An Integrated Italian Research Project on "Evolution of cropping systems as affected by climate change" (CLIMESCO): first results on spatial and climatic characterization of two agricultural lands

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1. Abstract

The climatic change induced by the global warming is expected to modify the agricultural activity and consequently the other social and economical sectors. In this context, an efficient management of the water resources is considered very important for Italy and in particular for Southern areas characterized by a typical Mediterranean climate in order to improve the economical and environmental sustainability of the agricultural activity. Climate warming could have a substantial impact on some agronomical practices as the choice of the crops to be included in the rotations, the sowing time and the irrigation scheduling. In this paper, a three-year Project, funded by three Italian Ministries (University, Agriculture and Environment) and involving Italian Research Institutions of Agricultural National Council, After presenting the different types of methodologies that we are applying, the first results will be presented with particular reference to the first workpackage (WP). The objective is to characterize the two areas in the southern part of Italy subjected to intensive agricultural activity. The characterization of two areas is based on spatially distributed data concerning the soil, the climate and soil use. Several techniques of data spazialization, clustering, geostatistical analysis, GIS are utilized in order to achieve homogeneous areas. Informative layers of GIS about land use, soil properties and climate are produced to describe the two areas. For estimating the local weather forecast for several decades at daily scale, starting from a General Circulation Models (GCM) data, two method of downscaling (regionalization techniques), dynamical and statistical, are adopted and compared.

2. Introduction

The human activities are affecting the composition of the atmosphere due to increase of emissions of carbon dioxide (CO_2) and other greenhouse gases causing an increase of the global average temperature. The Mediterranean region is considered particularly vulnerable and the temperature increase is expected to be higher than other regions. Concerning the rainfall, there is a great uncertainty with the projections by the various climate models frequently differing in both sign and magnitude for a given regions. The phenomenon is complex because the temperature affects the soil evaporation, plant transpiration, cloud characteristics, storm intensity, etc. Consequently, some regions can expect an increase in the amount of precipitation. In other areas, especially where the water deficit has been already experienced, the forecasted decrease of rainfall will substantially affect the quantity and/or the quality of the water resources for the agricultural activity.

For a particular region the forecasted warming is expected to depend strongly on several factors as the morphologic and geographical characteristics. For the Italian lands, some authors found a reduction for winter precipitation, and in particular for the regions of Southern Italy.

The climatic change induced by global warming is expected to modify the plant productivity and, in general, the agricultural activity. For the determinant herbaceous crops, the increase of temperature could shorten the cycle and determine a decrease of yield. The contrary will happen for the crops with indeterminate cycle if the irrigation water availability will increase. For the tree crops the temperature increase could expand the suitable area for plant requiring high temperature as grapevine (Olesen and Bindi, 2002). The impact of climate change on yield and product quality of cropping systems will depend on the complex relationships between increase of CO_2 and temperature and changes in evapotranpiration rate and rainfall, depending on average, variability and intensity of precipitation.

Considering the cropping systems, the agronomical strategies of adaptation can include: (1) crop substitution, (2) changes in sowing date and sowing depth, (3) cultivar choice, (4) adjusting of fertilizer applications and pesticides treatments, (5) conservative tillage for reducing soil evaporation and runoff and increasing water infiltration.

In areas where a reduction of water resources is expected, the adoption of localized irrigation methods, the optimization of irrigation scheduling, the continuous monitoring of soil water status could be the useful strategies in order to increase the Water Use Efficiency (WUE) of cropping systems (Ventrella et al., 1996).

The objective of this paper is to describe the tree-year Project "*Evolution of cropping systems as affected by climate change*" (CLIMESCO) and to present the first results about the spatial and climatic characterization of two areas located in Southern Italy subjected to intensive agricultural activity.

3. Methods

In a context characterized by climate change, high evaporative and transpirative demands, poor availability of water resources and/or decreasing of water quality for irrigation, the overall objective of the Project is: to individuate integrated approaches for optimizing water resources use by maximizing the cropping systems WUE, approaches that could be utilized by political stakeholders in land planning activity. CLIMESCO is founded by three Italian Ministries and involves Italian Research Institutions of Agricultural National Council, Research National Council and Universities.

The research activity is carrying out for two reference area in the Southern Italy: the Capitanata area in Apulia Region and the Diego Nivolelli basin in Sicily Region.

The Capitanata area, the second largest plain in Italy (about 4000 km^2), is located in the Northern part of Apulia region. It is one of the most important areas for the Italian agriculture, the most widespread crops are winter wheat (rainfed), sugar beet, tomato, vegetables, grapevine and olive orchard. The climate is semi-arid, with hot and dry summers (annual rainfall is about 550 mm) and short and temperate winters.

