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## Precision Agriculture Applications in a High Density Olive Grove Adapted for Mechanical Harvesting in Greece

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### Abstract

Worldwide olive production recently has undergone major changes in terms of harvesting technologies and planting densities. A new educational, research and exhibition olive grove was established at Perrotis College, Greece in 2010 to evaluate new production systems under a variety of planting densities and major input treatments for two of the most commonly used olive varieties globally, under high density planting systems adapted for mechanical harvesting. Precision agriculture practices were used in this olive grove, to identify possible “zones of variation” for yield, crop reflectance using the handheld GreenSeeker® NDVI sensor and for soil moisture and electrical conductivity. The results are presented herein for the second year after planting and they indicated distinctive zones of variability for the measured characteristics. These zones will be considered and further validated in the current season, to provide alternative management practices for optimization of olive production and combined with additional soil and agronomic parameters.

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### 1. Introduction

Olive production in Greece and Mediterranean climate countries is an essential part of daily diet and traditional agricultural practice for centuries. One solution to create enough olive products to meet the increasing demand, since the area of planting and adaptation is limited to Mediterranean and similar climatic conditions, is to increase the planting density of trees per unit of land. A major problem of olive production is the high cost of harvesting which is

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almost entirely done manually and accounts for over 85% of the total production cost. New systems of mechanical harvesting in linear systems of high density appear the last decade and are under evaluation in olive producing countries.

The mechanical harvesting has brought many changes to the way that the olives are harvested. The most important is the significant reduction on harvesting cost that dominates olive production. According to Ravetti and Robb a large number of olive producing countries have adopted the modern mechanical harvesting and also tried to improve any issues concerning the mechanical harvesting systems which are used for harvesting high density olives. More specifically, they stated that both, harvesters' manufacture industries and farmers of the above mentioned countries are rapidly changing their methods of harvesting as well as the agricultural practices that are used for the olive tree's growth [1].

Precision agriculture (PA) methodologies and technologies consist currently the most reliable and cost effective approach for simultaneous sustainable environmental management and efficient crop and animal production. Very recent development in sensory technologies and the significant reduction of their costs, allow more users to benefit from applications of PA. In addition to research and management uses, the educational benefits of PA are more than apparent and are extensively used in Perrotis College, being the only currently educational institution to award a B.Sc.(Hons) in the Precision Agriculture pathway [2].

The Normalized Difference Vegetation Index (NDVI) concept is used for evaluation of many soils and crop attributes and with the development of higher accuracy and resolution models it became a common use in very recently. Gomez et al. [3] reported on olive crown transmittance and Leaf area Index (LAI) of individual olive trees evaluation using spectral vegetation indices such as NDVI, renormalized difference vegetation index [RDVI], simple ratio index [SR], modified simple ratio [MSR] yielding better correlations with CASI images,  $r^2$  in the range 0.71 to 0.75 ( $P < 0.0001$ ) and 0.57 to 0.62 ( $P < 0.0001$ ) for crown transmittance and LAI, respectively. These methods enabled to obtain maps of biophysical parameters in olive trees at farm scale in an operational way demonstrating the validity of the methodology used.

YanYun et al. used NDVI to evaluate soil organic matter (SOM) and they concluded that for the study area as a whole [mobile dunes (MD), flat dunes (FD), grassy sandy land (GSL), flat sandy bedrocks (FSB), and swamps and salt lakes (SW0)] the FD, GSL, and MD, SOM was found to be the sole function of NDVI, whereas, for the FSB, SOM was influenced by several intrinsic variables, namely ground surface altitude, slope, and aspect, as well as NDVI [4].

Guilen et al., used physical models and multispectral airborne imagery and reported that the reflectance simulations conducted as a function of the orchard architecture confirmed the usefulness of the modeling methods for this heterogeneous olive crop, and the high sensitivity of the NDVI and Intercepted Photosynthetically Active Radiation (fIPAR) to background, percentage cover, and sun geometry on these heterogeneous orchard canopies [5].

