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Crop variability in cotton fields

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Abstract

Three experimental fields were cultivated with cotton (*Gossypium hirsutum* L) in Omorfochori Larissa in 2005. The correlation between electrical conductivity, plant density, plant height and yield were determined to draw conclusions and make farm decisions for the best management of the fields. The results showed significant variability in yield and Electrical Conductivity in the three fields. Electrical conductivity did not give adequate correlation to yield but it can be used to delineate management zones for targeted soil sampling. Plant height and plant density did not affect yield due to the uniformity of the plants.

Keywords: Cotton, Precision Farming, Yield mapping, Electrical Conductivity

Introduction

Precision Agriculture is a crop management system, which is based on the use of the latest technology, in recording and digital mapping the variability of 'soil-crop' system. It's goal is the rational application of inputs in all productive stages based on the identified variability and the most optimal balance of the system. Precision Agriculture (PA) can be defined as the management of spatial and temporal variability at a sub-field level to improve economic returns and reduce environmental impact (Blackmore et al., 2006). It generally aims at the optimisation of productivity, the long run viability of the crop production system, and the maximal possible reduction of environmental pollution. It is a broad term for techniques, technologies, and management strategies addressing within-field variability of parameters that affect crop growth. These parameters may include soil type, soil organic matter, plant nutrient levels, topography, water availability, weed pressure, insect pressure, etc. The technology supplies the tools and the management decides how the tools should be used (Blackmore et al. 2006). Precision Agriculture is a technology developed the last 15 years. It uses the Information and Computer Technology and applications of electronics in the Farm Management.

Precision Agriculture uses many techniques to measure soil and crop properties. Some of these techniques are automated and easy to use, such as yield mapping, mainly for arable crops. Some others are time consuming and costly, especially for grid soil sampling and mapping of soil properties. The need to fast and accurately measure soil characteristics would facilitate soil mapping and boost the adoption of PA practices. There is a number of techniques developed around the globe, such as the Nitrogen sensor offered by Yara company and others, which estimates the amount of chlorophyll in the crop canopy and variably apply nitrogen on the go. The Tokyo University of Agriculture and Technology has developed another on-the-go equipment that can measure pH, nitrates and organic matter, but it is not economical viable to purchase. The technique most commonly used in the real time measurement of Electrical Conductivity (ECa). The application of ECa in agriculture has inititated in 1970s and has evolved over the last 30 years, as one of the most frequently applied technology to identify soil variability to use in PA (Corwin and Lesch, 2003).

Friedman (2005) discussed the factors that influence ECa. He groups these factors into three categories: the bulk soil, the soil particle quantities and the soil solution attributes. In simple words the major factors that affect ECa are the water content, the salinity and the soil texture (clay and sand portion). Therefore, care should be taken to interpret ECa readings on what these measurements actually mean.

PA was initiated in Greece in 2001. The first applications were in cotton in Karditsa area, Central Greece. The results showed significant variability in soil, yield and lint quality, even in the small size fields (Gemtos, et al., 2004). Markinos et al. (2003) has correlated ECa with cotton yield in two fields. They concluded that while it is possible to delineate management zones from ECa maps, the correlations with yield is not high, due to many other factors that influence the yield. This has also been supported by Corwin and Lesch (2005) who have made a review of a series of papers in the influence of ECa to yield and have pointed out that the yield depends on "complex interaction of topographical, biological, anthropogenic and edaphic factors". These factors are all interact among each other and influence the final yield and the ultimate goal of PA is to understand these interactions to manage in-field variability.

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In other words, the final production of cotton depends on various factors, profoundly the climate conditions, the structure of soil, the physical and chemical soil properties, the genetic material, irrigation, fertilization, plant density, weed and insect infections. These factors are often mentioned as the biotic and non-biotic factors. The biotic factors are those that are related to crop characteristics, such as crop development stages, crop height and crop density. Cotton plant height and density was measured by a number of researchers during a growing season to estimate their influence in the crop. Cavalaris (2004), has measured cotton height and density to different tillage systems and found that the more intensive a tillage system was, the higher the plants. In this paper, the application of PA in three cotton fields is presented. The factors that were measured and correlated were yield, ECa, plant height and plant density.

