic, geological, topographical, hydrological and biotic conditions, under the influence of human activities, including land use and climate change. – At the moment, national and international research groups on critical zone processes are targeting this issue (Chorover *et al.* 2007).

Materials and methods
For answering this question, a first approach could be to identify the basic forms of energy involved in soil forming processes. With such an approach, it would also be possible to develop a comprehensive concept, which would allow to describe processes of soil formation as well as methods to measure them, e.g. weathering of rock parent material and the development of the regolith zone, as well as the further development from regolith to soil. This concept could also allow to define measurable indicators for the different characteristics of rock, regolith and soil and to sustain soil protection and conservation.

Results and discussion

Soil formation is driven by four main forms of energy: gravity, orogenic energy, solar energy and anthropogenic energy.

Gravity influences all movements of solid, liquid and gaseous materials. It is an inherent form of energy and influences the vector and the velocity of fluxes within soils (e.g. movement of solutes) as well as at their surface (e.g. soil erosion by water). – Therefore, gravity is one of the main factors of morphogenesis.

Orogenic energy is the second form of energy and is herited from the rock parent material, which was formed through orogenesis, an endogenic process which created very diverse types of rocks and minerals under high temperature and pressure. This endogenic energy, which can also be called orogenic energy, is still contained in rocks and in the rock forming minerals. This energy is normally not renewed for a long time, except in cases such as volcanic activities and others. – Through exogenic forces, derived from solar energy, e.g. through processes of weathering and transport (e.g. erosion), this orogenic energy pool is constantly lowered. Primary minerals, such as micas and feldspars contain more energy, derived from orogenesis as their weathering products, e.g. clay minerals and oxides. Moreover, the resistance of different minerals against weathering or the buffer capacity of soils against acidification can also be explained by orogenic energy. Orogenic energy is manifest in the texture and structure of rocks and the crystallography of minerals and their resistance to exogenic forces, which is mainly explained by the form and density of the mineral package in the rocks or the element package in the crystal structure of minerals. – Orogenic energy is also manifest in the chemical composition of minerals, which plays an important role, e.g. through the content of alkaline and earth alkaline cations in relation to silica, aluminium and metals such as iron, manganese, copper, zinc and others. In detail, this becomes evident in the thermodynamics and kinetics of weathering processes:

Thermodynamically, 4 characteristics of minerals are important for weathering processes:

- the type of mineral structure, e.g. phyllosilicates, chain silicates etc.;
- substitution of Si by Al in the mineral lattice (Al-ion is about 50% larger than Si);
- type of metal cations connecting the Si-tetraeder in the silicate structure, e.g. Ca, Mg, Fe^{2+} in biotite or Al in muscovite;
- amount of oxidizable Fe^{2+} and Mn^{2+} in the crystal structure.

Kinetically, 3 main factors are important for the weathering of minerals:

- the surface of minerals in the rock texture: fine-grained, e.g. basalt or coarse-grained, e.g. granite;
- the amount of protons in the soil solution, e.g. expressed by the pH or other specific indicators;
- the velocity of percolation (leaching) creating disequilibria in the weathering environment.

Solar energy is the third form of energy, deriving directly from solar radiation or from diffuse radiation through reflection. Solar radiation is the basis of photosynthesis producing biomass, which again is the basis of physical, chemical and biological weathering, producing protons in the form of H_2CO_3 and organic acids through the biological decomposition of litter at the soil surface and of roots within the soil or the delivering of photosynthates to root-mycorrhiza, which acts at the weathering front by exsudates and other organics delivering protons. Therefore it can be concluded that the intensity of photosynthesis is directly correlated with the intensity of weathering processes. This means that clear differences exist between the influence of forests, grass covers and land surfaces without vegetation, on weathering processes.

In the past, soils developed under different climatic conditions (paleoclimates) and types of vegetation, especially in the tropics and sub-tropics, which makes it difficult to use current climatic data, such as temperature and/or precipitation to explain soil formation over a long period of time.

Anthropogenic energy is the fourth form of energy, deriving from anthropogenic activities. It is a mixture of different energy forms, including human labour, and is mainly based on fossil energy and non-renewable resources, such as oil, coal, rocks and minerals. - Since the end of the 18th century, anthropogenic influences on terrestrial and aquatic ecosystems have been exceeding the natural impacts (Crutzen, 2002; Blum and Eswaran 2004).

Conclusions

In order to understand and to analyse soil formation and to promote soil protection, it seems to be interesting to use the energy concept in order to make soil formation understandable and soil protection feasible. This is also the current task of the critical zone approach.

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DETERMINANTES DE LA DISPOSICIÓN A PAGAR PARA LA CONSERVACIÓN DE SUELOS DEL SECANO COSTERO, VII REGIÓN DEL MAULE - CHILE

HUENCHULEO, C. [(2)], **VILLALOBOS, P.**[(3)], **BARKMANN; J.**[(4)]

[(2), (3)] *Departamento de Economía Agraria, Facultad de Ciencias Agrarias, Universidad de Talca, Chile.*
Casilla 747 Talca. chuenchuleo@utalca.cl, pvillal@utalca.cl
[(4)]*Instituto de Economía Agraria, Universidad Georg-August de Goettingen, Alemania.*
jbarkma@gwdg.de