The overall objective of the project is to evaluate in a long term the effects of various treatments on the olive yield and other agronomic characteristics as well as on the olive oil quality and economics of the various systems established. The specific objective of the present study is to apply principles of precision agriculture by implementing simple and friendly use sensors, to provide a more close insight into the systems characteristics and evaluate significant crop and soil parameters affecting growth and yield of olive trees grown under much higher planting densities from the conventional plantations.

## 2. Materials and Methods

A long term olive grove was planted in late 2010 to be used in research, education and demonstration at two locations in Greece (at Perrotis College campus, Thessaloniki and at Kolhiko, Langkadas). This study represents currently the only comprehensive and integrated long term research project in Greece, evaluating a large number of crop-soil-climate conditions for the new systems of high and super-high planting density olive production for mechanical harvesting. The experimental design includes two of the most commonly used varieties in linear systems for mechanical harvesting (Arbequina and Koroneiki), under three planting densities (500, 1000 and 1670 trees/ha) and at two fertility rates (conventional and 50% less) and two irrigation rates (conventional and 50% less). Data on some soil properties (soil moisture and apparent electrical conductivity) and agronomic characteristics (crop reflectance using the NDVI concept) measured in early March 2013 are presented.

Results in this paper are presented from one location only (Perrotis College), due to partial damage from frost in the second location. This year, the olives at the above location will be harvested mechanically in late December 2013, using the olive-grape harvester shown in Figure 1, except for the 4 replication trees from each treatment which will be harvested manually and timed.

Measurements with the Green Seeker (Figure 2) for NDVI (Normalized Difference Vegetation Index) and the ProChek and 5TE sensor (Figure 2) for soil properties were used to establish the digital maps shown in Figure 3 (NDVI) and Figure 4 (soil properties). Data on NDVI and soil moisture and ECa were collected from all 264 trees planted.



Figure 1. The straddle type mechanical harvester (Model Gregoire G120) to be used for mechanical harvesting in this study in December 2013.



Figure 2. The Green Seeker® and the ProChek™ datalogger and 5TE sensor used to measure NDVI and soil's Volumetric Water Content (VWC), Apparent Electrical Conductivity (ECa) and temperature, on the base of each olive tree.

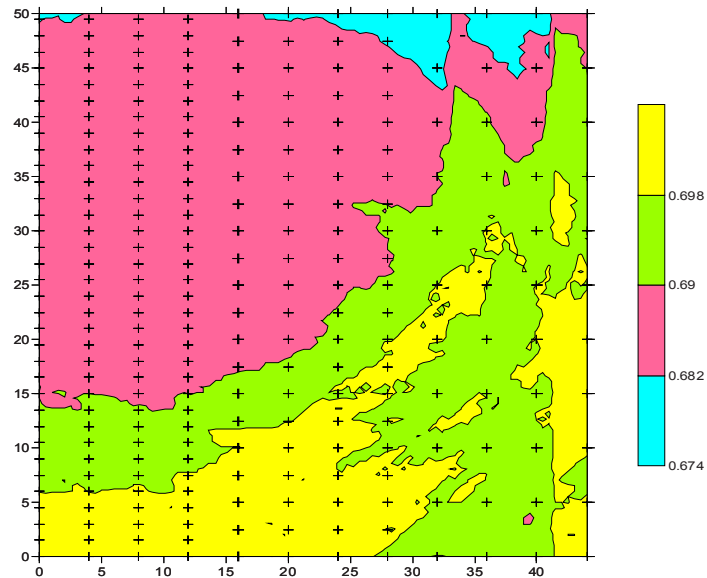


Figure 3. The NDVI variability map of the olive grove. The coordinate system used shows the planting arrangement (represented by the + symbol) and spacing between rows and in the row planted trees.

