65 години

Аграрен университет - Пловдив, Научни трудове, т. LV, кн. 1, 2010 г.
Юбилейна научна конференция с международно участие
Традиции и предизвикателства пред аграрното образование, наука и бизнес
Agricultural University - Plovdiv, Scientific Works, vol. LV, book 1, 2010
Jubilee Scientific Conference with International Participation
Traditions and Challenges of Agricultural Education, Science and Business

"DIGITAL PRECISION AGRICULTURE": A SOFTWARE FOR SUSTAINABLE MANAGEMENT OF AGRO-ENVIRONMENTAL SYSTEMS

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Abstract

"Digital Precision Agriculture" is a software product resulted from a recent research program, undertaken under the Poles of Innovation of Central Macedonia, in Greece. The software provides valuable information to farmers, consultants, students and other end-users for efficient and sustainable soil and crop management and for minimizing adverse environmental effects caused by conventional management practices. It considers and maps the soil-plant system variability and establishes optimal and integrated management zones (IMZ), based on important soil and plant properties affecting yield and soil fertility. The program can be used under almost any crop production system either field crops. Currently, the input information required to run it, includes soil texture, soil organic matter, soil reaction (pH) and soil electrical conductivity (EC). It uses ArcGIS® as the running platform and provides as output "Integrated Management Zones" of all the above four properties.

The principles and approaches of Precision Agriculture were integrated in the program which is directly compatible with the forthcoming legislation on the reformed Common Agricultural Policy (CAP) and with the climate change. Demonstration results from case studies are presented in this paper. The software is under further development, to include a larger database and more soil-crop-climate properties as input variables and to be transferred and run under other GIS systems.

Key words: *Precision Agriculture, management zones, GPS, GIS, soil electrical conductivity, soil pH*

INTRODUCTION

Modern management practices for agro-environmental systems demand compilation of multiple kind of information in the entire continuum "soil-plant-atmosphere" in order to provide the most effective and sustainable decisions. Cutting-edge technology is becoming a cornerstone of any contemporary management system and new developments greatly facilitate decision making and best management practices to be applied.

Precision Agriculture (PA) is also termed Precision Farming or Site Specific Management Agriculture in literature, is a set of management practices and cutting edge technologies used to identify soil and crop variability in space and provide optimum crop and soil management practices per uniform unit areas established known as management zones. Current use of technologies is rather complicated and expensive for use by single farmers or even small groups. However, latest developments in technology and friendlier use of equipment (sensors and data loggers) coupled with related software, enable the use of PA techniques by more end users. In addition, the cost of all above has significantly reduced in the last 10 years and continues to further decrease and so it becomes available to more and diversified end users including farmers.

Educational aspects of this approach are also emphasized and case studies are presented in this paper to demonstrate that simple technologies can be used efficiently enough to provide better management of crops and soils, using the principles of PA, resulting in a more sustainable use of soil, water and crop resources. The PERROTIS COLLEGE (a partner educational Institution validated by University of Wales Institute Cardiff) is currently the only educational institution in Europe and globally, offering a B.Sc. (Hons) degree in "Precision Agriculture" pathway. Therefore the development of this software is an added value to our educational program.

The lack of software to integrate basic and easily measured soil properties that affect crop growth and productivity is a gap in the area of PA. An existing model, "Management Zone Analyst" (Fridgen et al., 2004) does not offer the capability of integrating properties to establish MZs and it can be used to provide basically number of MZs. This software program was developed using a "clustering analysis" procedure to create management zones. The program is called Management Zone Analyst (MZA) and is available free to the public at http://www.fse.missouri.edu/ars/decision_aids.htm. MZA was developed using Microsoft Visual Basic 6.0 and operates on any computer running Microsoft Windows (95 or newer). An advantage of MZA over many other software programs is that it provides concurrent output for a range of potential management zones so that the user can evaluate the number of areas into which a field should be partitioned. It was used to delineate MZs of nematodes by Ortiz et al. (2007). Other approaches to delineate MZ's were used by Mzuku et al. (2005) and Taylor et al. (2003); however no integration was provided for a number of critical soil properties.

DIGITAL PRECISION AGRICULTURE® (version 1.0 - DPA) is a software developed under a 2-years research program funded by the acknowledged agencies (www.innopole.gr) and leaded by Dr. A. Gertsis, in Hellas (Greece) with the objective to provide valuable integrated information and guidance to farmers, consultants, policy makers, researchers, students and other end-users for efficient and sustainable soil and crop management. INFODIM S.A. a partner of the project, has compiled the software.

