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AUTOMATION AND COMPUTER-BASED TECHNOLOGY FOR SMALL VEGETABLE FARM HOLDERS

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Abstract

The present paper relates a method of computer controlled irrigation/ fertigation/ chemigation which : a.) optimizes water/ nutrients/ pesticides inputs and protects natural resources (water, soil and soil nutrients), b.) uses the correct rates of nutrients and water for plants, being essential not only for the improvement of irrigation system but also for reducing inputs costs and increasing crop yield. The concept of this research is to save water and to apply fertilisers and pesticides responsibly – based on an intelligent and interactive control system for effective irrigation/fertigation and chemigation scheduling. It will be easy to use and reliable for small and medium vegetable farms (2 ha or less) which dominate the vegetables market in Romania. The connexion with precision agriculture and variable rate technology is direct and strong. The use of electronics in fertigation/chemigation process brings many benefits due to its accuracy, powerful calculation software and automation. Electronics is involved in the detection of the environment parameters (humidity, temperature, in soil and in the air, wind direction, rain sensors, clouds detection, colour of the plant leaves), in the management of the inputs (water level control, mixing the fertigants), system control (pressure control, cleaning of the tanks) and data processing (data storage, computation, data reports, real-time clock). The electronic equipment of the automated interactive system for the optimisation of water, nutrients and pesticides inputs contains a central processing unit, a data acquisition unit and a driving unit mounted together on a mobile platform (tractor or car driven) comprising various tanks for water, fertilizers, pesticides, associated with automation elements which makes this unit an independent and flexible one. The connection with water supply and electricity is also provided.

Key words*: vegetable farms, chemigation, wireless sensors, computer, automation.*

INTRODUCTION

With the rapid rise in demand for both agricultural crop quantity and quality and with the growing concern of non-point pollution caused by modern farming practices, the efficiency and environmental safety of agricultural production systems have been questioned (Gebbers and Adamchuk, 2010).
While implementing best management practices around the world, it was observed that the most efficient quantities of agricultural inputs vary across the farmland due to various naturally occurring, as well as man-induced, differences in key productivity factors such as water and nutrient supply. Identifying and understanding these differences allow for varying crop management practices according to locally defined needs (Pierce and Nowak, 1999). Such spatially-variable management practices have become the central part of precision agriculture (PA) management strategies. PA is an excellent example of a system approach where the use of the sensor fusion concept is essential.
Among the different parameters that describe farmland variability, topography and soils are key factors that control variability in crop growing environments (Robert, 1993). Variations in crop vegetation growth typically

respond to differences in these microenvironments together with the effects of management practice. Our ability to accurately recognize and account for any such differences can make production systems more efficient. Traditionally differences in physical, chemical and biological soil attributes have been detected through soil sampling and laboratory analysis (Wollenhaupt et al., 1997; de Gruijter et al., 2006). The cost of sampling and analysis are such that it is difficult to obtain enough samples to accurately characterize the landscape variability. This economic consideration resulting in low sampling density has been recognized as a major limiting factor.

Remote sensing involves the deployment of sensor systems using airborne or satellite platforms. Proximal sensing requires the operation of the sensor at close range, or even in contact, with the soil being measured, allowing *in situ* determination of soil characteristics at, or below, the soil surface at specific locations (Viscarra Rossel et al., 2011). Alternatively, the crop itself can be viewed as a bio indicator of variable growing conditions. Yield maps summarize the overall impact of management activities and of natural conditions, such as weather and soils. However, yield data provide only a retrospective analysis and does not allow the user to address any spatial and temporal inconsistencies in crop growth during the corresponding growing season. Therefore, different in-season sensing scenarios have been implemented to provide feedback on crop performance in time to alter management decisions according to local needs. It has been demonstrated that detection and identification of weeds using machine vision systems is feasible as well; other crop status sensing techniques such as laser florescence, thermal imaging and ultrasonic proximity sensing are the subject of ongoing research.

One of the main limitations of any sensor-based management is that virtually every layer of information can respond to more than one soil, landscape, or crop property used to describe growing conditions and process. This makes a corresponding decision-making strategy uncertain and/ or complex when attempting to deploy it over different production settings (McBratney et al., 2005). Using a combination of conceptually different sensing techniques and integrating the subsequent data holds promise for providing more accurate property estimates, leading to more robust management and increased adoptability of sensor-based crop management.

