INTEGRATION OF SOIL SPECIFIC PARAMETERS IN DESIGNING DECISION SUPPORT SYSTEM IN PRECISION AGRICULTURE

Ciprian George Pirna, Simona Lache
University "Transilvania" of Brasov, Romania
ciprian-george.pirna@unitbv.ro, slache@unitbv.ro

Abstract. Within the field of precision agriculture there has always existed the question of correctly evaluating the fertility of a certain land lot. In assessing and displaying the fertility levels of soils one typical uses fertility maps generated by GIS family software. However, current techniques and technologies only focus on the mapping of soil electro-conductivity. The paper presents the integration of soil specific parameters within GIS based mapping systems. Depending on the topography, the native soil vegetation and other parameters like the humus concentration, carbonate percentage, pH levels variation, clay concentration, the fertility of soils greatly fluctuates. Operational integration of soil specific parameters in a predesigned GIS based decision support system offers a highly accurate image of the distribution of soil fertility within a certain land lot. Using, collecting and combining readings and data from multiple sources like an outdoor sensor network, a GPS receiver, reports on soil composition from soil sampling procedures and historical data regarding the average crop yield for that land lot is the way to get a complete and exhaustive overview over the factors which have a determining impact on the productivity of a certain land lot.

Keywords: crop environmental parameters, crop division, GIS integration, decision support.

Introduction

The release of the GPS location and positioning technology by the U.S. military to the widespread civilian public has brought upon many changes in various research fields and many technologies and niche applications have been designed and developed ever since, as a support framework for the newly found research directions. Classic agriculture was no exception in this regard and the development of field machinery which had GPS support capabilities offered wide and new technological challenges. Subsequential to outfitting standard agricultural machinery with GPS receptors, the technology and the agricultural procedures advanced towards the concept of precision, thus the modern branch of "Precision Agriculture – P.A.". Field labor could now be precisely tracked by satellite and later technology advances would allow for general soil fertility mapping. As shown by Adrian et. al. (2005), the economic reason is the motivator behind the modern farmer's choice of investing into precision agriculture technology and applications [1]. Furthermore, it is stated that potential benefits of precision agriculture, which the farmers perceive, actually include reduced production costs, increased yields and environment protection [2]. As to what technological advances brought in precision agriculture, one clearly perceives three distinct development directions: satellite monitoring of mechanical field labor (with work division between multiple pieces of equipment), development of general field fertility maps and development of precision yield maps.

Problem Identification and Premises

The mapping processes (both of crop yield and of soil fertility degree) rely on data processing by means of GIS (Geographic Information System) family software. In the case of crop yield mapping, signals coming from sensors placed onto mechanical harvesters outfitted with GPS receptors are being mapped by help of the GIS software. The end result is an electronic map of the distributed yield on a certain field. By far, one of the most interesting research directions in precision is the fertility assessment of the soil before the sowing stage. The current technology relies on injecting a known voltage into the soil and then measuring the voltage drop which varies depending on many factors (different electro-conductivity of different soil components, composition of water molecules which bind the soil molecules). The in-field mapping of this significant voltage drop measuring process is dynamic and can be achieved by using a GPS receptor mounted on the chassis carrying the voltage injecting-measuring assembly – Figure 1. As in the case of crop yield mapping process, the end result of Electro-Conductivity (E.C.) – with GIS support – is an electronic map, usually stratified in a sense that it is layered and each layer can bear special, user defined characteristics. For instance, the bottom layer of the EC map usually is either a vector or a raster map and subsequently the user can add more layers with sensor readings or GPS coordinates. In essence, the classic precision agriculture technology correlates EC readings to GPS coordinates, so that the EC variation can be tracked in relation to the soil properties and the in-field position.

