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SOIL GEOSTATISTICAL TECHNIQUES APLIED TO SPRINKLE IRRIGATION EXPERIMENTS

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Introduction

Crops in the Mediterranean region are generally produced in fields known to have a high degree of variability in soil type, topography, soil moisture and other major factors that affect their production. Recent technological developments have paved the way for important and far-reaching changes in agricultural production practices.

More specifically, these technologies can enable micro-management techniques on a site-specific basis to account for the natural and human induced variations that exist in agricultural fields like variation in soil type, moisture, topography, chemistry, physical properties, and other factors. These technologies offer the possibility of optimising profit and reducing the adverse environmental impacts of farming (Larson, *et al.,* 1997). In recent years, major advancements have been made in the technologies required to implement precision farming practices.

A very high level of interest in precision farming is evident from the major agricultural sectors, including the farm machinery industry, co-operatives, and farmers. Many unknown factors are related to the implementation of precision farming, including the continued development of associated technologies and economic factors. Precision farming is an emerging technology and therefore limited research is available to practitioners who try to adapt it in southern soils and crops. Christensen and Krause (1995) pointed out that computer literacy, Geographic Information Systems (GIS), Global Positioning System (GPS), expert systems, and remote sensing can provide knowledge-based management of agricultural production to reduce adverse environmental impacts.

Precision farming technologies promise the ability to apply farm chemicals only where needed and in the appropriate amount, thus reducing the potential for pollution (Blumhorst *et al*., 1990). While precision agriculture shows promise for increasing profit margins, it also has application with respect to environmental quality.

As public concern over water quality continues to escalate, producers will be required to make more prudent decisions regarding the use of agricultural chemicals. The very nature of precision agriculture will require producers to keep accurate records while helping them to reduce unwarranted pesticide application and to better manage nutrients and water in sensitive areas. These intensive management skills will also lead to better use the animal wastes and other biosolids.

The ability of the soil to accept and retain water has a considerable impact on crop growth and yield. In Algarve, Portugal, the soil's ability to accept and retain water varies considerably. Many soils are sandy to considerable depths, and the texture of the argillic horizon varies noticeably (coarse-loamy to fine families). Though surface textures are commonly sand or loamy sand, surface crusting is frequent (Chiang *et al*., 1993), which increased surface runoff. In addition, redistribution of water from high to low landscape positions through shallow subsurface flow is widespread (Hubbard *et al*., 1983).

When irrigation water contains a significant concentration of soluble salts, it could affect crop production, if not properly managed (Letey *et al*., 1985). The mechanism affecting crop production is explained due to the fact that at high salinity, the water content at wilting point is higher than at low salinity, resulting in an insufficient amount of available water and, therefore, a reduced yield (Beltrão and Ben Asher, 1997).

The effect of salinity on horticultural crops yield has been modelled with a piece-wise linear response model (Maas and Hoffman, 1977; Beltrão *et al*., 1993): plants produce at their full potential yield until salinity reaches a threshold value. The threshold value is the maximum average salt concentration in the root zone that does not reduce the yield; above the threshold value, the yield decreases as a linear function of salinity until a point above which the plants die and yield drops sharply to zero. Generalised results from crop yield models with saline waters were developed by Solomon (1985) and Warrick (1989). Plaut (1997), Beltrão *et al*., (1997) have obtained the production of horticultural crops affected by salinity.

The objective of the present work was to study the effects of salinity and other environmental factors on lettuce yield under the use of sprinkler irrigation and to decrease the lack of randomisation in this kind of experiments with the use of geostatistics in a geographic information system.

Materials and Methods

Establishing relationships between spatially variable attributes is very important and will allow the development of new understanding that can be used in precision farming. To establish those relationships it was evaluated and quantified the impacts of spatial field parameters (elevation, slope, etc), soil properties (chemical, physical, and biological) on spatial distribution of crop yield, and yield potential. Spatial soil and crop data were collected for soil types and lettuce in the experimental field. All data were entered into a field-scale GIS (ArcView), and interlayer data analytical tools were utilised to quantify spatially dependent relationships.

A field trial was established in Gambelas Campus of University of Algarve at November 1999, in a salinised plot to study the capacity *of Limoniastrum monopetalum, Lotus creticus* and *Tetragonia expansa* to extract salts from soil without irrigation (winter season). If significant biomass production could be produced by that way, salt soil contamination could be avoided, because irrigation water is the first source of soil salinisation at Algarve conditions.

