Vegetation Cover for Sustainable Olive Grove Management

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Abstract: Two types of vegetation covers were compared to the common soil management techniques in olive culture areas to design, introduce, test and disseminate cover crops as ecological olive production systems. In the first vegetation cover, natural vegetation development was allowed until water competition arises, whilst weeds cover was enriched with a leguminous species, in the second. The common soil management techniques tested was ploughing and herbicides. Olive trees vegetative development and nutrients content were monitored. The potential for natural revegetation ability was evaluated. Organic matter, nutrients and water contents in the soil were also measured. Infiltration and erosion were estimated using the field-saturated hydraulic conductivity (Kfs) "Guelf permeameter" method and the revised universal soil loss equation (RUSLE). In order to understand the variation of some soil physical and chemical properties, graphical interpretation of these soil properties was done using geostatistics and geographic information systems.

Keywords: Cover crops, sustainable agriculture, geostatistics, soil erosion, geographic information system.

1 Introduction

Olive groves are a major crop and traditional culture in the Mediterranean region well represented in Portugal. Olives are cultivated in slopped orchards at shallow and eroded soils at the foothills of the mountains combined with vineyards, arable and grazing land. Following the traditional soil management techniques, soil is harrowed and heavy use of herbicides are used in order to destroy the weeds, leaving bare soil exposed to erosion. Tillage is also responsible for increasing production costs and soil compaction.

Crops in the Mediterranean region are generally produced in fields that have a high degree of variability in soil type, topography, soil moisture and other major factors that affect crop production. Many authors used classical statistics and geostatistics to analyse the spatial variability of soil properties and crop yield [10, 11, 12]. Precision farming is an emerging technology [13] and therefore limited research is available to practitioners who adapt precision agriculture for Mediterranean soils and crops. Christensen and Krause [4] pointed out that computer literacy, GIS, global positioning system (GPS), expert systems, and remote sensing can provide knowledge-based management of agricultural production to reduce environmental impact.

While precision agriculture shows to be promising with respect to environmental quality, it also could increase profit margins. The variability within the field implies inefficient use of resources. Precision agriculture defines different management practices to be applied within single variable fields, potentially reducing costs and limiting adverse environmental side effects [1].

The major objective of Precision Agriculture is to increase the productivity of yield with a more rational approach on resource consumption. To achieve such objective gathered field data estimate the most needed parts of the production field and scarce resources are better distributed [5]. This should reduce nutrient surpluses and environmental pollution from the rational use of chemicals like pesticides and herbicides [8].

Use of precision farming technologies requires better understanding of soil variability in physical, hydraulic and chemical properties. Some of that variation is natural and some is the result of the management history of the field [9]. Soils vary widely in their soil properties and in their ability to supply nutrients in quantities sufficient for optimal crop growth.

An important contribution of geostatistics is the assessment of the uncertainty about unsampled values [3]. This uncertainty assessment can be combined with expert knowledge for decision making such as description of areas of good soil quality where specific management plans can be developed [6].

The main aim of the present work was to study the effect of ground cover management in olive culture groves for soil conservation and sustainable production.

2 Materials and Methods

The study area is located in South Portugal, at Monterosa low inclination olive groves. The climate of the area is Mediterranean with very hot and dry summers and mild winters. Algarve is under a strong climatic influence of the Mediterranean, and therefore characterised by a dry season and a very irregular distribution of rainfall during the year, as well as over the years. Average annual precipitation was 533mm.

In the present study, two types of vegetation covers were compared to the traditional soil management techniques in an olive orchard. At first cover (area C in figure 1), natural vegetation development was allowed until water competition arises and then was cut with a mower, whilst weeds cover was enriched with herbaceous species, at the second (area B in figure 1). The following species were broadcast seeded for the second soil cover: *Medicago polimorfa, Medicago truncatula, Trifolium resupinatum* and *Lolium perene.* The traditional soil management technique (area A in figure 1) was: ploughing twice per year and herbicides application at the end of winder.

Vegetation cover, management and soil data were collected from a total of 15 soil samples in as suggested for small heterogeneous areas by Carter [2]. Figure 1 shows the aerial photograph of one study area with the exact location of the sampling points. Those points were located in the field with the help of a GPS.

Organic matter, main macronutrients (available phosphorus, total nitrogen and exchangeable potassium) and water contents in the soil were also measured. Infiltration and erosion were measured using the field-saturated hydraulic conductivity (Kfs) "Guelf permeameter" method and the parameters needed at revised universal soil loss equation.

In order to understand the variation of some soil physical and chemical properties, graphical interpretation of these soil properties was done using geostatistics in a geographic information system. Olive trees vegetative development and nutrients content were monitored. The potential for natural revegetation ability was evaluated.

Figure 1- An aerial photograph of the Monterosa experimental area shows the exact location of the 15 sampling points. Traditional soil management techniques in area A, enrichment with a leguminous species in area B and natural vegetation development in area C.

In this work, ordinary kriging was used for the creation of several maps. Prior to this, semi-variograms were produced for each soil factor. Cross validation used to compare the prediction performances of the semi-variograms. The maps resulting from the interpolation techniques were introduced in a geographic information system and their values reclassified. After that, it was used spatial modelling to develop a final overlay map for soil erosion.

3 Results

It was created a dataset of soil properties and vegetation cover in their geo-referenced position in the field. Transformation and trend removal was done when necessary to create more accurate prediction maps. Kriging after trend removal was done on the residual data of hydraulic conductivity, texture (clay), organic matter phosphorous and pH. The prediction map of each factor was calculated and trend was added back to the output surface.

Figure 2 is showing the map of hydraulic conductivity after ordinary kriging, demonstrating that the highest permeability will occur most probably at the Western part of the experimental area. Figure 3 is showing the map of texture derived from clay percentage data after ordinary kriging, demonstrating the existence of a spot of light textured soils at the Eastern part of the experimental area.