Resumen
La presente investigación indaga las variables determinantes que afectan la Disposición a Pagar (DAP) de los agricultores por la conservación de suelos del Secano Costero de Chile Central. La información analizada se generó a partir de una encuesta suministrada a 140 pequeños agricultores, seleccionados aleatoriamente, de la comuna de Curepto, VII Región del Maule. Utilizando el Método de Valoración Contingente (MVC), se valoró un conjunto de medidas de preservación del recurso, como parte de un programa propuesto de conservación de suelos para la zona de estudio. Además, variables actitudinales, provenientes de la Teoría de la Motivación a la Protección (TMP) fueron utilizadas como predictores de la DAP, tales como eficacia de la respuesta y costos/ barreras para la implementación de prácticas de conservación del suelo. Los agricultores están dispuestos a pagar en promedio $31.000/año por el programa propuesto. Un modelo de regresión lineal por pasos indicó que la DAP es positivamente influenciada por la percepción de los agricultores acerca de la eficacia de las prácticas de conservación de suelo y el tamaño del predio. La edad, el conocimiento y la utilización de prácticas de conservación del suelo influyen notablemente también sobre la DAP. Adicionalmente, este presente estudio permitió dar a conocer y destacar la utilidad de la TMP como un nuevo enfoque para el análisis de las decisiones de conservación del suelo por parte de los agricultores.
Palabras clave: conservación de suelo; disposición a pagar; valoración contingente; teoría de la motivación a la protección, actitudes de los agricultores.

I. INTRODUCCIÓN

La degradación de suelos es una de las mayores restricciones para la producción agrícola en muchas partes del mundo. La agricultura es un importante sector de la economía chilena, la cual representa un 4,7% del PIB (INE, 2005). Actualmente, 17,2 millones de hectáreas son usadas

en el sector agrícola, de las cuales casi la mitad tiene significativos niveles de degradación de suelos (Aracena *et al.*, 2004). En este sentido, un programa nacional denominado Programa para la Recuperación de Suelos Degradados fue puesto en marcha el año 1997.

En particular, severos problemas de erosión restringen el uso agrícola del suelo en la zona semiárida de Chile Central, denominada Secano Costero. Los suelos en esta área son altamente susceptibles a la erosión, mientras que los agricultores continúan llevando a cabo prácticas agrícolas que aceleran este problema.

Si se analiza retrospectivamente la adopción a largo plazo de Prácticas de Conservación de Suelo (PCS), se observa que un alto número de programas a nivel mundial han fracasado (Hellin & Haigh, 2002). El reconocimiento de este problema ha llevado a aumentar la atención en aquellos factores que influencian la adopción. Un primer grupo, que incluye la mayoría de los estudios, analizan la influencia de características socioeconómicas y productivas sobre el nivel de adopción (Ervin & Ervin, 1982; Norris & Batie, 1987; Segarra & Taylor, 1987; Pagoulatos et al., 1989; Ramírez & Shultz, 2000; Swinton, 2000; McLeod *et al.*, 2001; Lichtenberg, 2001; Tenge *et al.*, 2004). Un segundo grupo de estudios incluyen variables actitudinales a partir de la percepción de los agricultores, por ejemplo, en relación a la severidad de la erosión y la eficacia de las PCS propuestas (Westra & Olson, 1997; Cramb *et al.,* 1999; Ólafsdóttir & Júlíusson, 2000; Bielders *et al.*, 2001; Bewket & Sterk, 2002; Hellin & Haigh 2002, Viser *et al.*, 2003, Daba, 2003, Kerr & Pender 2005). Un tercer grupo, utiliza técnicas de valoración económica, tales como Valoración Contingente, que pueden ser usadas para predecir la adopción basadas en las preferencias económicas subjetivas (Cooper, 1997; Tegegne, G.E. 1999; Roe *et al.*, 2002; Asrat *et al.*, 2004).

La inclusión de las percepciones y actitudes de los agricultores representa un importante paso hacia un análisis interdisciplinario de la erosión del suelo y otras formas de degradación de este recurso. La variables actitudinales conectan el análisis del suelo y la degradación de éste con la disciplina de la psicología que investiga los determinantes sociales e individuales de la acción humana. En este sentido, el desarrollo de una investigación de los determinantes de la adopción de PCS, necesita estar basada en una perspectiva teórica coherente, dado que las teorías conductuales más prominentes emplean un set de constructos relacionados sistemáticamente. Este es el caso, por ejemplo, de la Teoría de Acción Razonada (Aizen, 1991), Teoría de la Motivación a la Protección (Rogers & Prentice-Dunn, 1997), y el Modelo de Activación Normado (Schwartz & Howard, 1981). Todas estas teorías han sido empleadas en la explicación de la conducta humana frente a una amenaza ambiental.

Los estudios citados en los párrafos anteriores aún están carentes de fundamentos teóricos rigurosos basados en la Psicología Social, incluso si ellos emplean variables de percepción y actitud. Este presente estudio pretende demostrar que es posible desarrollar, emplear y beneficiarse usando determinantes conductuales de la adopción de PCS. En el caso particular de esta investigación, se estudió la adopción hipotética de PCS en un área del Secano Costero de la Región del Maule (Valle Central de Chile). Para el análisis conductual se ha seleccionado la Teoría de la Motivación a la Protección (TMP) como un modelo psicológico-social apropiado. En la práctica, se espera que la inclusión de los constructos de la TMP entreguen información adicional acerca de las razones para la baja adopción a largo plazo de las PCS en el área de estudio.

La presente contribución se divide de la siguiente manera. En primer lugar, se explicarán los fundamentos de los dos principales enfoques empleados en la parte empírica de este estudio: la Teoría de la Motivación a la Protección y el Método de Valoración Contingente. Posteriormente, se describirá del área de estudio y el detalle de los métodos usados. Una vez presentados los resultados de la adopción hipotética de PCS, se entregarán algunas conclusiones aplicadas en relación al diseño de futuros programas de conservación de suelo en el área de estudio, y evaluar la propuesta metodológica de este estudio, la cual sugiere que la inclusión de constructos conductuales de la psicología-social realmente ayudan al entendimiento de los factores que determinan la conservación del suelo.

II. ANTECEDENTES TEÓRICOS

II.1. Teoría de la Motivación de la Protección (TMP).