MATERIALS AND METHODS

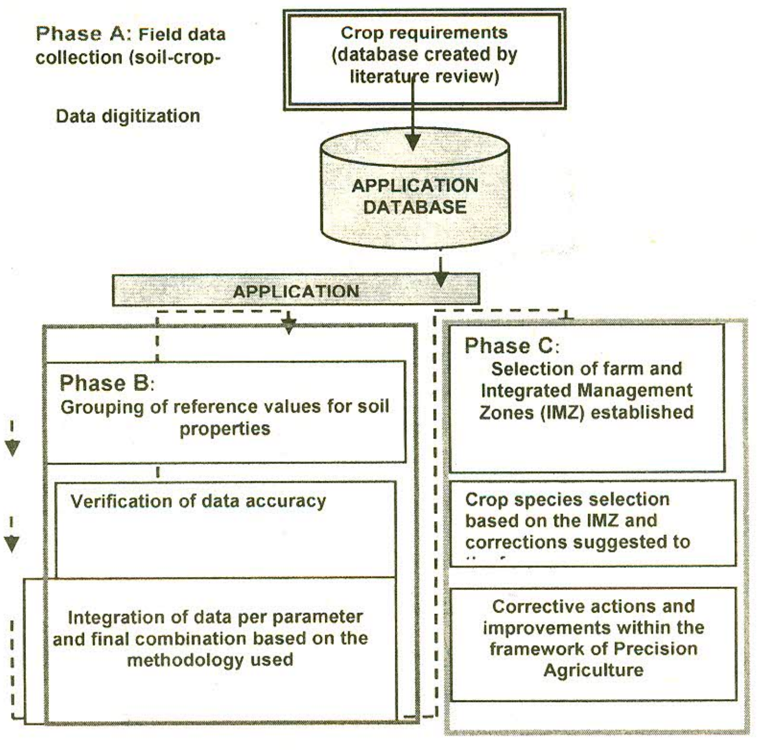
Model description

The software receives inputs on fundamental but easily measured soil properties affecting crop growth and yield, taken in a substantial number of points per farm site. Currently the model accepts data on: pH, SOC, EC, soil texture, rainfall, and temperature and crop yield. It outputs integrated digital maps of relative homogeneous Management Zones (MZ) of the input soil properties, which can be used for optimization of Input Use Efficiency (IUE) and therefore provide higher income and cause less adverse environmental effects.

The current version of the model considers the variability of the soil system and provides an integrated methodology to weigh each parameter measured, in order to provide the "integrated management zones" and a map of each field. Also, the model provides a basic output about the suitability of the cultivated plant species for each field along with the "best alternative scenario" for the alternate crop best adapted under the specific soil-weather conditions.

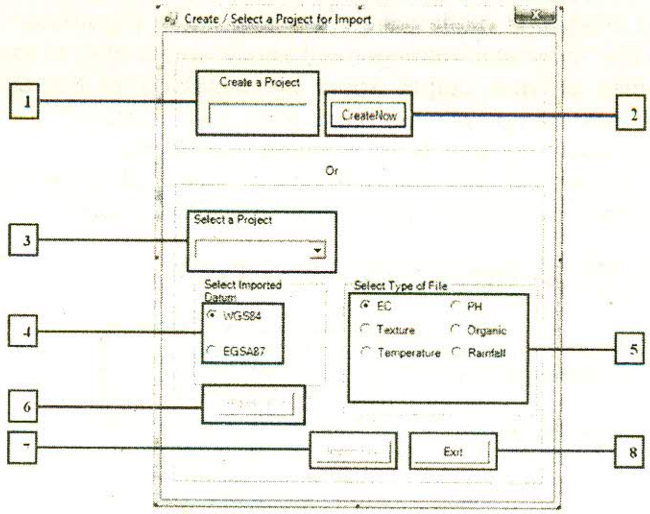
Figure 1 shows the conceptual model on which DPA was based and the fundamental procedures and steps applied for model construction.

Figure 1. The conceptual model of the software.



The model was embedded in the ArcGIS® format and is running (needs installation) under this program. In a next phase of this research an autonomous program or a less expensive or free-domain GIS package will be used to run it, so that it could be more broadly used and under less restricted conditions. Figure 2 shows the main (entrance) menu of the software, where the user starts the creation of each project for each field, and enters the associated information files.

