

# Study on soil management strategies enhancing crop production and soil conservation

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## 1. Abstract

Nowadays, due to the overall attention developed on environmental topics, the challenge for soil scientists is to identify eco-compatible farming techniques that, at the same time, do not leave out crop productivity. In this paper some wheat production parameters and soil quality indicators were estimated jointly, as affected by different management strategies (cropping systems, crop residues management, fertilizer levels), on a long-term field trial.

For the productivity aspect, different quantity and quality parameters of wheat production were analyzed: number of spikes  $m^{-2}$ , grain yield (Gy), grain specific weight (Sw), 1000 kernel weight (Kw). These yield components were also used to develop a set of coefficients for determining the C in wheat crop (NPP). In order to estimate the potentiality of the soil management strategies compared in preserving soil quality, soil texture, water extractable organic C (WEOC) and N (WEN) were considered.

The results from single d.f. contrast method allowed to obtain comparisons among the wheat based cropping systems. Overall analysis of variance pointed out statistically significant differences in only two parameters in relation to the treatments under study: WEN and Kw.

## 2. Introduction

The studies focusing on how to manage crops and agronomic techniques in order to preserve and increase soil quality, often omit “the other side of the coin” i.e. if changes in soil quality are followed by changes in crop productivity. In this work these important aspects of agricultural research were analyzed and interpreted simultaneously considering that agriculture is also (and sometimes mainly) an economic activity. Therefore, under a long-term field trial comparing different management strategies (cropping systems, crop residues management, fertilizer levels), various wheat production parameters (quantitative and qualitative) and soil quality indicators were estimated jointly.

Diverse management strategies could be used to increase and sustain crop production and, at the same time, enhance soil quality. Effective and worldwide recognized strategies that meet production and conservation goals include reduced tillage, legume- or forage-based crop rotation, crop residues incorporation, organic manuring. On the other hand some farming practices, e.g. irrigations and fertilization, have a direct and well known positive effect on crop productivity, but, if not properly managed, may cause negative impacts on environment. For example high fertilizers levels could produce nutrient runoff and leaching, hence within this context fertilisers use and management is a specific concern.

Based on above considerations, the goodness of different management options in a field trial set up in 1972 was tested by measuring quantity and quality parameters of wheat production: number of spikes  $m^{-2}$ , grain yield (Gy), grain specific weight (Sw), 1000 kernel weight (Kw); and soil quality indicators: soil clay content, water extractable organic C (WEOC) and water extractable N (WEN), estimated net primary productivity (NPP). The selection of this last set of parameters was based on previous results concerning some basic physical and chemical soil quality indicators that showed absence of statistically significant differences (Armenise et al., 2007) and then prompted to investigate the main factors linked with SOM turnover. In particular, soil texture was chosen because it is common knowledge that clay plays an important part in SOM turnover; WEOC and water extractable N were taken into account as indices of SOM qualitative variation; estimated crop C input to evaluate the role of crop species in influencing SOM level.

## 3. Methods

A long-term field experiment was initiated in the autumn of 1972 at the experimental farm of Bari University “E. Pantanelli” located in Southern Italy (Policoro-MT: 40° 12'N, 16°40' W). The soil (soil type-FAO: Fluvisol, silty clay loam) main average characteristics (0-35 cm) in 2006 were 303 g clay  $kg^{-1}$ , 574 g silt  $kg^{-1}$ , 123 g sand  $kg^{-1}$ , 17.5 g organic C  $kg^{-1}$ , 60.3 g  $CaCO_3$   $kg^{-1}$  and a pH (1:5, soil:  $H_2O$ ) of 7.6. Durum wheat (*Triticum turgidum* L. var. *durum*) was managed, under diverse fertilization levels and stubble treatments, in three different crop sequences: continuous wheat [CW]; continuous double cropping of wheat/bean [Wb]; three-course rotation (sugar beet-wheat/bean- wheat [SW<sub>1</sub>bW<sub>2</sub>]).

The fertilization formulas were obtained by factorial combination of three N, three P<sub>2</sub>O<sub>5</sub> and two K<sub>2</sub>O levels. The stubble management under study was stubble retained [I] and burnt [B]. CW did not receive stubble incorporation. Considering the results reported in previous works (Caliandro et al., 1984), only the nil, intermediate and optimal N-P-K treatments were tested in this study.

