"DIGITAL PRECISION AGRICULTURE", a Software to Manage Soil Information for Establishment of Integrated Management Zones

A. Gertsis

Perrotis College, American Farm School, P. O. Box 23, GR 551 02, Thessaloniki, GREECE , agerts@afs.edu.gr

ABSTRACT

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 a set of management practices and cutting edge technologies applied to identify spatial and temporal soil and crop variability and used to provide optimum crop and soil management practices by providing precicely inputs per iniform unit areas established and known as management zones (MZ). The lack of a commercial or research software to integrate basic and easily measured soil properties that affect crop growth and productivity is a gap in the area of PA. A software was developed through a field research project to attempt establishment of Integrated Management Zones (IMZ), which include simultaneously more than one soil properties. The model requires inputs from fundamental but easily measured soil properties affecting crop growth and yield taken from sampling an appropriate number of points per farm. Currently the model accepts data on four soil properties: pH, soil organic carbon (SOC), electrical conductivity (EC) and soil texture. 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" (IMZ) and a map of each field. This paper describes the overall conceptual model used to build the software and provides some case studies applications in fields. Educational aspects of this technology are also important for increasing the efficiency undesrtansding dynamics involved in biological systems management.

INTRODUCTION

Management decisions 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 solutions. 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), also termed Precision Farming (PF) or Site Specific Management (SSM) in literature, is a set of management practices and cutting edge technologies used to identify spatial and temporal soil and crop variability and to provide optimum and precisely crop and soil management practices per uniform unit areas established, generally known as management zones (MZ). Current use of technologies is still and in most cases, 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 was significantly reduced in the past five to ten years and continues to further decrease and therefore, it becomes available to more and diversified end users including farmers, researchers, educators , consultants and others.

Educational aspects of this approach are also emphasized and case studies are presented in this paper to demonstrate that simple or advanced 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 with degrees validated by Cardiff Metropolitan University, UK) 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 and is used extensively the past years in education and student projects.

The lack of a commercial or research 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 more than one properties to establish MZs and it can be used to basically provide the 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, integrated zones can not be provided for a number of critical soil properties considered simulatenously.

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 based on the conceptual model and data provided by A. Gertsis.

MATERIALS AND METHODS

Model description

The model uses and requires inputs from fundamental but easily measured soil properties affecting crop growth and yield (Brady and Weil, 2008), taken from sampling a substantial number of points per farm. Currently the model accepts data on: pH, SOC, EC, soil texture. Rainfall and temperature data will be implemented in the next version of it. 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" (IMZ) and a map of each field. The critical values and ranges for each of the four basic soil properties were established based on general soil literature review (Brady and Weil, 2008) but are adjustable at the user's desire. Also, the model provides an output screen about the suitability of the plant species grown at the studied soil along with the "best alternative scenario" for the alternate crop that is best adapted under the specific soil conditions. A next version of the model is foreseen to include a weather scenario as well.

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

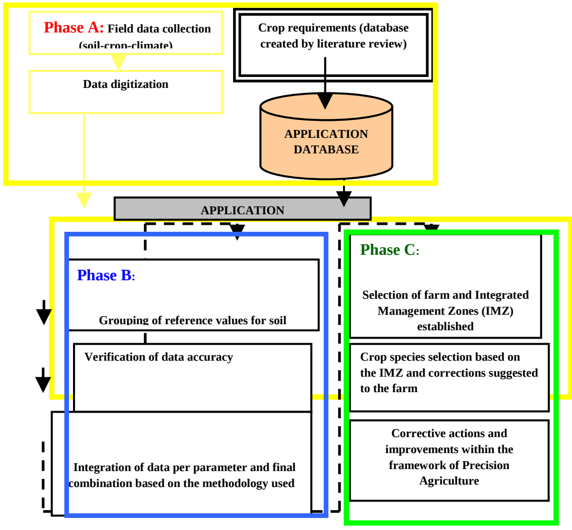

Figure 1. The conceptual model of the software.