The Delia-Nivolelli basin, with an extension of about 60 km^2, is located in the South-Western Sicily. The climate of the area is semi-arid, with dry summers and short, temperate winters. The annual evapotranspiration is always greater than rainfall, determining drought conditions that make irrigation necessary for agriculture. The main crop is the grapevine, covering about 83% of the whole cultivated area and the 93% of the total catchment area. Other crops present in the area are olives and citrus

The Project is structured in four workpackages (WP) with specific objectives, high degree of interaction and information exchange.

WP1: Identification of homogeneous areas

The objective is to characterize the two areas. The characterization is based on spatially distributed data concerning soil, climate and land use. Several techniques of data spazialization, clustering, geostatistical analysis, GIS is utilizing in order to achieve homogeneous areas. Informative layers of GIS has been produced to describe the two areas and manage the data for the other WPs.

WP2: Climatic change

The first objective of this WP is to provide temperature, precipitation and radiation scenarios according to several forecasted of greenhouse-gases emission by using the General Circulation Models (GCM). The GCMs are complex models that consider mass and energy exchanges between ocean, land and atmosphere at the whole planet for providing temperature, precipitation and radiation scenarios, according to some scenarios of greenhouse-gases emissions. Regional models have been used in several climate impact studies for many regions of the world. The regional climate models obtain sub-grid scale estimates (sometimes down to 25 km resolution) and are able to account for important local forcing factors, such as surface type, land use and elevation. Therefore, the aim of this WP is to estimate local weather forecast for several decades at daily scale according two method of downscaling (regionalization techniques): (i) dynamical, increasing the spatial resolution in the reference areas or adopting global cells as boundary conditions and (ii) statistical, based on the identification of statistical correlations between meteorological variables at global and local scales.

WP3: Optimization of water resources

The topics of this activity involve the irrigation management of water resources that are expected to become more and more the main limiting factor for the agricultural activity. In particular, researches at field scale are carrying out for agronomical studies regarding the following the following irrigation studies: (1) irrigation management with saline water in Mediterranean environments at high desertification risk, (2) cropping systems and water requirements, (3) agronomical strategies for soil leaching (4) temporal evolution of crop coefficients (Kc) and crop resistance depending on climate change and (5) evaluation of new procedures to determine hydrological soil parameters used in soil water balance models.Another important issue of this WP is to parameterize the simulation models about crop growth and photosynthesis translocation, soil water fluxes and solute transport.

WP4: Scenarios analysis

This WP will be the conclusive WP. Using the information deriving from WPs 1 and 2, simulations will be run both at field and regional scales by using numerical models for simulating crops and cropping systems. In particular, calibrated and tested crop and hydrological models will be utilized in order to evaluate the effects that the future climatic scenarios will have on crop yields and to individuate the best agronomical strategy to optimize the use of water resources.

In order to select the models to be used in the framework of CLIMESCO, a comparison has been carried out taking into account the modeling approaches than can be addressed for the crop water management. DSSAT

(Jones et al. 2003), CropSyst (Stockle et al., 2003), EPIC (Williams et al., 1989), SWAP (Van Dam et al., 1997) models have been selected.

4. Results

The Geographic Information System (GIS), realized in the framework of CLIMESCO, represents the possibility to manage the information of different features with the objective to characterize the agro-environmental parameters. The GIS is an essential tools for capturing, managing, analyzing, and displaying all forms of geographically referenced information. The implementation required to collect data of different types of information related to CLIMESCO. All the data were checked and homogenized to the same measurement units, temporal and spatial resolution and their variances. Moreover, the same geographical reference system was utilized.

4.1 The Capitanata Area

The GIS was characterized by 5 features: (1) geography, (2) remote sensing, (3) geo-lithology, (4) soil and land use and (5)climate. The Fig. 1 shows the geographic area of Capitanata with the surface hydrography. Images of LANDSAT TM from remote sensing were utilized with a resolution of 30 m related to two dates in

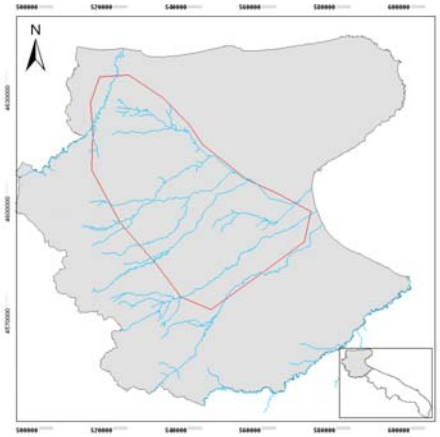

Figure 1 The Capitanata area in the Puglia Region

April and July of 2006.