TMP fue inicialmente desarrollada en el año 1980 para explicar la adopción (y no adopción) de medidas de protección individual frente a riesgos para la salud, tales como el SIDA, Cáncer, entre otras enfermedades (Rogers, 1987; Rogers & Prentice-Dunn, 1997). Luego, la TMP fue aplicada a la investigación de respuestas a otras situaciones riesgosas, entre ellas riesgos medio-ambientales (Wolf, 1986; Mulilis & Lippa, 1990; Menzel, 2004).

TMP asume dos procesos centrales de evaluación subjetiva: evaluación de la amenaza y evaluación de las medidas de control. La evaluación de la amenaza se conceptualiza a partir de dos aspectos: percepción de la severidad de la situación riesgosa, si esta ocurriera, y la percepción de la vulnerabilidad o frecuencia de este evento negativo. La evaluación de la capacidad individual para tomar medidas de control frente a una amenaza es influenciada por la percepción de la eficacia de las

respuestas para evitar la situación riesgosa; la percepción de la propia capacidad para enfrentar una situación negativa; y la evaluación de las potenciales barreras o costos para enfrentar la situación riesgosa.
La variable final resultante de la TMP es una «motivación a la protección», la cual se manifiesta en una intención conductual para llevar a cabo una acción específica, como por ejemplo, la Disposición a Pagar para la prevención y control de la erosión de suelos.

II.2. Método de Valoración Contingente (MVC).

Uno de los métodos más recurrentemente utilizado para valorar económicamente PCS es el Método de Valoración Contingente, el cual pregunta directamente a los agricultores por su Disposición a Pagar (DAP) para la implementación de un programa de conservación de suelos. Algunos ejemplos son los trabajos desarrollados por Cooper & Keim (1996), Cooper (1997), Roe *et al.* (2002) y Asrat *et al.* (2004). Estos estudios generan información acerca de la demanda (DAP) que puede servir como un predictor de la adopción futura de PCS.
El objetivo de un estudio de Valoración Contingente (VC) es captar las preferencias individuales, en términos monetarios, por cambios en la cantidad o calidad de un bien o servicio sin mercado (Bateman *et al.*, 2002). De acuerdo a lo expresado por Pearce *et al.* (2002), el cambio es a menudo descrito en términos de los resultados de una política o proyecto hipotético o actual. La DAP es definida como el monto de dinero tomado desde el ingreso de cada persona, después de un mejoramiento en el bien o servicios ambiental, manteniendo su utilidad total constante (Asrat *et al.*, 2004).

$$U (I, P, S, Q^0) = U (I, P, S, Q^1)$$

donde:
U: Utilidad total, I: Ingreso, P: Precio de otros bienes, S: factores socio-económicos y psicológicos, Q^0: Nivel actual del bien o servicio ambiental y Q^1: Nivel futuro del bien o servicio ambiental.

En este estudio, se utilizó un modelo de regresión múltiple para cuantificar el impacto de I, P, S y Q^0- Q^1 en la DAP por un programa de conservación de suelos hipotético. Dicho programa está enfocado en la introducción de diferentes PCS en el área de estudio. Bajo S, se incluyeron los constructos de la TMP.
La aplicación de la TMP para la predicción de la DAP está facilitada por el hecho de que esta teoría resulta en la predicción de una intención conductual; desde un punto de vista psicológico, la DAP en un estudio de VC es una intención conductual. De esta forma, teorías tales como la TMP son estructuralmente apropiadas para explicar la DAP.

III. METODOLOGÍA

III.1. Área de Estudio

El área de estudio está situada en la zona semiárida del Valle Central de Chile, denominada Secano Costero, específicamente en la comuna de Curepto. Esta comuna está localizada en la VII Región del Maule, Provincia de Talca (35°06' S, 71°01' W). La superficie comunal es de 1.074 km^2 y cuenta con un clima templado cálido (mediterráneo) con una estación seca prolongada y una estación lluviosa de corto período (CIREN, 1990:60-61). La precipitación anual promedio es 813 mm. La superficie del suelo está altamente erosionada con frecuente erosión en cárcavas y baja fertilidad. Curepto tiene una población de 10.812 habitantes, de los cuales un 70% están ubicados en áreas rurales. La mayoría de los agricultores están clasificados como productores de subsistencia, con altos niveles de pobreza y degradación de suelos. La producción agrícola está focalizada en cereales, legumbres y hortalizas para el autoconsumo. El principal cultivo es el trigo, el cual es cultivado principalmente en tierras con pendiente y sin riego.

III.2. Diseño de la muestra

La investigación de campo fue realizada en Octubre de 2008. Un cuestionario estructurado fue usado para entrevistas personales (face-to-face). El cuestionario fue pretesteado, con 20 agricultores seleccionados aleatoriamente, y luego mejorado. El marco muestral estuvo conformado por agricultores participantes de PRODECOP Secano Costero (Programa de Desarrollo de Comunas Pobres), microregión de Curepto, durante el período 1996-2001. El listado fue proporcionado por INDAP[1] y chequeado por agentes de extensión de Curepto; encontrándose que la población objetivo estaba compuesta por 350 agricultores distribuidos en 17 localidades. El marco muestral fue estratificado por nivel de erosión, en cada una de las 17 localidades, basado en información geográfica provista por agentes de extensión local. Se seleccionó aleatoriemente el 40% de los agricultores desde cada uno de los tres estratos considerados. Un total de 140 agricultores fueron entrevistados, incluyendo 48 mujeres y 92 hombres.

Tabla 1: Estratificación de la muestra por nivel de erosión.

Nivel de erosión	Área (ha)	Total de agricultores	Muestra de agricultores
Bajo	4,137	157	63
Medio	2,059	115	46
Severo	4,614	78	31
Total	10,810	350	140

[1] Instituto de Desarrollo Agropecuario – Chile.