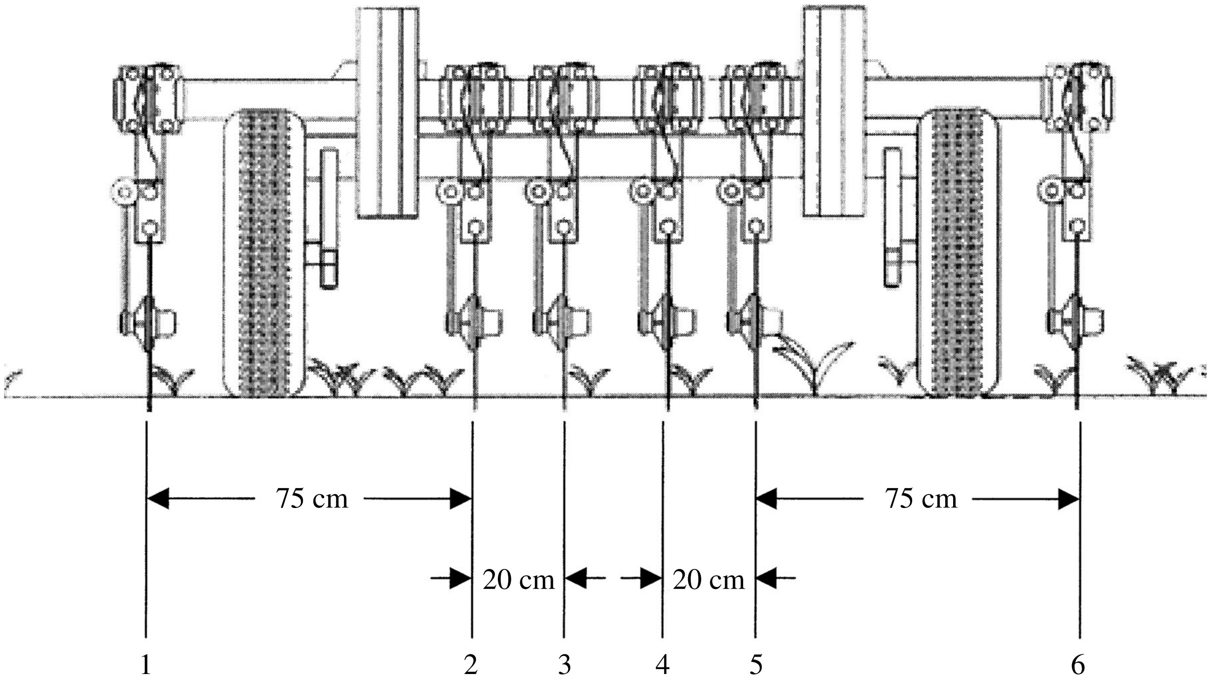

Fig. 1. **Veris Technologies 3100 soil electrical conductivity (EC) mapping system:** 2, 5 – voltage injector electrodes; 1,6; 3,4 – voltage drop measure electrodes; 1-2, 5-6 – deep soil profile; 2-3, 5-4, – shallow soil profile [3]

The great disadvantage of E.C. mapping technology is that it only offers general soil fertility degree information and can be regarded as quite imprecise. It takes into account only one variable and it makes no connection to the crop type that is to be planted on the soil. The E.C. mapping helps farmers vary the site specific management (for example N – nitrogen fertilizer application within fields) (Hurley et. al. 2004)) [4], but only if two or more productivity areas within the same field with different fertilizer regimes are present [5], but there is still a lot that can be done to improve the existent technology.

Materials and Methods

This paper aims to propose a system design which takes into account a whole range of environmental factors with an undeniable impact over the yield and quality of the future crops. Based on the same GIS data processing platform as current technologies, the system which has been designed SIGAA (Advanced Agricultural Geographical Information System) combines the features of a complex agricultural field monitoring network with those of precision mapping systems. The design is centered on an extended field data collection network with various sensor types as its primary data acquisition segment, featuring data temporary storage on data loggers operating with ROM (Read Only Memory) type memory and after the fore mentioned data processing, the system is meant to have as an output, an electronic interactive map of the intended land lot. Since SIGAA can take into account various interactions between different types of environmental factors, it is capable of identifying the most suitable crop type that would best fit different configurations of soil characteristics and environment inside the same land lot. The system uses the integrated image viewer of any GIS type family software to graphically represent the areas (GPS defined) that are suitable for a certain crop type. This, in return, of course leads to a successful tool for supporting the decisions of farmers and entities using precision agriculture practices.

