PUTTING INTERNET-OF-THINGS AT THE SERVICE OF SUSTAINABLE AGRICULTURE. CASE STUDY: SYSAGRIA

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Abstract

Continuous growth of global population requires a better management of food resources: increasing productivity, maximizing crop yields, reducing losses (water, energy, chemicals), protecting the environment, preventing plant disease, minimizing the manpower. Since the mid-1980s when precision agriculture has its roots, the new concept could rely on advancement in electronics, agriculture research and emerging technologies. Syswin Solutions has been focused on Internet-of-Things, since it seems to be more adequate compared to drones or satellite imagery because it offers much more complete data from sensors placed directly in the cultivated environment. Thus, was born SysAgria, a system that provides comprehensive, real-time environmental information and development conditions at various phenological stages of crops, fruit trees, vines and vegetables, on the basis of which proactive treatment, planned fertilization, sowing and harvesting can be achieved. The system monitors the vital parameters of soil, air and light and identifies prototypes through a series of intelligent algorithms that analyze the data obtained and correlates them with a relevant history of the culture. Built using very low power consumption circuits, the system is energetically independent since it uses solar power and optimized algorithms for communication. Data is available anywhere in the cloud, thus the farmer can act immediately if parameters change. Syswin Solutions has five systems under test in real operating conditions, in different places around Romania, in greenhouse and in field, for monitoring cereals and vegetables. The paper presents the SysAgria system and some eloquent results of the monitoring. Soil sensors placed at different depths revealed possible water absorbtion problems. The automation of the ventilation in the greenhouse has been shown to be beneficial for plant development.

Key words: internet of things, precision agriculture, sensor, energy independent.

Even from the end of the last century the scientists understood that the humanity's chance to provide food to a growing population in conditions of diminishing water and fossil energy resources is precision agriculture (PA). Also known as precision farming, satellite farming or site-specific crop management, the concept presumes continuous monitoring of the parameters influencing the plants' growth. Monitoring, meaning observation, measurement and action, is referred to many agents like air, light, plant disease, soil, water. Because, as was pointed out in an earlier survey (Zhang N. *et al*, 2002), agriculture production systems have benefited from technological advances previously developed for other industries, nowadays it can be understandable that the transition from Industry 4.0 to Agriculture 4.0 is quite natural. One of the emerging technologies is the Internet of Things (IoT) which is increasingly penetrating agriculture (seen in a broader sense: vegetable growing, horticulture, fruit growing, viticulture, but also animal husbandry, beekeeping and fish farming, a.s.o.). Thanks to IoT a great deal of information provided by a wide variety of sensors is available everywhere, anytime. The development of an information and communication network appears to play a vital role in the progress of precision agriculture, overcoming barriers such as the lack of basic data and farm oversight as well as non-compatibility and standalone systems (Lutticken R. E., 2000). In livestock monitoring, ranchers can use wireless IoT applications to gather data regarding the health, well-being, and location of their cattle. The main benefit is the possibility to identify sick animals and to extract them from the herd to prevent the spread of the disease. A common application of IoT is the monitoring of plant and soil conditions. The main benefits of such applications are a better management of the resources (water, fertilizers) by sensing the soil moisture and nutrients, determining the optimal

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time to plant and harvest and predicting possible plant disease situations. The highest efficiency of IoT applications in agriculture is when the most appropriate sensors are chosen and when data interpretation benefits from correlations between different parameters.

A recent study on 1 ha potato plot on wireless sensors network (WSN) measuring soil temperature and humidity, the most important parameters for this culture, was conducted to determine how the response to applications is determined by measurements of performance in wireless communications (Petearson Anzola J. *et al*, 2017). The specificity of this study was the large number of network sensors (100) placed on a restricted area. Even though the results obtained do not help to directly improve potato crop performance or production, they help engineers to estimate how long it would take a user to obtain the “real time” crop data for a given query or how long a server or machine can obtain a temporary crop response, items that are of great importance in IoT applications. One solution to avoid blocking when in case of a big amount of data is a special architecture proposed for dynamic processing of events in the context of IoT and PA which was implemented in a virtual machine with a 1.9 GHz CPU and 6 GB RAM and successfully tested for fifteen days into an intelligent irrigation system (Mazon-Olivo B. *et al*, 2018).

Since the work is presented at a conference held at the National Research and Development Institute for Potato and Sugar Beet, a funny experiment should be mentioned: Potato-powered IoT, whose idea was to test how less power would be needed for supplying a WSN (Lozano Fernandez J. *et al*, 2015). IoT technology is associated with low-power, so the circuits could also be fed from potatoes, but that's a false impression: just as the whole lead-free technology is considered to be more thermally aggressive because the most used alloy, SAC, requires more than 30°C heat than SnPb alloy, as there are other lead-free alloys whose melting temperatures are even lower than that of SnPb, so there are sensors connected to WSNs requiring more powerful sources (batteries, photovoltaic cells, a.s.o.).