Materials and Methods

Three experimental fields (Apothiki: 1,76 ha, Vasoula: 2,43 ha, Foulouli: 2,92 ha) were cultivated with cotton (*Gossypium hirsutum* L) in Omorfochori area, Central Greece in 2005. The soil type was in the territorial order of Inceptisols. In the three fields the same variety was used (Celia). In the field Apothiki drip irrigation was applied, in the field Vasoula gun-sprinkler traveller irrigation system and in the field Foulouli sprinkler irrigation using small sprinklers in the western part, while gun-sprinkler traveller irrigation system in the rest of the field. The following measurements were performed:

- Cotton yield mapping
- Soil Electrical Conductivity (ECa) Mapping
- Plant height
- Plant density (number of plants/m).

Cotton yield mapping was performed on October of 2005. For yield mapping a commercial yield monitor system from AgLeader Company was used, borrowed from the University of Georgia. The yield monitor system was placed on a two row picker. The yield mapping system consisted of (i) the central control unit, (ii) two pairs of infrared yield sensors, (iii) the speed and the units position sensors and (iv) and the GPS antenna with the corresponding receiver (Fig. 1).

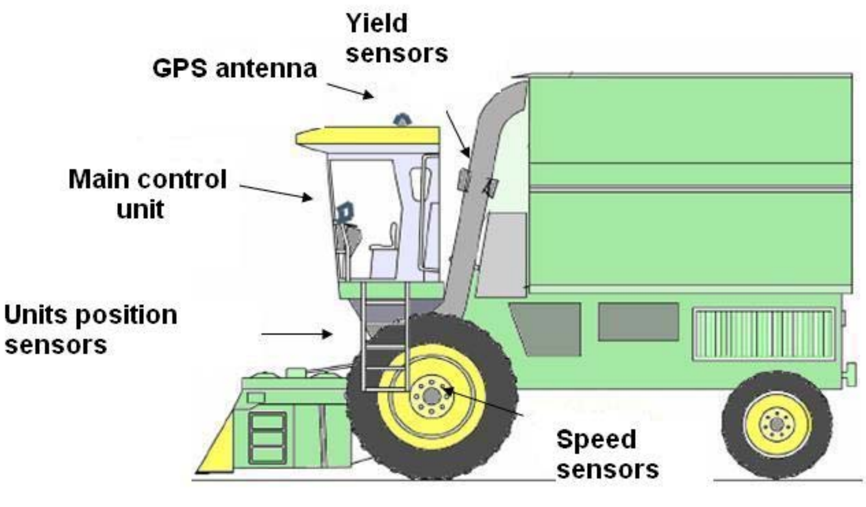

Fig. 1. Cotton Yield Mapping system

The central unit gathers and stores the sensor data every 2s and shows them on a LCD display in a form of current yield, average yield, harvested area and estimated weight in the basket. The cotton sensors are measuring the volume of cotton flow through air ducts from the picking point to the basket of the machine. These sensors fitted on the air ducts consist of a transmitter of infrared light beam and an opposite receiver measures the incident light (Wallace, 1999). Using a calibration factor the system converts the volumetric flow to mass flow

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of cotton every moment. This calibration factor depends from the cotton variety and the cotton moisture content In each field a new calibration factor must be calculated.
Auxiliary signals from a speed sensor are also sensed. Logged data were a combination of geographical coordinates of the spot of cotton picker, with speed and yield at the same point. All data were stored in a memory card. A height of the drum sensitive switch stopped recording the data when the picker units were not picking cotton. After harvesting the yield data were transferred to computer were using a GIS software yield maps were generated.
In the Spring of 2005 a VERIS machine was used to form soil ECa maps at two depths 0-30 cm and 0-90cm for the three fields. The VERIS machine (Fig. 2) is consisted of a sensor cart with four vertical disks mounted on it. Using different spacing between the disks the soil electrical conductivity at different depths can be measured. A DGPS connected to the recording unit permits the spatial recording of the soil ECa. The machine was pulled through the field at a speed of 7 km/h and every 4 m with recording every 1 s.