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

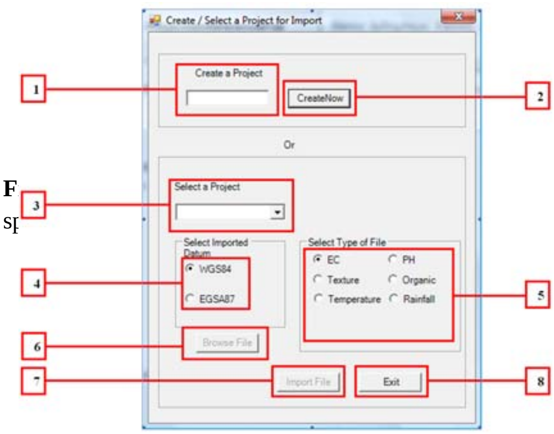

Figure 2. The initial screen menu of the DPA.

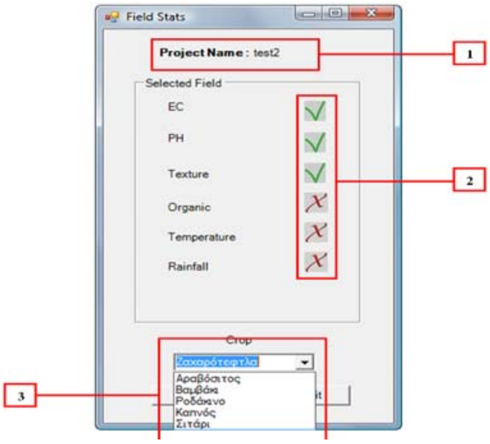

Figure 3. Some input information on the selected project (crop species grown, soil info, etc.)

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**.**

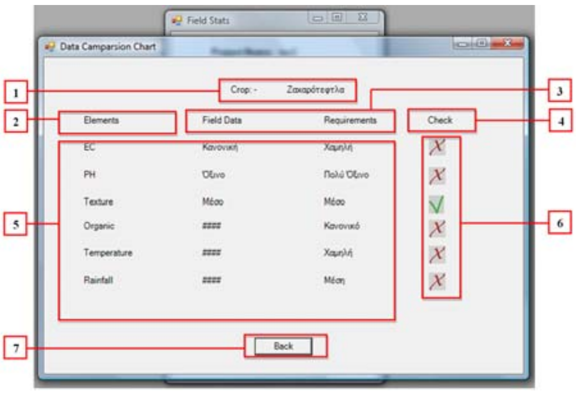

Figure 4. The menu for data compilation and appropriateness conditions for the grown crop species. Under the Field Data column, it is shown the level of each soil property and under Requirements the optimal levels of each property for the specific crop species (the words above are in Greek language).

Equipment used for data collection and input.

In this study the VERIS® 3100 system (Figure 5) (http://www.veristech.com) was used for mapping soil's Electrical conductivity. Figure 5 shows the systems in the American Farm School (AFS) campus study field and Figure 6 shows a set of portable equipment used to measure additional soil properties, such as soil surface volumetric water content, apparent electrical conductivity and soil temperature, and a PDA computer 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 (top soil EC from 0-30 cm was used in this study) for soil sample site selection, and the deeper map for variable rate applications and for nitrogen management

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 including 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 that measures volumetric soil water content, soil apparent Electrical Conductivity and soil temperatuer with the HH2 data logger (www.delta-t.co.uk) , mini programmable weather stations (http://www.onsetcomp.com) , 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.

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

Additional programmable and continuous monitoring of weather data collecting equipment (wireless Automated Weatehr Stations) were used and are available for research and teaching uses in Perrotis College.

RESULTS

Figure 7 shows the firts produced map and the two IMZs in different colours. The particular field (ca. area of 10 ha) at the AFS campus was a clay loam soil and had a slope and an increased soil electrical conductivity in IMZ#1, which consistently produces lower in yield of corn and wheat, partially because the higher soil EC. This information is used from the Farm manager to apply modified fertilization and irrigation practices, which will tend to minimize in a long-term, the salinity effect.

Figure 7. The map output of DGA from the AFS Campus case study. Creation of two IMZs from the model, based on multiple soil criteria (EC, pH and SOC). Case study Area ~ 10 ha.