The soil in the Tavoliere area is mainly constituted by continental and marine sediments. A preliminary study based on the interpretation of the official geological maps of the area allowed to group different geological units in seven lithological classes outcropping over the area: Cretaceous Limestones, Plio-Quaternary clays, Plio-Quaternary Sands, Plio-Quaternary Gravelly Deposits, Terraced Marine Deposits, Terraced Alluvial Deposits and Actual River-Bed Deposits. The most diffusely outcropping lithology is represented by the alluvial deposits, composed by terrains with heterogeneous grain size and texture.

The soil database include 1353 pedological profiles distributed in the area of Foggia district. The data characterize two layers of 0-40 cm and > 40 cm.

The Landsat images with 2400 points of ground inspection were utilized to yield a land use map applying a procedure based on “Maximum Likelihood” and the geostatistical tool of the Indicator Kriging. The land use include 4 classes: cereal crops (67%); tree crops (11%), vegetable crops (10%) and vineyard (12%)

The climatic feature is constituted by data coming from 20 meteorological stations homogenously distributed in the Foggia district. In particular, the database includes data of precipitation and temperatures (minimum and maximum) at monthly scale. The ”climatological unit” of CLIMESCO (WP2) are utilizing these data in order to apply the statistical downscaling metodology.

4.2 The Delia-Nivolelli basin

The basin of Delia-Nivolelli is located in the South-West area of Sicily Region near the city of Mazara del Vallo in the Trapani district.

The GIS is organized in 5 layers, geo-referenced with the U.T.M. system (longitude zone 33N with datum ED50): (1) geography and topography; (2) remote sensing images; (3) Geo-lithology; (4) soil and land use and (5) climate.

The geographical layer is constituted by (1) physiographic and administrative features useful for the geographical location; topographic data for obtaining the DTM elaboration. In particular, starting from the national cartography (1:25000), the following geographical features were digitalized and stored in shape files: (1) regional administrative boundaries; (2) study area boundaries and (3) hydrographic network.

In order to realize the DTM model, an other GIS layer was implemented by digitalizating 3591 elevation points collected from regional topographic maps (1:10.000). In particular, a first sampling of 2364 elevation

points were extracted from the 1:5.000 technical topographic maps and a further sampling of 1227 elevation points were carried out from the 1:10.000 technical topographic maps for increasing the DTM resolution.

The remote sensing layer includes orthophoto strips with a resolution of 1.5 m. They were utilized for individuating the vineyard cultivated areas.

In the Delia-Nivolelli area the earth materials are composed by continental and litoral deposits, belonging a miocene and quaternary sedimentary sequence which covers the evaporitic rocks of the gypsum-sulphuric formations. The older lithology outcropping in the area is represented by the Marly Clays, upper Miocene in age. In the western sector, the clay deposits are covered by the plio-pleistocene Litoral Deposits, constituted by gravelly and calcareous deposits, with organogenic detrital and local clayey-sandy levels. The eastern sector of the area is characterized by Alluvial Deposits Olocene in age, with a variable grain sizes.

The soil feature is represented by maps of pedological characteristics, hydraulic and chemical soil parameters and land use. The pedological map was obtained by digitalizing of the Sicily soil maps (1:250000) enanched by information coming from further 10 soil profiles. Four soil classes, according to USDA

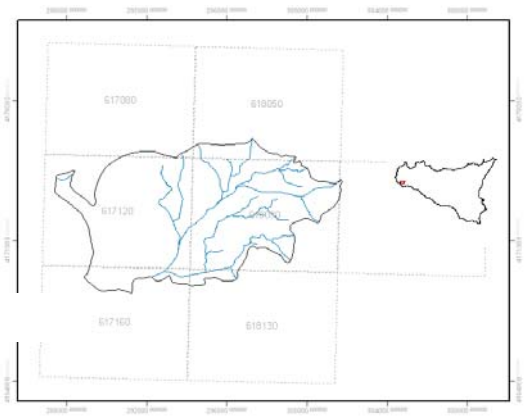

Figure 2 The Delia-Nivolelli basin in Sicily

classification, were recognized and acquired in the GIS: Lithic Xerorthens, Typic Chromoxerert, Vertic Xerochrept and Vertic Xerofluvent. In order to characterize accurately the soil hydraulic properties, the following data, coming from 330 sampling points of two soil surveys were utilized for implementing the soil GIS layer: soil electrical conductivity (by EM38 and laboratory determinations), textural data and bulk density, soil water content, pH organic matter, soil water retention and hydraulic conductivity (Crescimanno, 2001 and Crescimanno et al. 2002).

Data from five meteorological stations distributed in the Delia-Nivolelli basin have constituited the climatic layer.

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