Fig 2. EC mapping with Veris

Plant height and plant density were also measured in a grid of 20x20m in August of 2005 for each field. The positions that the measurements were taken were geo-referenced in order to make the maps.
Statistical Analysis and mapping was carried out using the GIS program SSToolbox (Version 3.5 SST Development Group, Inc). All maps created using kriging in a 2x2m grid.

Results and Discussion

The results for yield mapping and ECa for Apothiki field are presented on Fig.3. It can be seen from the yield map (left) that the field could be divided in two zones. The northern part of the filed had higher yield than the southern. This is due to the different soil types of the field. The soil of the northern zone was holding more water than the soil of the southern zone. In 2005 the weather was dry and the northern part of the field took advantage of this extra soil moisture and had higher yield. Also in the ECa maps (centre and right) it can be seen that the northern zone had higher Shallow and Deep EC from the southern zone and this perhaps is another reason for the better yield in this part of the field.

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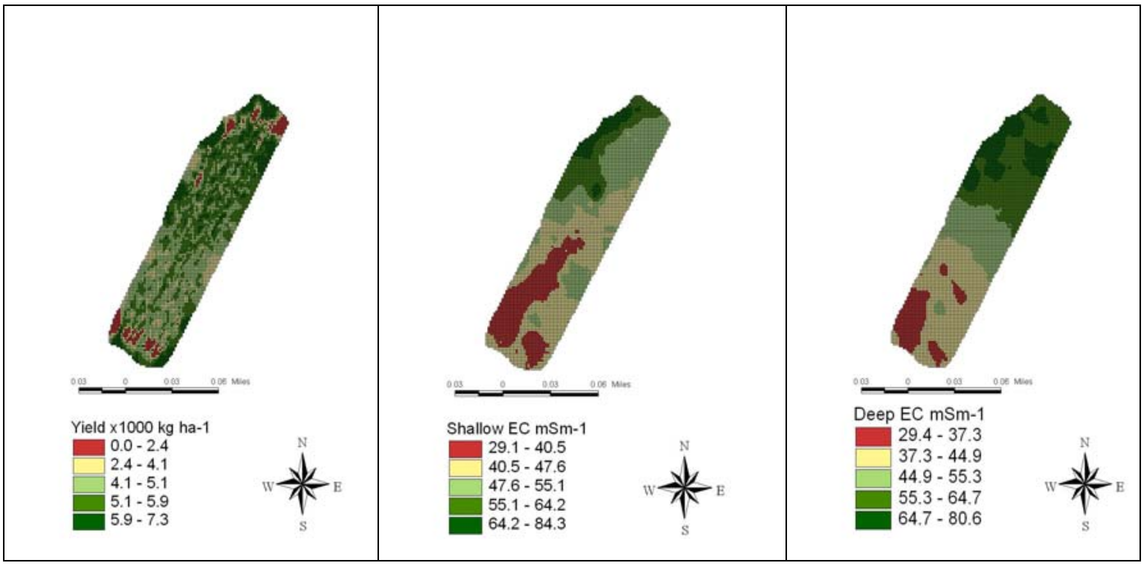

Fig 3. Maps for Yield (x10^3 kg/ha), Shallow ECa (mS/m),0-30cm depth and Deep ECa (mS/m), 0-90cm depth, for Apothiki field.

In the yield map for the Vasoula field there were three different zones (fig 4).Two narrow zones in the north and the south of the field with low yield and a third zone that includes the rest of the field which had high yield. The reason for the low yield in the south part of the field is that the soil type was different and did not hold moisture for the plants. The different soil type can be seen from the Veris map and especially for the shallow ECa map (Fig. 4. Also at the east boundary of the field there is as small strip with low yield. This part of the field was sloppy and did not keep the necessary moisture for the plants. Probably for this reason the plant height was also low in this area as shown in Fig 6.