The experimental design was a randomised trial bloc with 3 repetitions. Each bloc has 3 perpendiculars lines to salinity gradient, spaced of 0.5 m between each species. The salinity gradient was obtained according to the concepts of Hanks *et al*. (1976) and Magnusson and Ben Asher (1990). Some days after the end of the experiment of the desalinisation with the use of endemic vegetation species the experimental field was cleaned from vegetation to be prepared for the cultivation of lettuce.

In June of 2000, 1081 lettuce plants were planted in rows of 2 meters wide and with 1 meters distance between plants. The lettuce was irrigated during summer with saline water with a middle sprinkler line as it is shown in the Figure 1. At the end of October it was measured lettuce weight and diameter. Samples of every plant were guarded for laboratory analyses.

Many soil and water parameters that could explain the cause of spatial variability in the productivity of lettuce were analysed. Soil samples, geographically positioned, were sampled before the beginning of the experiment and at the end of every of its phace. The data were inserted to a database file as described from Yialouris *et al*. (1997) and geostatistics and presentation of the results was made with ESRI ArcView Geographic Information System software.

The Spatial analyst of ArcView was used for the study of those parameters. Many different geostatistical methods were tried to choose the most appropriate for each soil or water parameter (Kitanidis, 1997). The Kriging interpolator method that was used for Electric Conductivity, organic matter and pH, assumes that the distance or direction between sample points reflects spatial correlation that can be used to explain variation in the surface (Issaks and Srivastava, 1989; Armstrong, 1998).

For the geostatistical analysis of soil texture was used the Spline interpolator. The Spline interpolator is a general-purpose interpolation method best suited for gently varying surfaces, but not appropriate if there are large changes in the surface within a short horizontal distance, because it can overshoot estimated values. For the geostatistical analysis of hydraulic conductivity was used the Inverse Distance Weighted (IDW) interpolator assumption. The Inverse Distance Weighted interpolator assumes that each input point has a local influence that diminishes with distance. It weights the point closer to the processing cell greater than those farther away (Longman *et al*., 1995; Chilès and Delfiner, 1999).

Results and Discusions

Figure 1 is showing the results of lettuce growth. Notice that the bigger the symbol the larger the weight of the plant. Some spots on the field were empty because the plants died. In the same figure it can be seen the effect of soil texture on lettuce growth. The map of soil texture made with the Spline interpolator assumption method shows that the field was not uniform in texture and a heavy textured clayish area in the north of the field provoked the death by suffocation of many lettuce plants.

In the southeastern part of the field there was an other area with dead lettuce that probably was provoked by the high hydraulic conductivity of the sandy soil that was dominant in the area as it can be seen in Figure 2. In the same figure it can be seen the effect of salinity and water permeability on lettuce productivity.