The concept of the whole project is saving water and applying fertilisers and pesticides responsibly - manage irrigation and fertilization together to optimize efficiency. This project proposes an intelligent and interactive control system for effective irrigation/fertigation and chemigation scheduling. It will be easy to use and reliable for small and medium vegetable farms (2 ha. or less) which dominate the vegetables market in Romania.

The goal of this publication is to discuss the concept of sensor fusion relevant to precision agriculture, a method of computer controlled irrigation/ fertigation/ chemigation which optimizes water/ nutrients/ pesticides inputs and protect natural resources (water, soil and soil nutrients) and also to provide a framework for future research in this area.

MATERIALS AND METHODS

It is the *purpose* of the project of the above organizations to provide a method of irrigation/ fertigation/ chemigation that uses the correct rate of nutrients and water for plants using an intelligent system, computer based. Our project relays on *variable rates* irrigation/ fertigation/ chemigation which, in our opinion, is very essential not only for the improvement of irrigation system but also for reducing the inputs costs and for increasing crop yield. Intelligent control based irrigation is necessary to maximize efficiency and production. The originality of the project consists in proposing such a system which uses a computer based decision support (Figure 1).

The use of electronics in fertigation / chemigation process brings many benefits due to its accuracy, powerful calculation software and automation. Electronics is involved in the detection of the environment parameters (humidity, temperature, in soil and in the air, wind direction, rain sensors, clouds detection, colour of the plant leaves), in the management of the inputs (water level control, mixing the fertigants), system control (pressure control, cleaning of tanks) and data processing (data storage, computation, data reports, real-time clock).

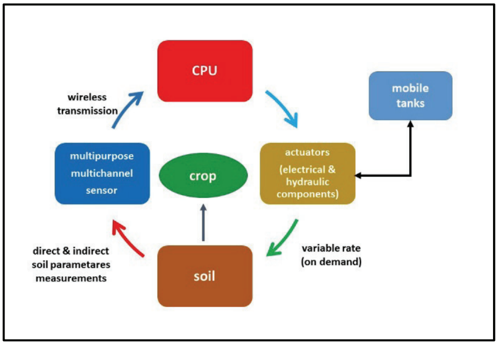

Figure 1. The concept of computer-based irrigation/fertigation/chemigation system

Our system will: **a.)** monitor the state variables within the agricultural system, **b.)** compare the state variables with their desired or target values, **c.)** decide what actions are necessary to change the state of the system, **d.)** carry out the necessary actions.

The electronic equipment to control the automated interactive system comprises a central processing unit, a data acquisition unit and a driving unit.

The **central processing unit** is built around a microcomputer structure which embedded software will supervise the control elements and will drive the execution elements accordingly to manage the irrigation process.

The microcomputer-based control system consists of a combination of hardware and software that acts as a supervisor with the purpose of managing irrigation and other related practices such as fertigation and pesticide treatments. Our computer-based control system will be a *fully automatic* one which means that it controls performance of the system by automatically actuating pumps, valves, etc., in response to feedback received from a sensor-based monitoring system.

The central processing unit will be provided with a robust, easy-to-use interface for an external operator, and with an intelligent machine specifically programmed to react properly to any changes of parameters monitored by sensors. The automatic functions are activated by feedback from field units (sensors) and will make corrections in the flow parameters by controlling devices in the irrigation system until the desired performance level is attained. This automatic systems will also perform auxiliary functions such as stopping irrigation in case of rain.

The embedded software will process data acquired from soil and plants through sensors in real time and will command appropriate quantities of chemicals to be pumped. Thus waste of water and energy will be prevented, specially when a natural soil humidity exists. The System is conceived for a medium size farm and to easily be transported into and from the field.

A step of novelty is the development of a software for vegetable growers, a versatile and useful tool to enables every grower to master irrigation, fertigation and chemigation at a professional level. The software will be conceived as a practical and efficient tool to calculate (based on information which determine the crop's needs) irrigation and fertilisation needs for vegetables using drip/sprinkle irrigation, under set conditions described by the user. It will be interactive, which means that they can be seen, modified, printed, etc.

This programme will use: **a.)** information of crop, soil texture and number of drips (size of the irrigated area and irrigation time), **b.)** information of the EC (electrical conductivity) of water from source, percentage of water availability, and nutrient content of the water. Nutrient content of the irrigation water is useful, so that any nutrients found here can be deducted from the fertiliser, **c.)** fertiliser data base (name and type of fertiliser - to obtain the fertigation proposal), to select and calculate the optimal fertilizer quantity, based on water/soil composition and growing needs (to avoid undesirable chemical combinations, over-fertilizing or under-fertilizing, damage to soil or water sources, salinity build-up).