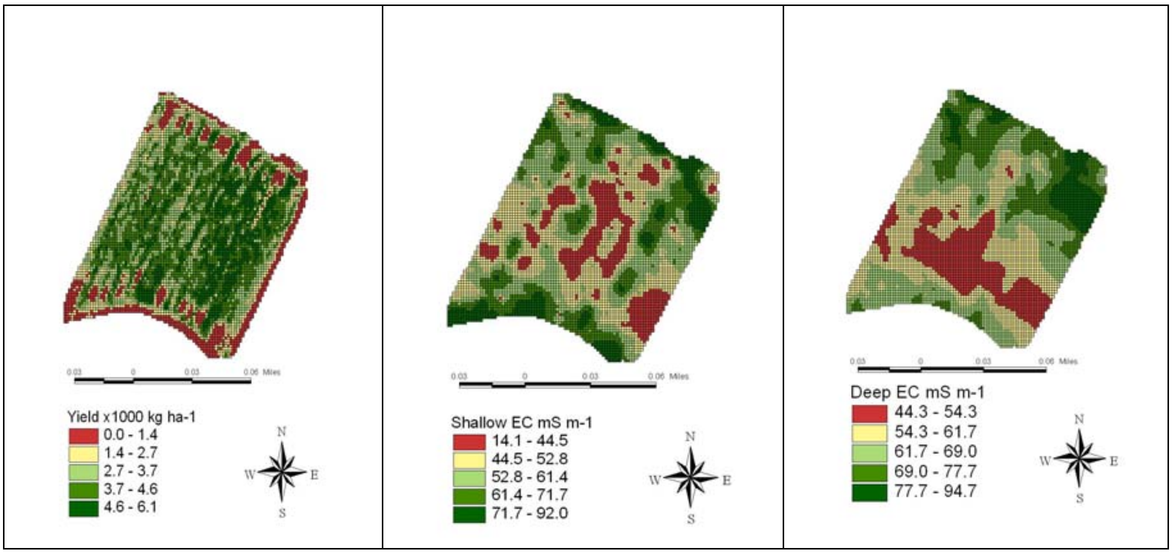

Fig 4. Maps for Yield (x10^3 kg/ha) left, Shallow ECa(mS/m) centre,0-30cm depth and Deep ECa(mS/m) right, 0-90cm depth, for Vasoula field.

The yield and ECa maps for Foulouli field are presented in Fig. 5. This field was irrigated with two different methods, sprinkler irrigation with small sprinklers in the western part and gun-sprinkler traveller irrigation system in the rest of the field. The yield map shows that the part of the field that irrigated with small sprinklers had higher yield from the rest field. It seems that irrigating with small sprinklers is more efficient than gun-sprinkler traveller irrigation because the distribution of the water in the soil is more uniform. In the northern and the southern border of the field the yield was low due to the border effect.