III.3. Diseño del cuestionario y variables utilizadas

El cuestionario diseñado consideró las siguientes secciones:

- Introducción del estudio
- Constructos de la TMP (preguntas cerradas usando escalas Likert de 4 niveles y formato dicotómico).
- Conocimiento y uso de PCS (CYU).
- Gasto actual en Conservación de Suelos (GCS).
- Introducción al escenario de valoración, para obtener la DAP por un programa de conservación de suelos
- Preguntas de seguimiento para conocer la superficie destinada a conservación a través del programa.
- Variables socio-económicas y productivas (VSP).

El escenario propuesto a los agricultores estuvo basado en un incentivo económico del 80% de los costos para la implementación de las PCS ofrecidas. Esta propuesta fue diseñada de acuerdo a las actuales condiciones del programa de conservación de suelos en Chile. Para evaluar la adopción hipotética de PCS, fueron consideradas ocho PCS promovidas por el actual programa de conservación de suelo, el cual incluye: zanjas de infiltración, terrazas, diques de contención, curvas de nivel, mínima labranza, incorporación de rastrojos, uso de residuos orgánicos y construcción de canales de desviación de aguas.

La DAP indica el monto de dinero que los agricultores estarían dispuestos a pagar al año por estas PCS, de acuerdo al programa propuesto, considerando que el incentivo es entregado una vez que las prácticas hayan sido realizadas y previa supervisión del organismo certificador. De esta forma, primero se les consultó por su DAP en formato dicotómico (Si/No) y posteriormente, aquellos que respondieron positivamente, se les preguntó su máxima DAP. Enseguida, los agricultores fueron consultados por la superficie de terreno que comprometerían en estas PCS.

Como potenciales determinantes de la DAP fueron considerados las variables construidas desde la Teoría de la Motivación a la Protección (TMP), Conocimiento y Utilización de PCS (CYU), Gasto actual en Conservación de Suelos (GCS), y variables socio-económicas y productivas (VSP). La siguiente tabla entrega un detalle de las variables utilizadas en la presente investigación.

Tabla 2: Variables independientes utilizadas.

Variable	Tipo	Medida
SEVERIDAD	TMP	Likert
VULNERABILIDAD (FRECUENCIA)	TMP	Likert
EFICACIA DE LAS MEDIDAS	TMP	Dicotómica
CAPACIDAD INDIVIDUAL	TMP	Dicotómica
FALTA DE MANO DE OBRA	TMP	Likert
FALTA DE ANIMALES DE TRABAJO	TMP	Likert
GASTO ACTUAL EN CONSERVACIÓN	GCS	Cuantitativa
NUMERO DE PCS CONOCIDAS	CYU	Cuantitativa
NUMERO DE PCS UTILIZADAS	CYU	Cuantitativa
EDAD	VSP	Cuantitativa
EDUCACION	VSP	Ordinal
INGRESO	VSP	Cuantitativa
SEXO	VSP	Dicotómica
TAMAÑO DEL PREDIO	VSP	Cuantitativa
TIPO DE TENENCIA DE LA TIERRA	VSP	Nominal
GRADO DE EROSIÓN	VSP	Ordinal

III.4. Análisis Estadístico

El análisis estadístico está focalizado en la construcción de un modelo de regresión múltiple para la identificación de predictores de la adopción hipotética (DAP) de PCS. El modelo final fue construido en dos pasos. Primero, se calcularon las correlaciones lineales entre las variables explicativas y la DAP, y luego se llevó a cabo una regresión múltiple por pasos. Para la regresión múltiple de la DAP, se asumió una función explicatoria lineal, indicándose a continuación la DAP individual para cada agricultor.

$$DAP\ (q^0, q^1) = b_1 * I + b_2 * P + b_3 * S_1 \ldots b_x * S_{x-3} + e$$

q^0, q^1 : nivel presente y nivel del escenario, para el servicio de control y prevención de la erosión ofrecido.
$b_1 \ldots b_x$: coeficientes lineales de la función.
I : ingreso familiar
P : precio de los bienes con mercado.
$S_1 \ldots S_{x-3}$: actitudes, percepciones (TMP) y otros factores socio-económicos y productivos (todas las variable independientes excepto el ingreso familiar).
e : diferencias entre los valores del modelo y la función real (residuos).

Se utilizó el software SPSS 11.0, tanto para el análisis de los coeficientes de correlación como para la evaluación de los coeficientes del modelo, a través de los procedimientos de regresión múltiple por pasos. Se asumió que el precio de los bienes de mercado no cambia, por lo tanto, b_2 no fue estimado.

Para los residuos de la función se testearon los supuestos de normalidad, homocedasticidad y no-multicolinearidad. La variable DAP no cumplió satisfactoriamente con los supuestos de normalidad y homocedasticidad, por lo cual se aplicó una transformación raíz cuadrada ($DAP^{0,5}$). Una vez aplicada esta transformación, no se detectaron desviaciones adicionales a partir de los supuestos necesarios para una interpretación convencional de los resultados del modelo de regresión.