A more detailed overview of the system can be observed in the picture below:

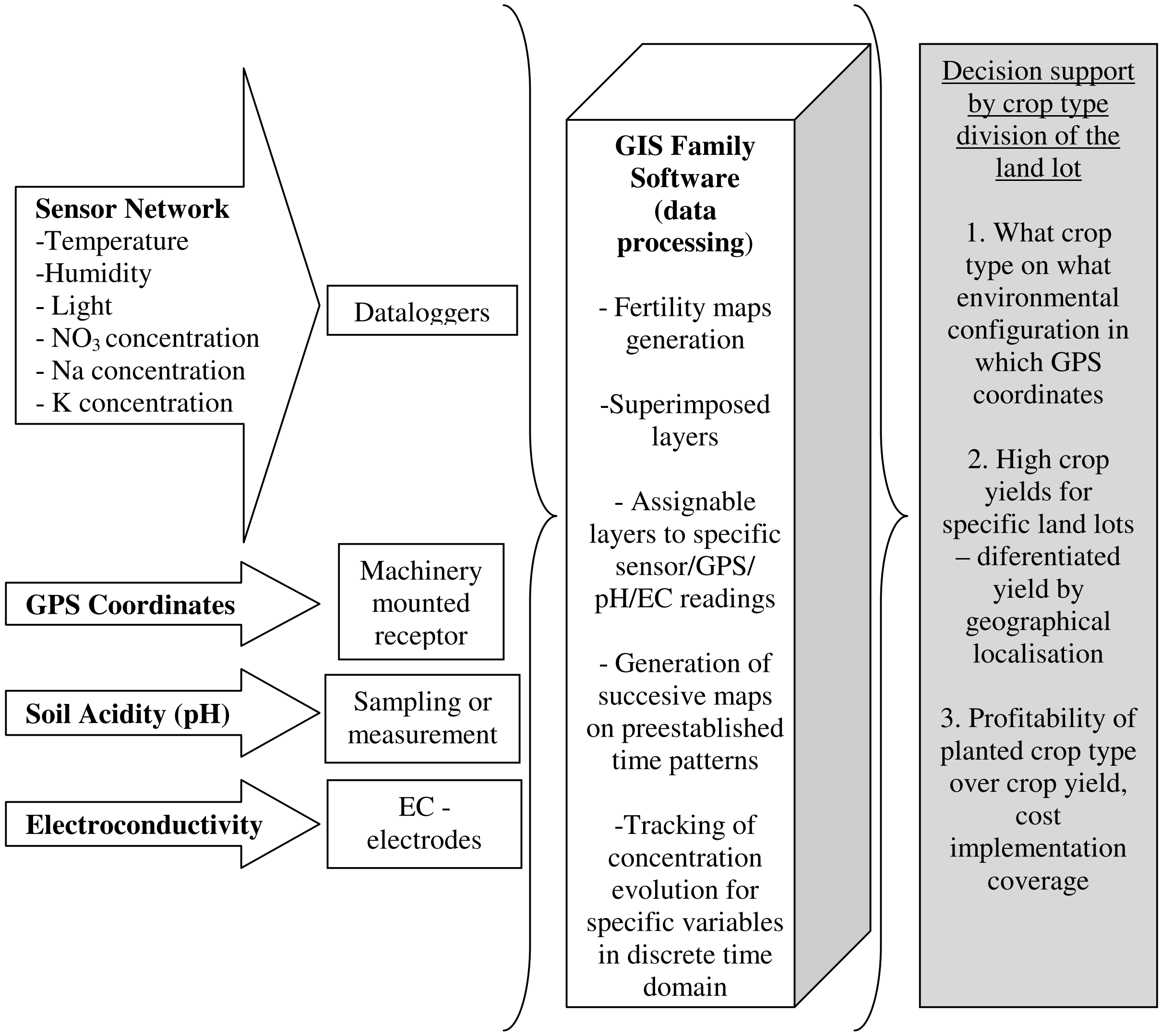

Fig. 2. **Logic scheme of the SIGAA decision support system**

The fact that the system is based not only on one type of input (E.C.), but on an entire network of field monitoring sensors ensures that it has enough input data to recognize specific plant growth and development profiles. Based on these profiles which have been documented by many botanical and agricultural studies, in essence nothing more than specific configurations of optimum plant development soil characteristics and environmental conditions, the system is able to assert geographical areas best suitable to specific plant growth profiles.In order to actually build the SIGAA system, compatibility issues between different pieces of equipment have to be solved. As part of the research program meant to bring the SIGAA program to reality, it has been experimented with components (at a theoretical level) from the same manufacturer. For this purpose, the “VERIS Technologies” company was chosen, mostly due to the ease in which it makes available most of the manuals for its products [6]. Technical specifications for almost every sensor available from VERIS can be found and used to ulterior purposes. Like in any case when attempting to build a prototype for a mechatronic system, simulations for the components and the entire working assembly must be accomplished in order to offer a way to predict the possible behavior of a complex system made up of different pieces of technology and to give an idea to the designer about the future challenges that await in the actual construction of the model.