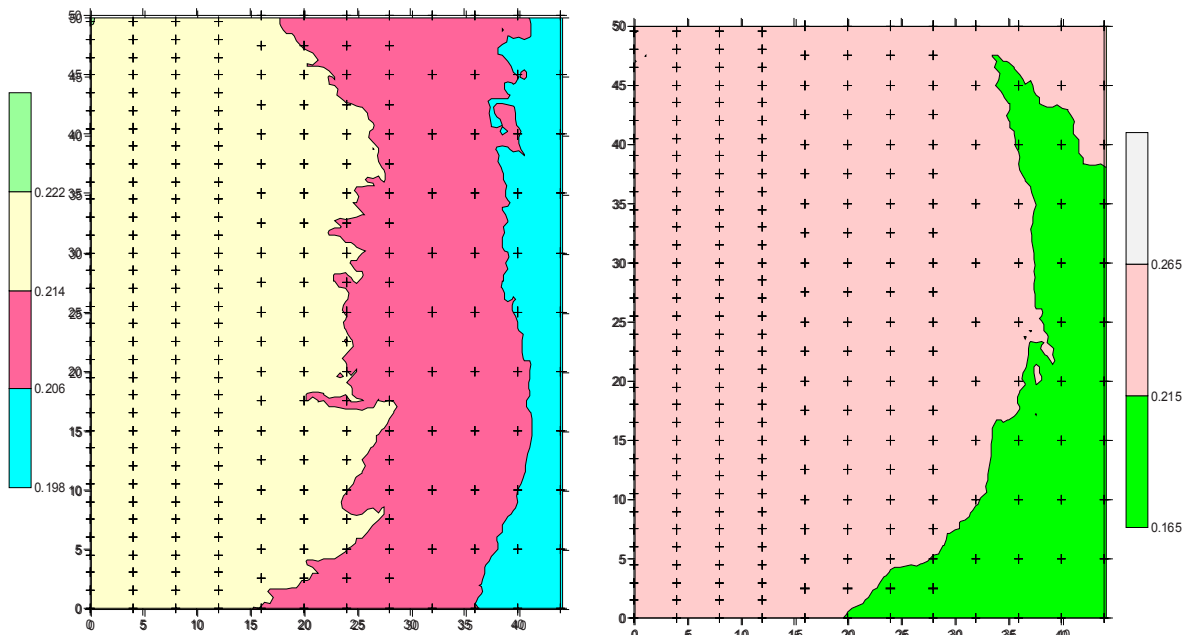


Figure 4. The Volumetric Water Content (VWC) in left and the apparent Electrical conductivity (ECa) in the right side of the olive grove.

### 3. Results and Discussion

Preliminary results on cold tolerance from the first two years of planning indicated some significant differences between the two varieties and across the two diversely different soil-climate experimental locations [6]. Also, last year's preliminary first yield data evaluation showed numerical differences only differences for the two varieties [7]. The yield was very small in this year, ranging from 0 to 700 g/tree) and therefore can not be considered for

evaluation. It is expected that this season's yield data will be significant to establish reliable relationships with measured variables in the soil-plant system.

New measurements were taken recently (March 2013) with the GreenSeeker®, sensor [8], at two points-directions (from East and West side of the olive tree canopy) and mapped using a mapping software. The 264 points were mapped and indicated three distinctive zones of NDVI variability, hypothesized to be caused by the direction of the soil's slope and drainage (Figure 3). The slope on this soil is about 2-3% from East to West (about 45°). When soil moisture and apparent soil's electrical conductivity was measured at the same time of NDVI measurements, the same trend in variability zones was shown and it appears to validate the previous hypothesis, (Figure 4). The same measurements will be taken again in the middle of the 2013 growing season and in late season, before harvesting, to further evaluate the existence of the reliability zones and to correlate with yield potential. Michaloudis used PA principles to report a simple "potential yield" model to be used in the middle of season to evaluate the "actual yield" of olive trees [7]. This model will be further evaluated during the coming growing season.

#### 4. Conclusions and Recommendations

The knowledge database established last and early this year, will be coupled with the first significant yield data of this year (expected December 2013) in order to identify areas for crop improvement. The results on important soil and crop characteristics measured, indicated that there was a variability which needs to be validated with yield characteristics. Precision agriculture methodologies appear to be very useful in optimization of production management and will benefit the overall evaluation of these new olive production systems under high density plantings.

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