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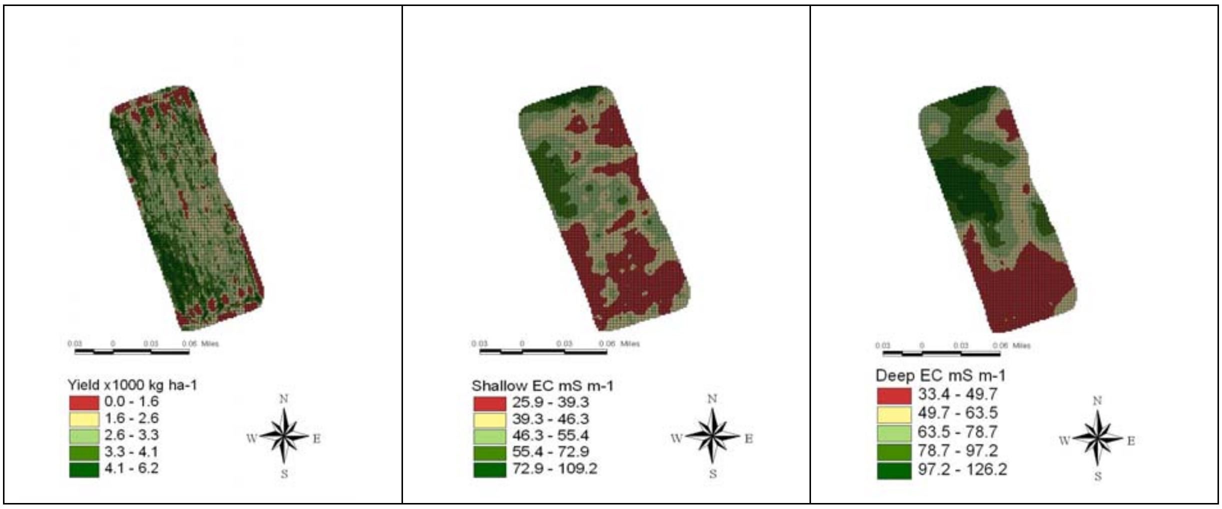

Fig 5. Maps for Yield (x10^3 kg/ha) left, Shallow ECa(mS/m) centre,0-30cm depth and Deep ECa(mS/m) right, 0-90cm depth, for Foulouli field.

Plant height varied from 67 to 104 cm Apothiki and Foulouli field and from 45 to 93 cm in Vasoula field (maps are presented in Fig. 6). Plant height did not affect yield, probably because plants were sprayed with plant growth regulators which decreased plant growth and did not let plants to get too high and therefore there was no competition between vegetative and reproductive growth. The 2005 year was a high yielding and therefore there was uniformity in the crop characteristics.

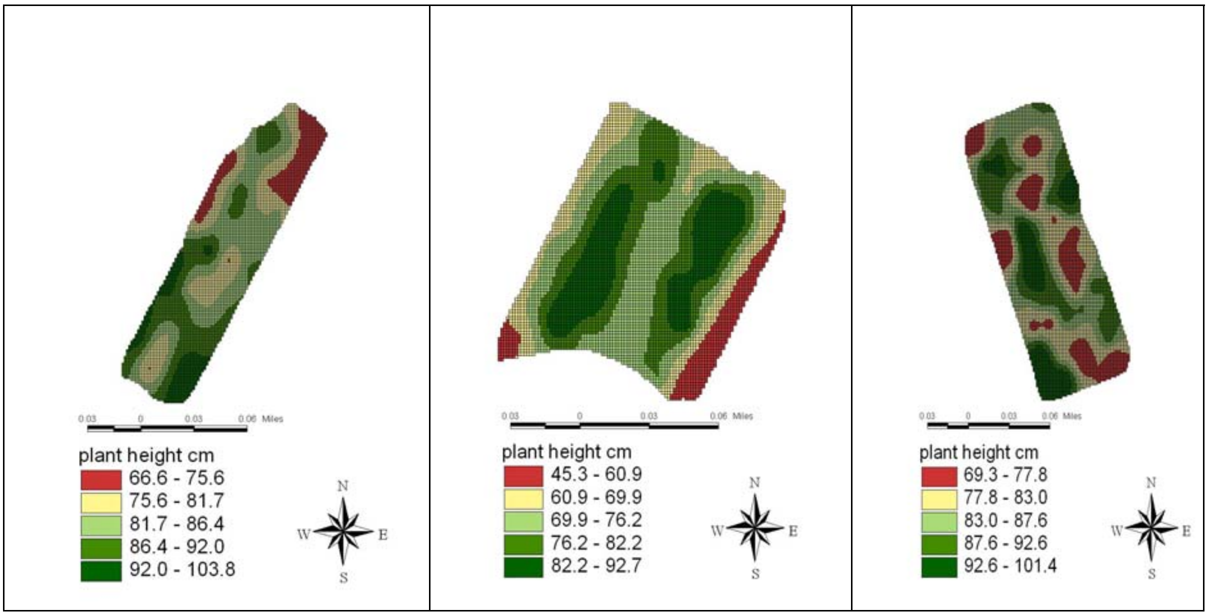

Fig. 6 Maps for plant height (cm), for Apothiki field (left), Vasoula field (centre) and Foulouli field (right)