IV. RESULTADOS Y DISCUSIÓN

IV.1. Resultados Descriptivos

- El 71% de los agricultores considera que la erosión del suelo es un problema muy severo en la zona, mientras que el 40% considera que el costo de conservación de suelos es muy alto. Un 38% de los encuestados considera que el recurso mano de obra es una limitante para implementar PCS, mientras que por otro lado, un 35% consideró que los animales de trabajo es una limitante para llevar a cabo estas prácticas.
- Los agricultores tienen un buen conocimiento de las PCS dado que la mayoría de ellos (56%) conoce al menos cinco de las ocho PCS analizadas. Sin embargo, un gran porcentaje de los encuestados (71%) utiliza sólo una o dos PCS; incluso casi un 20% de ellos no las utiliza. Lo anterior, indica que existen barreras importantes para incorporar estas prácticas conservacionistas a nivel predial.
- La edad promedio de los agricultores es 54 años. La mayoría de de los agricultores (64%) cuenta con educación primaria incompleta y un 17% no tiene educación formal. El ingreso familiar promedio es $83.300 al mes y además el 83% de las familias percibe un ingreso mensual bajo el salario mínimo nacional ($125.000/mes). El tamaño de los predios es en promedio 16 hectáreas, sin embargo, usando medidas de tendencia central más representativas la mediana indicó un valor de 8 ha. Finalmente, en relación al tipo de tenencia de la tierra predominante, un 66% de los agricultores entrevistados son propietarios de su predio.
- Con respecto al procedimiento para estimar GCS, este consideró tanto gastos en efectivo como la cuantificación monetaria de horas asignadas, tanto en mano de obra como en animales de trabajo, para la construcción y mantención de PCS. Los resultados indicaron que los agricultores invierten anualmente en promedio $48.356 (Error Estándar $5,709). Sin embargo, conside-

rando una medida de tendencia central menos sensible a valores extremos, la mediana indicó un monto de $20.000 al año.

IV.2. Determinantes de la Disposición a Pagar (DAP)

- El 79% de los agricultores está dispuesto a invertir en prácticas de conservación de suelo de acuerdo al programa propuesto. Un 37% de de los agricultores está dispuesto a utilizar menos del 20% de su predio en actividades de conservación de suelo. No obstante, un 15% de la muestra está dispuesto a utilizar más de un 80% del predio en estas tareas. Los agricultores están Dispuestos a Pagar en efectivo un promedio de $31.000/ año (Error Estándar $2.676/año) en el control y prevención de la erosión del suelo.
- De acuerdo a los coeficientes de correlación de Pearson, las variables que correlacionan positivamente en forma significativa con la DAP fueron: percepción del nivel de eficacia de las PCS, número de PCS utilizadas y el tamaño del predio. Por su parte, la edad de los agricultores correlacionó negativamente con la DAP, lo cual indica que a mayor edad de los agricultores menor es la disposición a invertir en PCS. Adicionalmente, basado en un test de comparación de medias, se logró establecer que existen diferencias significativas en la DAP entre hombre y mujeres. Estas últimas están dispuestas a pagar una menor cantidad de dinero en PCS.
- El modelo de regresión lineal por pasos (Tabla 3) indicó que la DAP es positivamente influenciada por la percepción de los agricultores acerca de la eficacia de las prácticas de conservación de suelo y el tamaño de la propiedad. Para el primer caso, este resultado significa que cuando un agricultor percibe que una PCS es realmente eficiente para controlar o prevenir la degradación del suelo, mayor será su DAP por estas prácticas, en función del programa de conservación propuesto. En el segundo caso, se logró establecer significativamente que a medida que un agricultor cuenta con una mayor superficie disponible, mayor será su DAP en medidas para prevenir la degradación de suelos.
- De acuerdo a lo señalado por Mitchel y Carson (1989), un coeficiente de determinación R^2 aceptable para estudios de Valoración Contingente debiera estar sobre un 15%. En términos metodológicos, los supuestos de un modelo estadístico están referidos a un grupo de condiciones que deberían ser cumplidas para garantizar la validez del modelo. En términos generales, un análisis de los residuos nos da la información necesaria para

Tabla N° 3: Regresión por pasos para la DAP como variable dependiente.

Modelo	Coeficientes No estandarizados		Coeficientes estandarizados		
	B	Error Std.	Beta	t	Sig.
Constante	- 3,841	25,923		- 0,148	0,882
Percepción de la eficacia	213,776	38,598	0,421	5,539	**0,000 ****
Tamaño del predio	0,757	0,341	0,169	2,223	**0,028 ***

**, * Significancia a niveles de probabilidad del 1 y 5 por ciento, respectivamente. R-cuadrado: 0.210

comprobar estos supuestos. Los resultaron indicaron que el modelo cumplió satisfactoriamente con los supuestos de independencia, normalidad, homocedasticidad y linealidad.

V. CONCLUSIONES

- Se ha comprobado la influencia de determinantes socioeconómicos para comprender la Disposición a Pagar de los agricultores, tal como se ha manifestado en estudios anteriores.
- Este estudio ha permitido dar a conocer y destacar la utilidad de la Teoría de la Motivación a la Protección como un nuevo enfoque para el análisis de las decisiones de conservación del suelo por parte de los agricultores.
- La Teoría de la Motivación a la Protección puede llegar a ser un enfoque muy eficiente para estudiar intenciones conductuales representadas por la Disposición a Pagar por un mejoramiento ambiental o para evitar el deterioro del mismo.

Dado que la DAP por programas de conservación se ve positivamente influenciada por la percepción de los agricultores acerca de la eficacia de las prácticas de conservación de suelo y el tamaño de la propiedad, se recomienda ahondar en los siguientes aspectos:

- Reforzar los aspectos de capacitación del programa, en particular el aprendizaje efectivo de las técnicas de conservación de suelo por parte de los agricultores.
- Asegurar la sostenibilidad del programa, a través de la implementación de incentivos para la mantención de las prácticas y estructuras de conservación, estableciendo criterios de evaluación, tales como: calidad de la mantención, la incorporación de nuevos terrenos con PCS, y la relación entre estas tecnologías y el uso productivo que se dé a estas superficies, entre otros.
- Aumentar la credibilidad en la eficacia de las PCS entre los agricultores. Sin duda que este es un proceso a mediano y largo

plazo, donde el desafío se centra en la continuidad de estos programas de conservación incorporando herramientas de difusión de tecnologías en forma innovativa.