Figure 2. The entrance menu of the DPA



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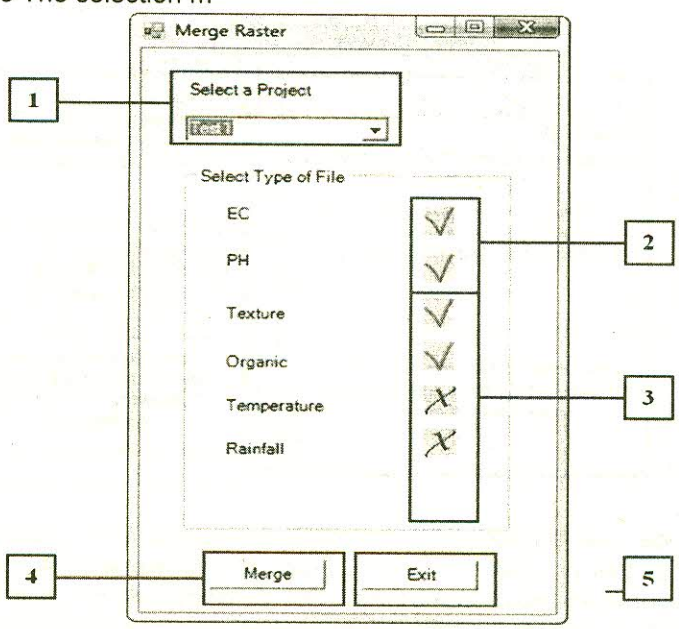


Figure 3. Some input information on the selected project (crop species grown, soil info, etc.)

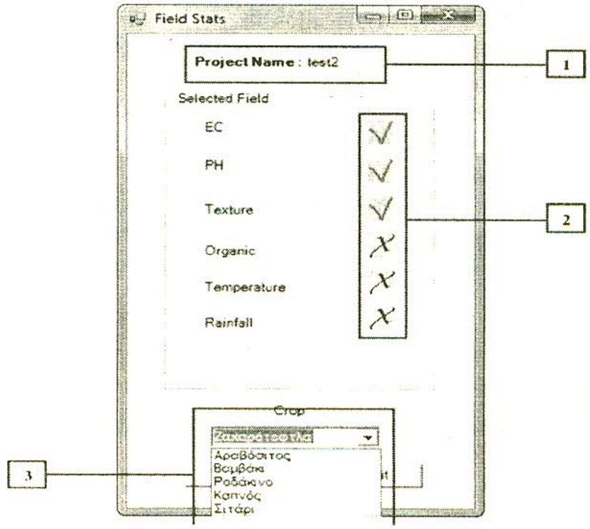
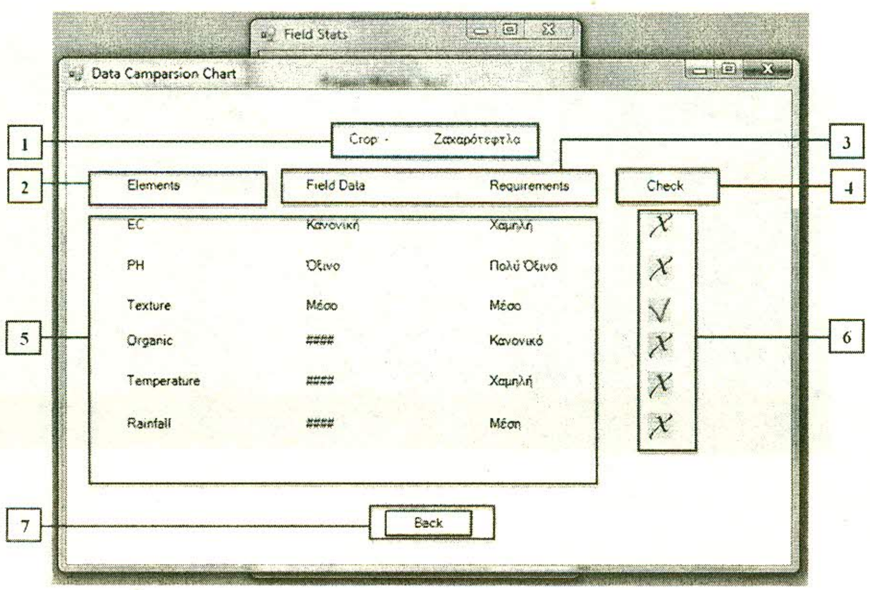


Figure 4 shows the compiled results from the specific field and crop species grown and checks for appropriate conditions by matching the crop and soil requirements for this crop species. The available database will be enhanced and upgraded with more cultivated crop species and their specific soil and climate requirements.

Figure 4. The menu for data compilation and appropriateness conditions for the grown crop species.