The **data acquisition unit** will collect information from distributed multichannel, multipurpose sensors for humidity, temperature, level of the liquid in the tank, etc. The information is transferred into the central unit either directly, from sensors in the pipeline, or from intermediate data acquisition unit which collects the data from a number of sensors and then process and store them temporarily for further transfer to the central unit. All kind of input parameters like air temperature, soil moisture, radiations and humidity are collected and modelled. Various sensors, tensiometers, relative humidity sensors, rain sensors, temperature sensors control these processes scheduling. These sensors provide feedback to the controller to control its operation.

The **driving unit** will be the interface between the central processing unit and other elements of the system such as pumps, electro valves. The field devices such as valves, regulators, pumps, etc. are fitted with electrically operated servo-devices which enable actuation of the pumps, closing and opening of valves, and adjusting pilot valves of flow regulators. This type of system will also permit the system to govern flow from the central computer by controlling flow parameters such as pressure and flow rate, according to specific needs at the given time, and to receive immediate feedback on the response of the system. The system has also features that enable an operator to transmit commands back to the various control units of the irrigation system. The energy for the electronic equipment will be supplied from the mains (230 V/50 Hz).

Also, the whole system and acquisition data unit can plan a strategy to get profit and save money on chemicals, to apply to and to use special treatments database (herbicides/ insecticides/ fungicides): name of the treatment, month(s) in which we want the program to remind us to apply it/them, and which variety to receive treatment; discount the days when special treatments are applied from those when fertilisation was planned; and to obtain and keep a historical database: all the treatments proposals are stored, to easily find out what was done, to facilitates planning, a.s.o.

Safeness and safe use of equipment are other priorities of the project. The whole philosophy is to realize a product that is not harmful to the environment and complies to European Union regulations. To achieve this goal it is taken into consideration the following aspects: **a.)** water excess, which could bring to a salty soil or specific water diseases, will be prevent because of the interactivity of the System by permanent monitoring of the soil humidity in several points, **b.)** avoid harmful substances (all electronic components will comply to the Directive 2002/95/EU on Restriction of Hazardous Substances in Electrical and Electronical Equipments (RoHS), to Directive 2002/96/EC on waste electrical and electronic equipment (WEEE), and to Regulation (EC) No. 1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH); that means the soldering process of electronic modules will use the lead-free technology, the electronic components and the printed circuit board finishing will not contain Pb, Cd, Hg or other harmful substances.

Physically, beyond electronics, the system will contain various tanks, of various volumes for water and chemical substances. The substances will be mixed in water and pumped through the drip irrigation system which can be manually or automatically operated. Water can be obtained from a fountain or from a large stationary reservoir. A network of smaller diameter polytubes, poly fittings and accessories to make connections and emitting devices at plants complete the System.

Using automation and microcomputers, the calculation process is automated, and different alternatives can be analysed to provide the necessary nutritive elements for crop. A computer program is easier to use if it is complemented by one or more data bases; this saves much time in planning for technicians responsible for setting up nutritive programmes on the estates they manage. Real time feedback is the application if irrigation based on actual dynamic demand of the plant itself, plant root zone effectively reflecting all environmental factors acting upon the plant. Operating within controlled parameters, the plant itself determines the degree of irrigation/ fertigation/chemigation required.

Drip irrigation at variable rates may help achieving water conservation by reducing evaporation and deep drainage when compared to other types of irrigation such as flood or overhead sprinklers since water can be more precisely applied to the plant roots.

Traditional pesticide application is by sprayer; however, spray application may not be efficient due to a variety of factors, such as spray drift, and spray operator skill. Chemigation, or injection of insecticides, pesticides, herbicides, etc. through irrigation systems, offers an alternative strategy for efficient and economical application of pesticides to targeted zones in soil. Improving water distribution uniformity of drip irrigation systems has been studied extensively, but the specific evaluation of a designated pest control agent's uniformity throughout drip lines is lacking, especially for the microbial bio-pesticides before they are used for field trials.

Using irrigation systems to apply fertilizers and pesticides is commonly referred to as fertigation and chemigation. Fertigation / chemigation via drip irrigation has advantages compatible with environmental stewardship: no worker exposure to foliar pesticide residues, reduction of waste from cleaning out spray tanks, elimination of drift, and less exposure of biological control organisms to pesticides in integrated pest management programs. Systemic pesticides seem particularly well suited for application by drip chemigation and would be compatible with Integrated Pest Management if plant uptake was rapid enough to allow delay in application until a pest problem was developing. Insecticides of the neonicotinoid class, including imidacloprid, thiamethoxam, and acetamiprid, may be particularly suitable for drip chemigation. They have systemic properties, but they are arguably considered reduced risk pesticides.