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EVALUACIÓN DEL EFECTOS DE LAS OBRAS DE RECUPERACIÓN DE SUELOS BONIFICADAS POR EL DL 701, REGIÓN DEL MAULE

Samuel Francke C., Luis Carrasco B., Celso Carnieletto, Eduardo Gándara W.,Juan Troncoso I.[(1)]

(1)Corporación Nacional Forestal (CONAF)

Abstract:
Entre los problemas ambientales de Chile se reconoce que la erosión, o «cáncer del suelo», constituye desde el punto de vista ambiental y probablemente en términos socioeconómicos, el de mayor relevancia en el sector silvoagropecuario. A nivel nacional, de acuerdo a las cifras oficiales, la superficie total de suelos erosionados alcanza a 34,5 millones de hectáreas (46% del territorio nacional). De esta extensión, un 80,5% presenta categorías de erosión moderada a muy grave, lo que significa que los suelos han perdido entre el 40 y el 100% de su profundidad total.
La Ley de Fomento Forestal Chilena, contenida en el Decreto Ley 701, tiene como objetivo principal regular la actividad forestal en suelos de aptitud preferentemente forestal y degradados e incentivar la forestación, en especial por parte de pequeños propietarios forestales, a través de la entrega de instrumentos y técnicas para la prevención de la degradación, protección y recuperación de suelos del territorio nacional.
En la Región del Maule, las precipitaciones son casi exclusivamente de origen frontal y más abundantes en el invierno. Las precipitaciones entre mayo y agosto alcanzan entre el 70% a 75% del total anual, lo que indica que en estas latitudes las precipitaciones que no son invernales alcanzan ya cierta importancia. Entre octubre y marzo ocurre la estación seca, que se prolonga por 4 hasta 6 meses, en que llueve menos de 40 mm mensuales. En el invierno se presentan intensas nevazones en la Cordillera de Los Andes que se constituyen en importantes reservas hídricas para la temporada estival y definen el desarrollo de los sistemas fluviales de la zona.
Durante el año 2009, se realizó un estudio sobre el desarrollo de las plantaciones de Pinus radiata D. Don que comprendió un total de 17 propiedades de pequeños y medianos propietarios de la Región del Maule. En cada predio se tomaron distintos parámetros de las plantaciones y del suelo para posteriormente realizar análisis comparativos de plantaciones con edades similares con y sin tratamientos de obras de recuperación de suelos degradados.

Introducción:

Entre los problemas ambientales de Chile se reconoce que la erosión, o «cáncer del suelo», constituye desde el punto de vista ambiental y probablemente en términos socioeconómicos, el de mayor relevancia en el sector silvoagropecuario. A nivel nacional, de acuerdo a las cifras oficiales, la superficie total de suelos erosionados alcanza a 34,5 millones de hectáreas (46% del territorio nacional). De esta extensión, un 80,5% presenta categorías de erosión moderada a muy grave, lo que significa que los suelos han perdido entre el 40 y el 100% de su profundidad total.

Al considerar la magnitud de los procesos erosivos se requiere tener en cuenta, también, la vasta superficie de vocación forestal de los suelos de Chile, que cubre un 45% del territorio nacional. De esta manera, los programas orientados a la conservación de suelos y aguas a nivel de cuencas hidrográficas deberían tener una alta prioridad, compatibilizando esta variable con la productividad del sitio forestal.

La Ley de Fomento Forestal Chilena, contenida en el Decreto Ley 701, tiene como objetivo principal regular la actividad forestal en suelos de aptitud preferentemente forestal y degradados e incentivar la forestación, en especial por parte de pequeños propietarios forestales, a través de la entrega de instrumentos y técnicas para la prevención de la degradación, protección y recuperación de suelos del territorio nacional.

Con el objeto obtener información de base que permita el diseño de una metodología a nivel nacional, se ha definido como área piloto las plantaciones realizadas en la Región del Maule en las Provincias de Talca, Cauquenes y Linares, dado que esta Región es una de las que ostentan las mayores superficies plantadas (600.000 ha aprox. CONAF, 2009) y bonificadas con obras de recuperación de suelos degradados a nivel nacional, además de contar con plantaciones realizadas desde el primer año (2000) de aplicación de la modificación del DL 701.

En la Región del Maule, las precipitaciones son casi exclusivamente de origen frontal y más abundantes en el invierno. Las precipitaciones entre mayo y agosto alcanzan entre el 70% a 75% del total anual, lo que indica que en estas latitudes las precipitaciones que no son invernales alcanzan ya cierta importancia. Entre octubre y marzo ocurre la estación seca, que se prolonga por 4 hasta 6 meses, en que llueve menos de 40 mm mensuales. En el invierno se presentan intensas nevazones en la Cordillera de Los Andes que se constituyen en importantes reservas hídricas para la temporada estival y definen el desarrollo de los sistemas fluviales de la zona.

Los montos anuales de precipitación, que en la costa superan los 800 mm, como en Constitución y el Cabo Carranza, disminuyen a 700 mm. en Cauquenes, en la vertiente oriental de la Cordillera de la Costa; aumentan nuevamente a 720 ó 730 mm. en Curicó y Talca, superan

los 1.000 mm. en Linares y Panimávida y los 2.500 mm. en la alta cordillera andina.

Durante el año 2009, se realizó un estudio sobre el desarrollo de las plantaciones de Pinus radiata D. Don que comprendió un total de 17 propiedades de pequeños y medianos propietarios de la Región del Maule. En cada predio se tomaron distintos parámetros de las plantaciones y del suelo para posteriormente realizar análisis comparativos de plantaciones con edades similares con y sin tratamientos de obras de recuperación de suelos degradados.