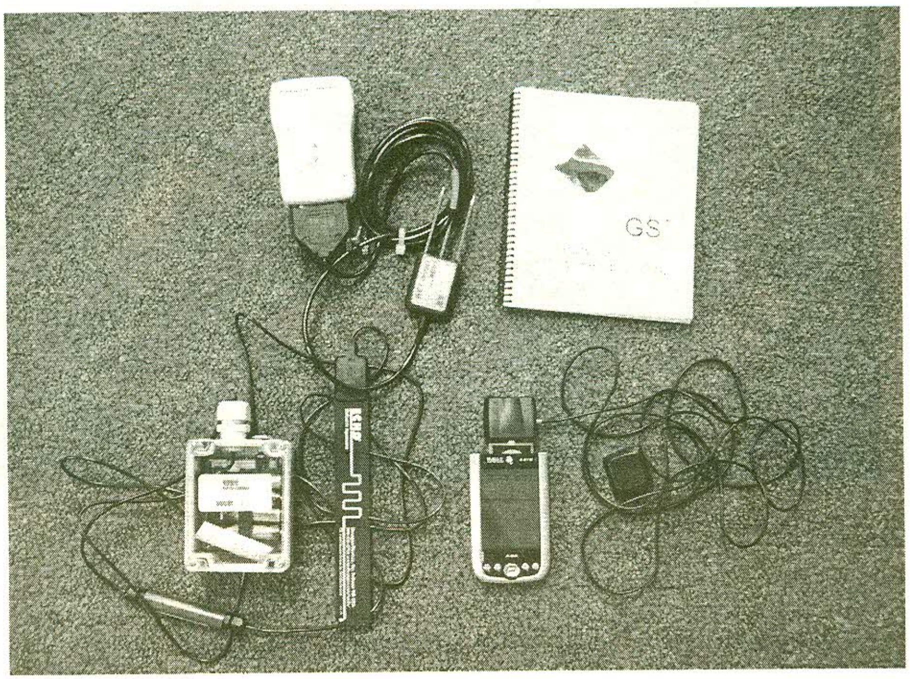
Equipment used for data collection and input.

In this study the VERIS® 3100 system was used for mapping soil's Electrical conductivity. Figure 5 shows the systems in the AFS study field and Figure 6 shows a set of the portable equipment used to measure soils properties, such as soil surface volumetric water content, electrical conductivity and a PDA equipped with a GPS for mapping the measurement points. The VERIS 3100® system generates two sets of maps, a topsoil map from 0-12" (30 cm) and one of the soil profile 0-36" (91 cm). While uses vary, the top layer is often used for soil sample site selection, and the deeper map for variable rate populations and nitrogen management (http://www.veristech.com). The second map of the deeper soil is a more integral type and can be used for further analysis along with soil water infiltration and drainage data.

Figure 5. The VERIS® 3100 system coupled with a GPS and joined in 4X4 car for measurements of soil's apparent electrical conductivity at 30 and 90 cm depths in the AFS study field.

Additional and portable equipment used for data collection, include the WET sensor and the HH2 data logger, mini programmable weather stations, GIS and geostatistical software for data analysis, PDAs equipped with field analysis software and GPS receivers and are collectively displayed in Figure 6. These equipment are monitoring mainly the surface soil properties (0-15 cm) such as volumetric water content, apparent soil electrical conductivity and soil temperature and can be used for quick assessment of the variability of these properties in the field and the mapping of corresponding properties. Additional programmable and continuous monitoring of weather data collecting equipment were used and are available for research and teaching uses in Perrotis College.

Figure 6. A set of sensors, data loggers, software used for soil and GPS data acquisition and analysis.



RESULTS

Figure 7 shows the produced map and the two IMZs in different colours. The particular field had a slope and an increased soil electrical conductivity in IMZ#1, which consistently produces lower in yield partially because the higher soil EC.

Figure 7. The map output of DGA from the AFS Campus case study.