At those maps were noticed many and easy to identify important facts to be taken in consideration, like areas of high or low nutrient and organic mater concentrations. Thus, those maps were important for the estimation of the optimal area for vegetation growth and helped to predict which property was limiting production and where.

Localized problems in soil properties could be solved with simple geographically restricted amendment treatments [7]. All maps of soil properties were reclassified, weighted and overlaid in Arcview model builder. A fertility map was produced first combining the maps for nitrogen, phosphorus and potassium.

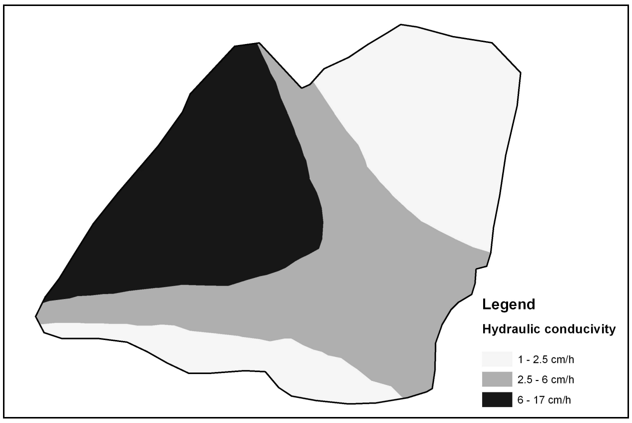

Figure 2- Prediction map of hydraulic conductivity resulted after ordinary kriging.

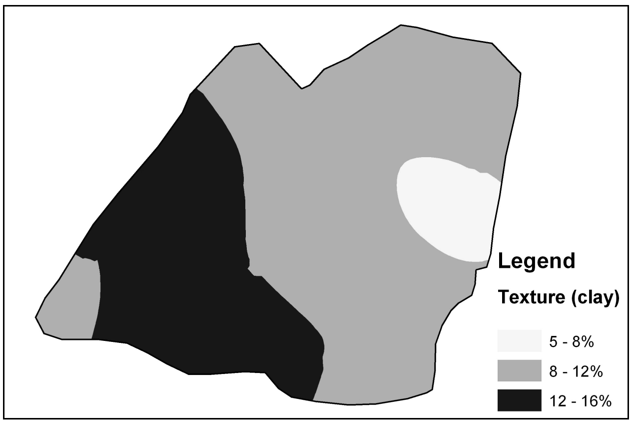

Figure 3 - Prediction map of texture resulted after ordinary kriging of the clay percentage.

A triangulated irregular network (TIN) was created from a topographic map and used to estimate the slope length factor LS. The rainfall and runoff factor R was estimated to be 87 for the experimental area after the creation of the R prediction map of Algarve region. The erosion control practice factor map and the vegetation cover factor map were estimated from values given on each of the 15 sample locations at the moment of sampling. The final soil loss prediction map resulted according to the RUSLE relationship following map algebra in Arcview (figure 4).

The final map of erosion risk was created to locate the optimal area for each of the vegetation management techniques. The final soil loss prediction map showed that the seeded area could have an increase of more than 30kg of soil erosion per hectare per year if traditional ploughing and herbicides were applied instead of cover crops development. The potential erosion at the area that natural vegetation development was allowed could be decreased for more than 15kg of soil erosion per hectare per year if it was seeded and reached the same ground cover, organic matter and permeability as at the seeded area.

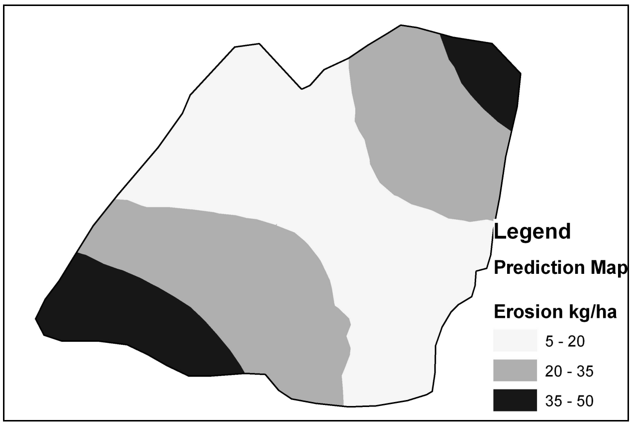

Figure 4 - Soil loss prediction map resulted according to the RUSLE relationship following map algebra in Arcview.

Therefore, management techniques, which imply less machinery needs, would cause less soil compaction and erosion. This can be achieved by maintaining a plant cover in the in-row. Furthermore, this technique improves water availability in soil, increases infiltration and diminishes evaporation and runoff. A better soil structure also improves mobility, a very important factor in the harvesting period. Plant cover also influences organic matter content, biodiversity, activity of soil microorganisms, and fauna. In addition, organic olive production offers agroecological and socioeconomic advantages.

The ultimate purpose of this research was to make the data available to olive growers and demonstrate that vegetation cover in olive orchards is advantageous environmentally and cost-effective comparing to traditional techniques. Demonstration of the above technologies was done during an open day of technology transfer to the society for any interested olive farmer.

5. Conclusions

The results of the present study were shown that cover crops grown to protect and improve the soil have the potential to control erosion and weeds, and maintain soil organic matter. They had reduced compaction, leaching of nutrients and increased water infiltration. Cover crops retained and recycled plant nutrients, provided habitat for beneficial microorganisms, and increased biodiversity. Sustainable management of natural resources reduced external inputs, minimized environmental degradation and improved system sustainability. Geostatistics can be used as an inexpensive way to apply precision management in small areas.

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