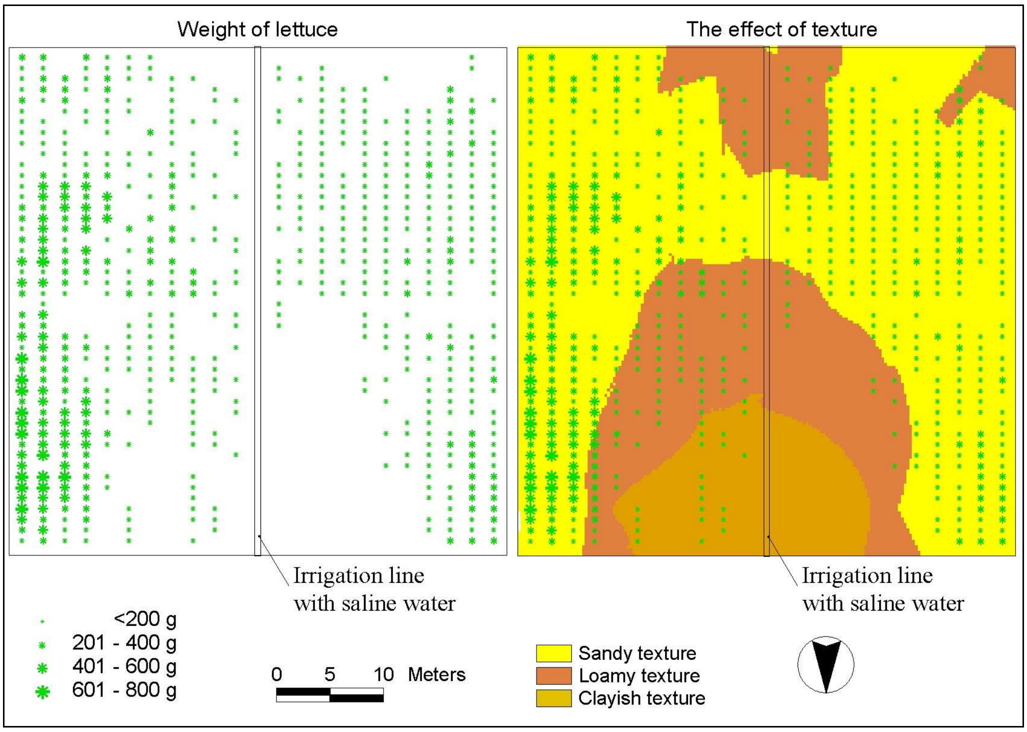

Figure 1. Shows the weight of lettuce and the effect of soil texture on it, the respective legend, scale and north location. The map of soil texture was made with the Spline interpolator assumption method in the Arcview Spatial Analyst.

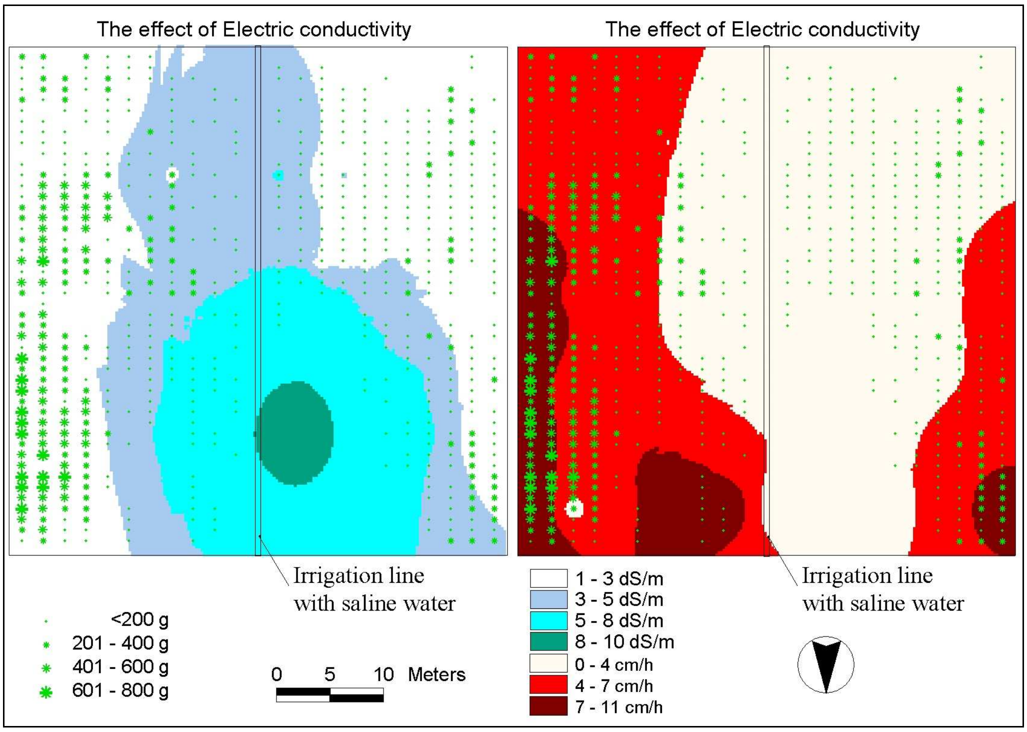

Figure 2. Shows the weight of lettuce and the effect of salinity and water permeability on it. The map of salinity was made with the kriging method and the map of hydraulic conductivity was made with the Inverse Distance Weighted interpolator assumption method in the Arcview Spatial Analyst.

The map of salinity was made with the kriging method and it is showing that the area with maximum salinity was not in the centre of the map, as it was expected but a little to the west, due to a small inclination of the field and an unpermeable clayish zone in this area. The map of hydraulic conductivity was made with the Inverse Distance Weighted interpolator assumption method so a small spot in the north of the field with very low permeability can be explained as a mistake of the method. The pH of the soil was varying between 6.3 and 8.2 and organic matter was uniformly very low, both attributes were not presenting a direction in their spatial variability.

Conclusions

After the examination of those maps it can be concluded that salinity was not the only factor that affected survival, growth and salt uptake of lettuce, but a combination of many soil and water parameters that has to be studied. A spatial model will be created after the end of the laboratory analysis of the lettuce samples, so more accurate and less expensive solutions could be given with the establishment of the desalinising endemic species to rehabilitate the field next year. The present study is opening the door of an inexpensive way to apply precision agriculture for small farms.

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