Material y Métodos:

Para llevar a cabo el trabajo propuesto, se tuvo presente las siguientes consideraciones para la selección de los predios o rodales:

a) **Comparar plantaciones con las mismas características realizadas bajo tres modalidades:**
   - **Tradicional (sin obras de recuperación de suelos),**
   - Plantación con zanjas de infiltración y
   - Plantación con subsolado con camellón.

b) Para las plantaciones con alturas menores a 1,30 m se consideró el Diámetro a la Altura del Cuello, medido a 10 cm de altura (DAC 10 cm) y la altura de la planta, medida en metros.

c) Para las plantaciones con alturas mayores a 1,30 m se consideró el Diámetro a la Altura del Pecho (DAP 1,30 m) y la altura del árbol, medida en metros.

d) Se consideró que 2 predios o 2 rodales forman un par comparable, teniendo presente las mismas siguientes variables:
   - Suelo (Serie, capacidad de uso, pendiente, profundidad, etc.)
   - Ubicación geográfica (coordenadas, posición, altitud, exposición, etc.)
   - Clima (precipitaciones, heladas, temperaturas, periodo seco, etc.)
   - Plantación (especie, tipo de planta, control de maleza, fertilización, etc.)

e) Para minimizar los efectos por factores distintos a los que se van a evaluar para cada uno de los tratamientos de recuperación de suelos, se realizaron las mediciones en plantaciones de un mismo predio en rodales distintos, no en sitios distintos.

f) Respecto del muestreo propiamente tal, se definió realizar 10 parcelas de 100 m2 para cada una en los 22 rodales, usando el promedio aritmético de cada variable medida para comparación, como se puede ver como ejemplo en el Cuadro N° 2. En total se medieron 220 parcelas.

g) En relación a los parámetros de fertilidad, se realizaron los siguientes análisis:

- Fertilidad base de suelo (Nitrógeno, Fósforo y Potasio, pH, Materia Orgánica) y densidad aparente, en base a 54 muestras (0 - 20 cm de profundidad).
- Materia Orgánica, en base a 54 muestras de hojarasca de pino.
- Análisis foliar básico (NPK), Boro y Cobre, en base a 54 muestras de follaje.

Resultados y Discusiones:

A continuación se presentan los resultados obtenidos en 17 predios de la Región del Maule, los cuales sustentan plantaciones forestales de Pinus radiata (D. Don) con edades entre 2 y 8 años. Los principales parámetros de las plantaciones para efecto del análisis son: El dap (cm), la altura (m) y el volumen expresado en incremento medio anual (m3/ha/año).

EVALUACIÓN LOS EFECTOS DE BONIFICACIONES DEL DL 701 EN EL CONTROL DE LA EROSIÓN - REGIÓN DEL MAULE

Provincia	Predio	Edad	Densid.	Obra bonificada	Promedio						Altura	Diámetro	IB	Area Basal	Volumen
					h	dap	dac	F1,3	G	V	IMA	IMA	IMA	IMA	IMA
Cauquenes	La Granja	2	1.690	Subsolado con camellón	1,6	1,0	3,8	0,41	0,13	0,65	0,80	1,90	195,23	0,07	0,33
		2	1.570	Sin obra	1,0	1,0	2,0	0,40	0,12	0,40	0,50	1,00	31,49	0,06	0,20
	Sta Patricia	5	1.750	Zanja de infiltración	5,5	6,7		0,36	6,17	13,24	1,10	1,34		1,23	2,65
	Las Vertientes	5	1.690	Sin obra	3,9	4,6		0,37	2,81	6,72	0,78	0,92		0,56	1,34
	San Ramón	7	1.350	Subsolado con camellón	10,0	11,6		0,27	14,27	31,64	1,43	1,66		2,04	4,52
		7	1.490	Zanja de infiltración	8,6	10,5		0,30	12,90	26,93	1,23	1,50		1,84	3,85
	San José	7	1.400	Sin obra	7,3	8,5		0,31	7,94	19,18	1,04	1,21		1,13	2,74
	San Roberto	8	1.420	Sin obra	9,1	11,0		0,29	13,49	28,70	1,14	1,38		1,69	3,59
Talca	Casas de Tanhuao	6	1.690	Zanja de infiltración	6,0	7,4		0,35	7,27	15,42	1,00	1,23		1,21	2,57
	Lote 1 del Lote A	6	1.260	Zanja de infiltración	5,7	7,7		0,31	5,87	13,52	0,95	1,28		0,98	2,25
	Soledad o Mal Paso	5	1.010	Subsolado con camellón	5,2	8,0		0,29	5,08	11,88	1,04	1,60		1,02	2,38
		5	1.250	Sin obra	2,8	3,6		0,35	1,27	3,50	0,56	0,72		0,25	0,70
	Los Sauce	3	1.530	Sin obra	1,3	2,6		0,38	0,81	1,30	0,43	0,87		0,27	0,43
		3	1.560	Zanja de infiltración	1,4	3,2		0,38	1,25	1,71	0,47	1,07		0,42	0,57
	Mal Paso	2	1.480	Subsolado con camellón	1,3	3,0		0,38	1,05	1,47	0,65	1,50		0,52	0,73
		2	1.290	Sin obra	1,0	2,2		0,37	0,49	0,81	0,50	1,10		0,25	0,40
Linares	El Llano	3	1.610	Subsolado con camellón	1,8	1,7		0,40	0,36	1,18	0,59	0,56		0,12	0,39
	Peñablanca	3	1.420	Sin obra	1,7	1,5		0,38	0,25	0,97	0,57	0,50		0,08	0,32
	Puchunqueo	3	1.320	Zanja de infiltración	2,4	2,6		0,36	0,71	2,22	0,78	0,87		0,24	0,74
	Lote A Higuela 4	3	2.100	Sin obra	2,3	2,1		0,43	0,71	2,08	0,77	0,69		0,24	0,69
	Santa Emilia	6	1.290	Subsolado con camellón	7,0	8,8		0,30	7,81	18,29	1,16	1,46		1,30	3,05
	La Higuera Lote A y B	6	1.540	Sin Obras	7,1	7,8		0,33	7,43	18,14	1,18	1,31		1,24	3,02

h = altura (m)
dap = diámetro a altura del pecho (cm)
dac = diámetro a altura del cuello de la planta (cm)
IB = índice de biomasa
G = área basal (m^2)
V = volumen (m^3)
IMA = incremento medio anual (ha)
F1,3 = factor de forma

En la Provincia de Talca fueron medidas las variables dasométricas de las plantaciones como altura en metros (h), diámetro a la altura del pecho en centímetros (dap), área basal por hectárea en m^2 (G), volumen por hectárea en m^3 (V) además de calculados del incremento medio anual (IMA) de los predios comparados con edades diferentes como se observan en los **Gráficos 1, 2, 3 y 4** a continuación. Con los gráficos se puede concluir claramente la diferencia de crecimiento mayor en los rodales con obras de conservación de suelo.