A split-split plot design was established with crop sequences as the main plot, stubble management as the split plot, and fertilizer rate as the split-split plot (split-split plots 7.5 m by 6 m). Treatments were replicated two times.

After anthesis the number of spikes per area (spikes m<sup>-2</sup>) was obtained by counting the spikes on a 2m-long row. At harvest, grain yield (Gy) and straw biomass (Str) were measured from a 9.80 m<sup>2</sup> equivalent area; on representative grain samples specific weight (Sw) and 1000 kernel weight (Kw) were evaluated.

Clay content was determined on air dried and sieved soil samples (<2 mm) collected from selected field plots to a depth of 0-0.35 m at the end of wheat cropping cycle (July 2006), while water extractable organic C (WEOC) and water extractable N (WEN) were estimated on field-moist soil samples (soil water content=0.107 g g<sup>-1</sup>) collected in the same soil layer in May 2007.

Particle size distribution was performed using pipette method after oxidation of the soil organic matter with H<sub>2</sub>O<sub>2</sub> and stirring in a sodium hexametaphosphate solution. WEOC and WEN were extracted from 30 g of fresh weight soil with 60 ml distilled water (1:2, soil:H<sub>2</sub>O). Soil and water were placed in a Erlenmayer flask, stoppered and shaken for 30 min. The extracts were centrifuged at 20000g for 10 min; the supernatant was then filtered through 0.45 µm Millipore filter (Haynes, 2000; Rees et al., 2005). Total organic C and total N were simultaneously analyzed using a Shimadzu TOC Analyzer (Model TOC-VCSH, Shimadzu, Kyoto, Japan). Organic C was combusted at 680°C to produce CO<sub>2</sub> which was detected by a non-dispersive infrared gas analyzer (NDIR) while total N was combusted at 720°C and the generated NO was measured by chemiluminescence method.

Results from the different soil management strategies (i.e. crop sequence, stubble management, fertilizers level) were subjected to analysis of variance with the GLM procedure of SAS software (SAS Institute, 1990). Statistical differences between cropping systems in relation to the yield components and soil quality indicators were also determined considering only one stubble management (stubble burnt) by single d.f. orthogonal contrasts (Gomez and Gomez, 1984).

#### 4. Results

Some yield components (grain yield and straw biomass) were used to develop a set of coefficients for estimating the C in wheat crop (also defined net primary productivity NPP; Bolinder et al., 2007) that can be considered a practical indicator of the overall wheat C accumulation, and consequently of the potential soil C input. C concentration of all plant parts was assumed equal to 0.45 g g<sup>-1</sup> (Bolinder et al., 2007), extra-root C (Er) as 0.65, and the average shoot: root ratio (S:R) of 5.2 (Bolinder et al., 2007; Kanchikerimath et al., 2001; Siddique et al., 1990)<sup>1</sup>.

The results from single d.f. contrast method allowed to obtain comparisons among the wheat based cropping systems (Table 1). The first contrast was performed in order to obtain a group-wise comparison of rotated against annual wheat cropping systems and showed a significant difference ( $P \leq 0.1$ ) for Kw with average values of 46.3 g for W<sub>1</sub>b-W<sub>2</sub> and of 43.7 g for Wb- CW, and for NPP with average values of 695 g m<sup>-2</sup> yr<sup>-1</sup> for W<sub>1</sub>b-W<sub>2</sub> and of 596 g m<sup>-2</sup> yr<sup>-1</sup> for Wb- CW. A yield quality difference, probably on the kernel protein content, may be hypothesized and it seems also confirmed by a trend in grain specific weight (i.e. 81.8 kg hl<sup>-1</sup> for W<sub>1</sub>b-W<sub>2</sub> vs. 81.35 kg hl<sup>-1</sup> for Wb- CW). The highest NPP value in crop rotation should induce a greater C amount returning to soil.

The second and third contrast were useful in highlighting differences within the two “macro groups”, rotated and annual. In particular, within the three-course rotation, soil WEOC content resulted significantly higher ( $P \leq 0.1$ ) in W<sub>2</sub> than in W<sub>1</sub>b (38.09 mg kg<sup>-1</sup> and 34.38 mg kg<sup>-1</sup> respectively). This evidence may be easily connected with a rotation effect: W<sub>2</sub> follows W<sub>1</sub>b, hence benefits from two species crop residues and in particular from the leguminous crop positive action. The higher WEOC content could have enhanced the tillering stage as well as the number of spikes m<sup>-2</sup> demonstrates (at  $P \leq 0.1$ , 470 against 426 respectively).