In another application of the DPA software, extensive soil sampling was done in a field in Zannas Farm and an area of ca. 30 ha, located 65 km from the AFS campus. The soil is predominantly sandy loam, low in soil organic carbon and largerly variable in electricla conductivity and the results from the model are shown in Figure 8. Two distinctive IMZs were established for this field. The main soil property influencing the IMZ was again salinity, with pH having secondary effects.

Figure 8. The two IMZs produced for the Zannas Farm location. from the model, based on multiple soil criteria (EC, pH and SOC). Case study Area ~ 30 ha.

DISCUSSION

The software is used to establish Integrated Management Zones (IMZs) based on multiple soil criteria. It was developed based on principles of Precision Agriculture and offers a simple and friendly user tool to establish IMZ's, where the appropriate inputs could be 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. Emphasis in eduactional aspects is given using the holistic approach, developed in the Perrotis College, and outlined in an acronym SO.CR.A.T.E.E.S.© (Soil Crop Atmosphere Technology-Educational & Evaluation Systems), copyrighted by Dr. Athanasios Gertsis. Further development of the DGA software is expected to provide a friendlier working environment, including additional features and input variables and extended crop adaptability information databases. If the IMZ's coupled with yield maps, the results of the IMZ's can be better evaluated; therefore, it is proposed that the next version of the software to include yield maps and local weather data and extent the database for crop specifi requirements, for selection of the most appropriate crop species to be grown in each soil-climate environment

CONCLUSIONS

The first version of this software provided an integrated approach for managing soils in a more efficient mode. The results were evaluated for each location and resulted to changes in management practices. The IMZ'sestablished can be managed using commercially available precision agriculture technologies for precision fertilizer and irrigation applications. If the IMZ's coupled with yield maps, the results of the IMZ's can be better evaluated; therefore, it is proposed that the next version of the software to include yield maps and local weather data and extent the database for crop specifi requirements, for selection of the most appropriate crop species to be grown in each soil-climate environment.

ACKNOWLEDGEMENTS

The project was equally co-financed from the General Secretariat of Research and Technology, through funds of the Hellenic Ministry of Development and the European Commission (3rd Community Support Framework operational programme "Competitiveness") and the Perrotis Colege, American Farm School, and INFODIM , Greece.

REFERENCES

Brady, N. C. and R. R. Weil. (2008) The nature and properties of soils (14th ed.) Pearson Education, Inc., Upper Saddle River, New Jersey, NJ.

Fridgen, J.L., Kitchen, N.R., Sudduth, K.A., Drummond, S.T., Wiebold, W.J., Fraisse, C.W. (2004) 'Management zone analyst (MZA): Software for sub-field management zone delineation' *Agronomy Journal* 96:100-108.

Ortiz, B., D. Sullivan, C. Perry, G. Vellidis, L. Seymour and K. Rucker. (2007) 'Delineation of Management Zones for Site Specific Management of Parasitic Nematodes Using Geostatistical Analysis of Measured Field Characteristics' *Proceedings of 6th European Conference of Precision Agriculture*, 3 June -2007 Skiathos, Greece.

Mzuku, M., Khosla, R., Reich, R., Inman, D., Smith, F. and Macdonald, L. (2005) 'Spatial variability of measured soil properties across site-specific management zones' *Soil Sci. Soc. Am. J.* 69 1572-1579.

Taylor, J.C., Wood, G.A., Earl, R. and Godwin, R.J. (2003) 'Soil factors and their influence on within-field crop variability. Part II: Spatial analysis and determination of management zones' *National Soil Resources Institute*, Cranfield University at Silsoe, Bedfordshire, UK.

http://www.innopole.gr/3.2.7_en.asp Digital Precision Agriculture –Short Project description (last accessed March 1, 2012)

http://www.veristech.com/products/soilec.aspx Information on the VERIS 3100 soil EC mapping system (last March 1, 2012

http://www.delta-t.co.uk (last accessed March 1, 2012

http://www.onsetcomp.com/ (last accessed March 1, 2012)