Use of fertigation/chemigation makes producers strive to be more efficient with production inputs and practice good environmental stewardship. It is usually practiced with high value crops such as vegetables, turf, fruit trees, vines, and ornamentals. The main advantage of fertigation is the application of nutrients at the precise time they are needed and at the rate they are utilized. Yields are optimized and fertilizer costs are reduced because the nutrients are applied when, where, and in the soluble form needed. Overall, fertigation conserves water and nutrients.

RESULTS AND DISCUSSIONS

Using the proposed system it is possible to reduce fertilizers needs by **70-90%**. Because fertilizer is absorbed as needed, and in small doses, the farmer uses far less fertilizer to achieve superior results. Since most of the fertilizer gets absorbed directly into the plant, fertilizer run-off is virtually eliminated. Fertigation also improves the plant's efficiency in holding water due to an increase in root mass thereby reducing total water needed.

The system, in its conception, can save of **20-50%** on water usage through fertigation (increased uptake efficiency by the plant). It is possible to cut back the watering time in each zone by 10%. Further cuts can be made based on how fertile the soil becomes and if there are used products that help to trap water in the root zone.

The computer-based system will reduce herbicides and pesticides needs**,** in addition to reducing water and fertilizer needs.

Drip application of pesticides includes: reduced risk to environment and farm workers: drift to non-target areas is eliminated; farm workers do not come into contact with residues on plant foliage; beneficial organisms not directly exposed; longer residual activity (not subject to loss from rain and UV light; not subject to plant growth dilution effects).

If managed correctly it will improve the crop's health and vitality, automatically.

CONCLUSIONS

This automated system, as it is developed now, can:

- reduce chemical application rates;
- uniformly apply chemical substances;
- apply any kind of treatment on time;
- reduce soil compaction;
- produce less crop damage;
- minimize environmental hazards;
- minimize operator hazards.

With respect to economic benefits, there is savings in labour, savings in water, fertilizer, herbicides and pesticides, energy and increased plant productivity and overall profit. With regard to environmental benefits, water and fertilizer resources are saved, the use of environmentally harmful chemicals is reduced, run-off into water sources is reduced, erosion is reduced, and the amount of land tied up in agriculture is reduced. While the project has been founded and started with reference to specific embodiments, it will be apparent that numerous variations, modifications and alternative embodiments are possible, and accordingly all such variations, modifications and alternative embodiments are to be regarded as being within the scope and spirit of the present project.

The consortium as it was constructed, by putting together the electronic designer partner and the technological designer partner, is favourable for obtaining maximum benefits resulted by applying the rules of Design for Manufacturing (DfM) concept and concurrent engineering methodology by taking into account in the early stage of the design of all the problems of the entire life cycle of the end-product. As known, the good application of DfM methodology leads to the best quality of a product, the lowest production costs, the reduction of the time-to-market and customer satisfaction. This is a guarantee of a competitive price of the end-product.

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REFERENCES

De Gruijter J., Brus D.J., Bierkens M.F.P., Knotters M., 2006. Sampling for Natural Resource Monitoring. Springer, New York, New York, USA.

Gebbers R., Adamchuk V.I., 2010. Precision agriculture and food security. Science 327:828-831.

McBratney A., Whelan B., Ancev T., Bouma J., 2005. Future directions of precision agriculture. Precision Agriculture 6:7-23.

Pierce F.J., Nowak P., 1999. Aspects of precision agriculture. Advances in Agronomy 67: 1-85.

Robert P.C., 1993. Characterization of soil conditions at the field level for soil specific management. Geoderma 60:57-72.

Viscarra Rossel R.A., Adamchuk,V.I., Sudduth K.A., McKenzie N.J., Lobsey C., 2011. Proximal soil sensing: an effective approach for soil measurements in space and time. Advances in Agronomy 113:237-283.

Wollenhaupt N.C., Mulla D.J., Gotway Crawford C.A., 1997. Soil sampling and interpolation techniques for mapping spatial variability of soil properties. The State of Site-Specific Management for Agriculture, F.T. Pierce and E.J. Sadler (eds), 19-53. ASA-CSSA-SSSA, Madison, Wisconsin, USA.