Between annual cropping systems, as expected, CW had a lower grain yield in comparison to Wb (at  $P \leq 0.1$ , 5.33 t ha<sup>-1</sup> vs. 3.88 t ha<sup>-1</sup>).

Overall analysis of variance pointed out statistically significant differences in only two parameters in relation to the treatments under study: WEN and Kw (Table 2). The soil WEN content was influenced by stubble management ( $P = 0.03$ ) and also by fertilization levels ( $P = 0.1$ ) (average data not shown). As previously observed with the orthogonal contrasts, Kw appeared to be a sensitive parameter for underlining the effects of

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<sup>1</sup> NPP = Cp + Cs + Cr + Ce,

where Cp = Gy \* 0.45, Cs = Str \* 0.45, Cr = (Gy + Str) / S:R, Ce = Cr \* Er.

the management options tested; in detail it varied as function of crop and stubble management in a significant and highly significant statistical way.

**Table 1 Comparisons among the wheat based cropping systems <sup>a</sup>**

Treatments and statistics	Soil quality indicators				Yield components			
	WEOC (mg/kg)	WEN (mg/kg)	Clay (g/kg)	NPP (g/m <sup>2</sup> yr)	Gy (t/ha)	Spikes/m <sup>2</sup>	Sw (kg/hl)	Kw (g)
Cropping system								
W <sub>1</sub> b	34.38	7.26	312	685	4.53	426	82.2	47
W <sub>2</sub>	38.09	6.66	298	705	5.2	470	81.4	45.6
Wb	36.30	6.23	296	648	5.33	455	81.8	44.2
CW	35.68	7.72	304	544	3.88	457	80.9	43.3
Contrast								
W <sub>1</sub> b-W <sub>2</sub> vs. Wb- CW	NS <sup>b</sup>	NS	NS	†	NS	NS	NS	†
W <sub>1</sub> b vs. W <sub>2</sub>	†	NS	NS	NS	NS	†	NS	NS
Wb vs. CW	NS	NS	NS	NS	†	NS	NS	NS

<sup>a</sup> W<sub>1</sub>b = wheat-bean double-crop included in the three-course rotation; W<sub>2</sub> = wheat included in the three-course rotation; Wb = continuous double cropping of wheat/bean; CW = continuous wheat

<sup>b</sup> †, \*\*, \*\*\*, Significant at P ≤ 0.1, 0.01 and 0.001 respectively. NS = not significant.

**Table 2 Cropping system <sup>a</sup> and stubble management <sup>b</sup> effects on soil quality indicators and yield components**

Treatments and statistics	Soil quality indicators				Yield components			
	WEOC (mg/kg)	WEN (mg/kg)	Clay (g/kg)	NPP (g/m <sup>2</sup> yr)	Gy (t/ha)	Spikes/m <sup>2</sup>	Sw (kg/hl)	Kw (g)
Cropping system (C)								
W <sub>1</sub> b	35.03	7.35	311	678	4.58	449	82.1	45.2
W <sub>2</sub>	38.30	7.13	296	673	5.13	464	81.9	45
Wb	37.29	8.08	301	694	5.15	467	81.1	43.7
CW	35.68	7.72	304	544	3.88	457	80.9	43.3
Crop residue management (M)								
B	36.11	6.97	303	645	4.74	452	81.6	45
I	37.49	8.32	303	685	4.88	469	81.6	43.7
Significance								
C	NS <sup>c</sup>	NS	NS	NS	NS	NS	NS	**
M	NS	†	NS	NS	NS	NS	NS	†

<sup>a</sup> W<sub>1</sub>b = wheat-bean double-crop included in the three-course rotation; W<sub>2</sub> = wheat included in the three-course rotation; Wb = continuous double cropping of wheat/bean; CW = continuous wheat

<sup>b</sup> B = stubble burnt; I = stubble retained

<sup>c</sup> †, \*\*, \*\*\*, Significant at P ≤ 0.1, 0.01 and 0.001 respectively. NS = not significant.

## 5. References

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