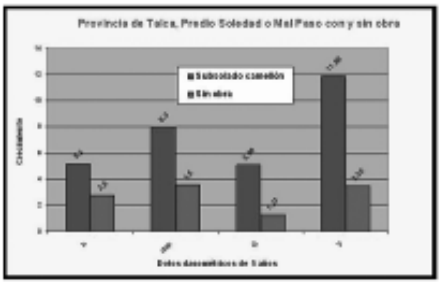

Grafico N° 1:
Comparación de crecimiento en rodales con subsolados con camellón y sin obra.

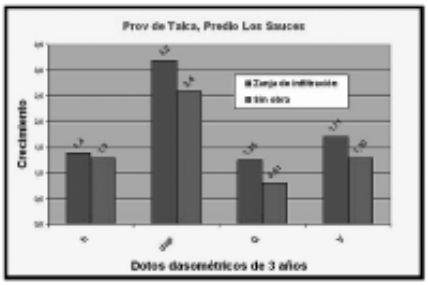

Grafico N° 2:
Comparación de crecimiento en rodales con zanja de infiltración y sin obra.

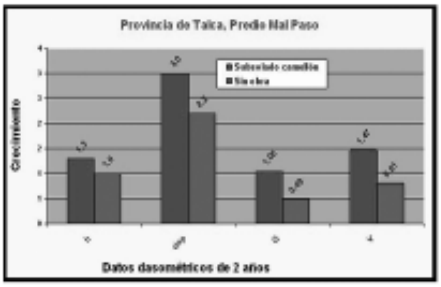

Grafico N° 3:
Comparación de crecimiento en rodales con subsolados con camellón y sin obra.

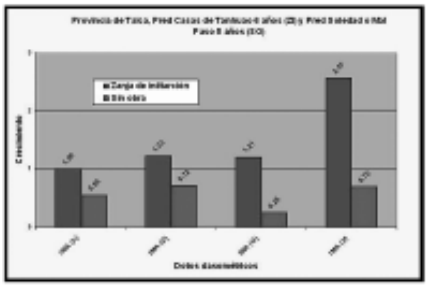

Grafico N° 4:
Comparación de crecimiento en rodales con zanja de infiltración y sin obra.

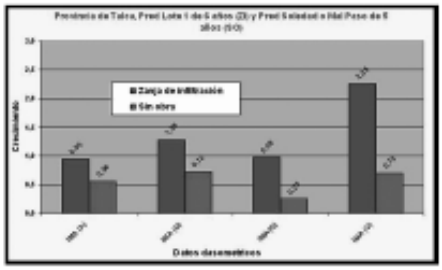

Grafico N° 5: Incremento medio anual IMA en altura, diámetro, área basal y volumen en rodales de 5 y 6 años de la provincia de Talca.

Conclusiones:

Las 17 plantaciones forestales de Pinus radita (D.Don) evaluadas presentaban edades entre 2 y 8 años, las obras de recuperación de suelos degradados consideradas en el estudio fueron las zanjas de infiltración y el subsolado con camellón, en ambos casos se compararon plantaciones con un tratamiento con respecto a plantaciones testigo sin tratamiento, en todos los casos se observaron diferencias positivas en diámetro, altura y volumen a favor de las plantaciones que recibieron tratamientos con obras de recuperación de suelos degradados.

Los resultados de este estudio se basan en la mensura de plantaciones de pequeños y medianos propietarios de predios con plantaciones forestales, y no corresponden a un diseño experimental o proyecto de investigación. Sin embargo, las diferencias son significativas al comparar el desarrollo alcanzado por las distintas plantaciones para una misma edad, obra de recuperación de suelos degradados y sitios similares.
En los casos en que se evaluó la respuesta al tratamiento zanjas de infiltración, se detectaron incrementos en diámetro de hasta 23% más, por sobre las plantaciones de la misma edad que no recibieron el tratamiento señalado.
En los casos en que se evaluó la respuesta al tratamiento zanjas de infiltración, se detectaron incrementos en altura de hasta 40% más, por sobre las plantaciones de la misma edad que no recibieron el tratamiento
En los casos en que se evaluó la respuesta al tratamiento subsolado con camellón, se detectaron incrementos en diámetro de hasta122% más, por sobre las plantaciones de la misma edad que no recibieron el tratamiento señalado.
En los casos en que se evaluó la respuesta al tratamiento subsolado con camellon, se detectaron incrementos en altura de hasta 85% más, por sobre las plantaciones de la misma edad que no recibieron el tratamiento
Se debe tener presente que las plantaciones forestales de Pinus radiata (D.Don) en la zona de este estudio, comprendió plantaciones entre 2 y 8 años y estas se deberían cosechar entre los 22 y 24 años para maximizar el ingreso de los propietarios, por lo tanto se hace necesario evaluar la proyección de los incrementos en diámetro, altura y volumen.
Se hace necesario avanzar en la determinación de los incrementos en volumen y productos, a partir de plantaciones con obras de recuperación de suelos degradados y sus efectos en plantaciones en sitios forestales con severas limitaciones.

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