Plant density varied from 7 to 16 plants/m for Apothiki field, and from 6 to 14 plants/m for Vasoula and Foulouli field. The between row spacing for cotton crop was 1m and therefore the plant density was 7-16 plants/m2 for Apothiki, and 6-14 plants/m2 for Vasoula and Foulouli field. Plant density was satisfactory and did not affect yield in any of the fields. Cotton is a crop which can regulate its growth and compensate for efficient plant densities. It is known to produce well from 5 to 25 plants/m2 although an optimum of 10-14 plants/m2 is well accepted for Greek conditions.

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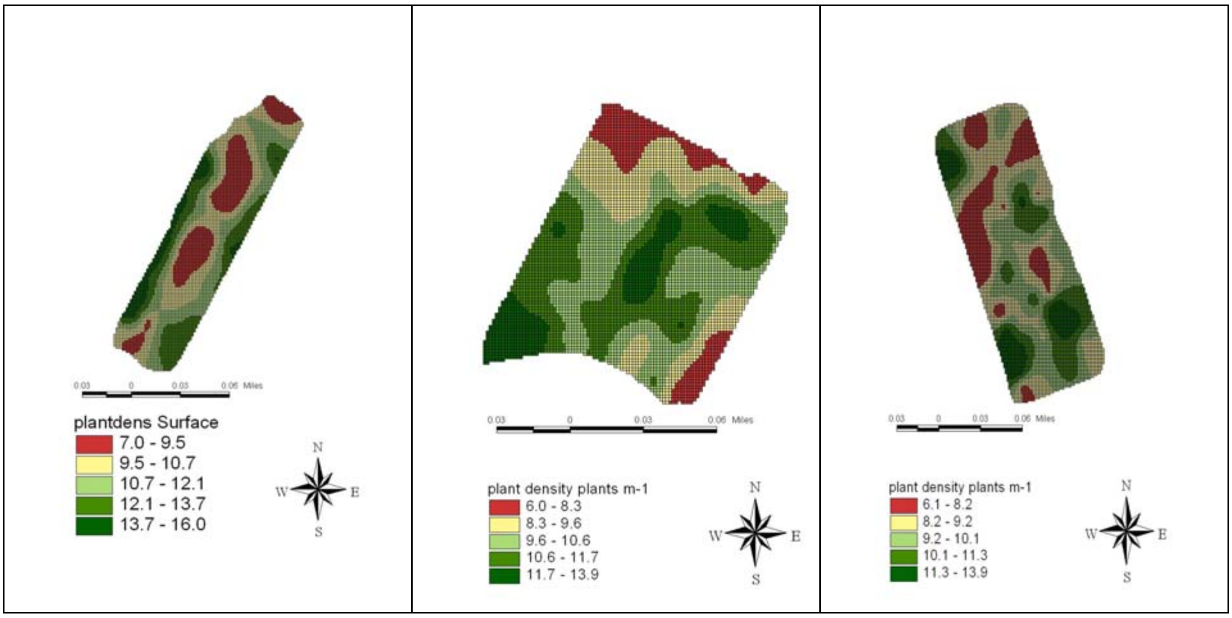

Fig 7. Maps for plant density (plants/m), for Apothiki field (left), Vasoula field (centre) and Foulouli field (right)

Conclusions

The main findings of this study can be concluded in the following:

- There was a high variability in yield and ECa for the three under study fields, which complies with previous work in PA in cotton in Greece
- ECa was not directly correlated to yield, but it can be a very useful tool to delineate management zones for targeted soil sampling
- Plant height and density were not correlated with yield mainly due to the uniformity of the plants as this was a high yielding year

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