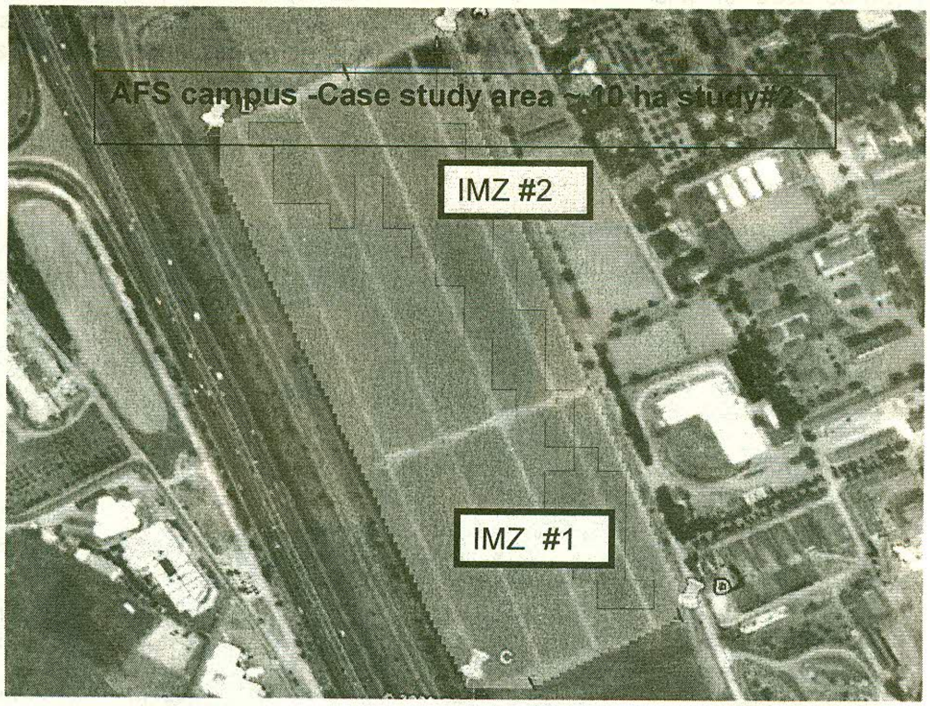
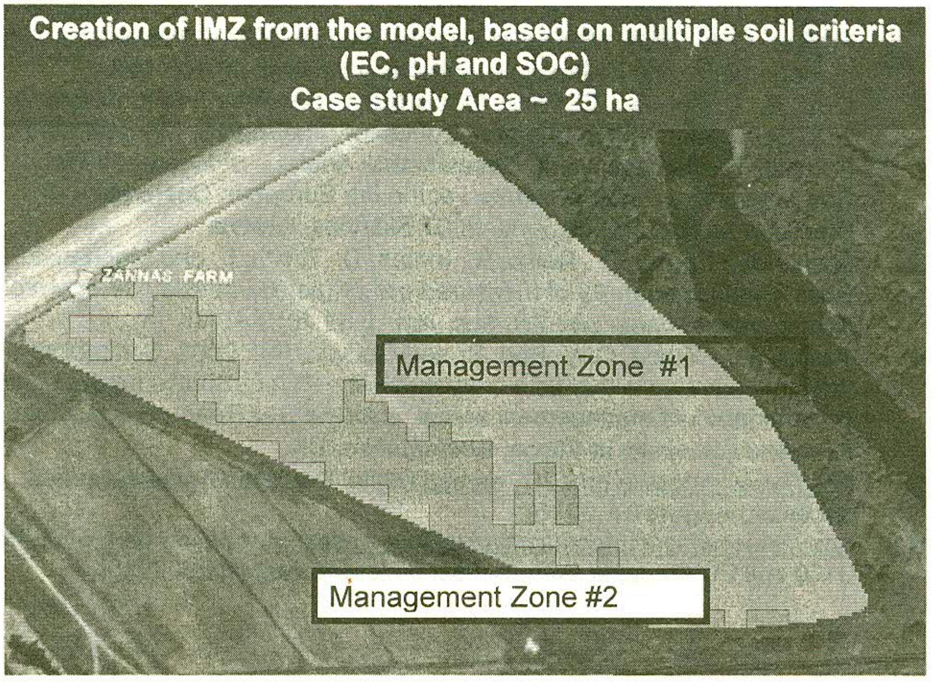


Figure 8. The IMZs produced for the Zannas Farm location.



DISCUSSION

The software is used to establish optimum Integrated Management Zones based on multiple criteria on the entire Soil-Plant-Atmosphere Continuum (S.P.A.C.). It was developed based on principles of Precision agriculture and offers a friendly user tool to establish IMZ's where the appropriate inputs could ne used for improved efficiency and sustainability.

The software can be used by environmental and farm consultants to assist farmers in their management and also it can be used as an educational tool for teaching Precision Agriculture approaches and for a number of related courses. Further development of the DGA program is expected to provide a friendlier working environment, additional features and extended crop and soils databases.

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ACKNOWLEDGMENTS

This project was equally funded by the Perrotis College (American Farm School at Thessaloniki –Hellas, www.afs.edu.gr), INFODIM S.A. (a partner of this project) and the General Secretariat for Research and Technology through the Hellenic Ministry of Development and the European Commission (3rd Community Support Framework operational programme "Competitiveness").

Also, the kind offer by Dr. Michalis Papaeconomou (www.agrology.eu) of the VERIS® 3100 system for use in this study is sincerely appreciated.