Usually, in case of implementing this system into actual fields, the central data processing site can either be in field or near the field in most cases for small enterprises and micro farming enterprises or it can be several kilometers away, in an urban area in the case of farming servicing companies. Its main tasks are to generate successive complex fertility and soil properties distribution maps in GIS family software and then compare significant variables for comparison: the crop specific nutrients concentration, biological matter concentration and so on. Through approach of different data transmission protocols and tools, different versions of the SIGAA system can be developed with minor but essential differences in technology use. One can choose the wireless system (with its range limitations and variable quality signal), the wired system (high implementation costs due to great distances between data acquisition segment and data processing – long cables with high wire costs) or even the GSM system which used the GSM band width as a carrier for data transmission [7].

Results and discussion

The integration of soil specific parameters (plant nutrient concentration, K, Na) and that of various specific environmental factors within a system capable of asserting personalized fertility of agricultural fields for various crop types represents more than a useful tool for modern farmers. It is more than an instrument: it is a way of efficiently and economically managing a land lot so that farmers can maximize profit, minimize loss due to poor application of the crop rotating principle and a way to improve environment management within the business field.

Furthermore, SIGAA can successfully be used to determine precision crop rotation. Planting the same crop type successively on the same land lot, it is only natural that in time, the chemical configuration of the soil changes, simply by the drainage of the same crop specific nutrients from the soil. In the past, this drainage on the same nutrients/ chemicals in the soil was adverted by simply rotating the crops meant to be planted on the intended land lot. However, the decision to rotate the crops had no other decision support either than the experience/ intuition of the farmer and in many cases it was actually wrong: either the soil could have sustained another culture of the same type and the farmers changed the crop type too soon without a reliable reason, or the culture rotation was done too slowly/ too late only after seeing a major negative difference in the crop yield on the same land lot. In many cases, this major negative difference led to the inability of the farmer to cover costs for other agricultural tasks: plowing, sowing, pest control and so on.

The change in the concentration and type of various chemicals specific to certain crop types can be tracked in time by analyzing successive interactive fertility maps which have been taken using the SIGAA system. Given enough time, and enough factors (either natural or artificial), areas within the same land lot will change their crop/ productivity profile. Farmers tracking these changes can properly adjust their crops and their long term farm management so that they can maximize profit, minimize losses and benefit to the full extent from their lands. As any other modern business, farming has become an economic field in which strategy, management and planning have as much to do with the business manager as they do with the tools and methods used to administer the business.

Conclusions

The new approach proposed in this paper and the related research carried out allow for formulating the following conclusions:

1. *Design.* The design of the SIGAA system is more advanced than any previous soil mapping technology. The interactivity that it provides, the feedback that it offers make it an ideal solution for backing up decisional processes especially when deciding over the crop type that should be planted next on a certain field lot.
2. *Use.* SIGAA can be used successively on the same land lot, in order to track changes in the intrinsic properties of the soil which can occur in time. It is a well-known fact that the chemical composition of the soil is dynamic and that it changes in time due to external factors: dust brought on the land lot by the wind, changes in the biological matter concentration that occur due to the successive planting / harvesting cycles and so on.
3. *Hardware.* Multiple hardware configuration possibilities can be employed to build the system in regard to the demands of the farmers or the entities operating the land lot.
4. *Purpose.* The system is designed to provide solid decisional support for farmers using precision agriculture technologies.
5. *Research Direction.* Current research line is being taken into the direction of developing electronic models for each component of the system, and then interfacing these models into a complex simulation which is supposed to offer a complete and wide image of all interactions between the components.

6. *Applicability.* Precision agriculture is largely based on niche applications which serve peculiar and very distinct purposes within the large research field. However SIGAA, though based on niche technology, is a system designed to serve the general area of precision agriculture field and has large applicability.

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