Syswin Solutions has developed SysAgria, a complete system based on IoT technology for monitoring vital parameters from soil, air, light by means of sensors spread over an area of interest, for data collection and transmission to a remote central unit where there are analyzed in order to offer the results of the measurement, as well as the interpretation and recommendation for the farmer *(figure 1)*. The processed information can be accessed from fixed or mobile devices. The system consists in at least one base station (SysAgria 1, … SysAgria n) that constitute the nodes of a Wireless Mesh Network (WMN), each node communicating with each other and through a gateway with a server, which assures the interconnection to the Web. Each node controls all the sensors by wire mainly interconnected on serial buses (I2C, RS-485). The system does not only perform detection, measurement of parameters, but also can generate commands through an IC interface for other equipment (fans, windows, pumps) in greenhouses or irrigation systems (this is an option). Besides greenhouses, it can also be installed in grain fields, vegetable gardens, flower gardens, orchards, vineyards, a.s.o. The supply voltages are obtained from a power unit consisting of a rechargeable battery (12V, 9Ah) and a photovoltaic panel (50W); where electromechanical devices are required, the power is supplied from external voltage sources (230V/50Hz).

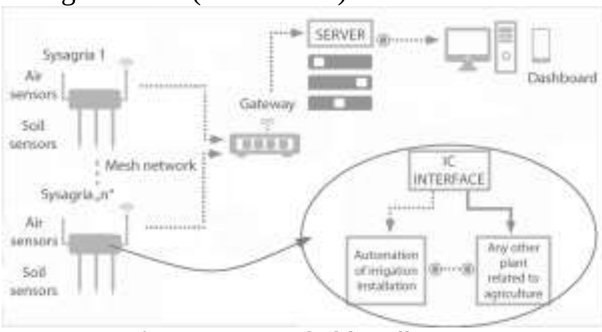

Figure 1 **SysAgria bloc diagram**

MATERIAL AND METHOD

Constructively, the base station is made up of an IP 67 grade cabinet in which the electronic module containing the processing and control block is placed, including analogue to digital converters and communication block, the IC interface module, the battery and the battery charger from the photovoltaic panel. The photovoltaic panel is mounted at a sufficient height not to be overshadowed by vegetation or other natural obstacles and facing South.

The processing and control block is built around an advanced RISC microcontroller, AVR architecture, ATmega2560 (Microchip Technology) working at 16 MHz. Its main characteristics are: 256KBytes of In-System Self-Programmable Flash memory, 4 KBytes EEPROM, 8 KBytes internal SRAM, 16-channel, 10-bit ADC, 10 digital communication peripherals (4 USART, 5 SPI, 1 I2C), ultra-low power consumption (0.1µA at 1.8V), temperature range (-40°C to 85°C). For wireless communication the base station supports a Long Range low power (LoRa) transceiver module RFM98W - 433MHz (Hoperf Electronic), as well as a GPRS module equipped with SIM800C (SIMCom) circuit. The communication within the WMN is based on LoRa technology which offers to SysAgria system several advantages:

- allows long range distance between the nodes, up to 15 – 20 km, so a single central unit can monitor large areas or smaller dispersed areas;

- the frequency range used by LoRa is part of the unlicensed ISM band, so the communication between the nodes is costless;

- the very low power consumption allows a better management of the energy so the system can work even in the case of several cloudy days.

The sensors are outside the cabinet, buried in the soil or placed at different heights over the ground level and they are connected to the electronic module through rugged connectors. SysAgria base station allows the connection of up to 92 sensors.

Because the most sensible part of the system is sensory, SysAgria does not use home-made sensors but only certified sensors produced by renowned specialized firms, such as Honeywell, Atlas Scientific, RIKA Electronic Technology. The sensors are measuring parameters of soil (moisture, temperature, pH, electroconductivity), air (temperature, relative humidity, speed and direction of the wind, barometric pressure, rainfall, leaf wetness, leaf temperature), light (ultra-violet index, solar radiation, illuminance). SysAgria can perform some measurements up to three (or more, if requested) levels in depth of in height. This allows a more accurate mapping of the parameters, not only horizontally, but also vertically. It is known, for example, that in the first period of vegetation the superficial rooting of onion requires a soil moisture level of around 80-90% of field capacity at 30-40 cm depth, until bulb formation, i.e. in the period of intense growth of roots and leaves.

SysAgria was previously tested in the Laboratory. The scope of this testing was to verify the capability of the system to control each sensor, to perform the measurement of the parameter, to display its value on a monitor and to compare with the measurement performed with another instrument. The most laborious task, already presented in another paper (Zarnescu A. *et al,* 2018), was the pH measurement in the soil, which required a prior calibration with known pH solutions and comparison with the measurements made with a tool of greater precision.The security of system is assured by data encription using a hardware crypto engine and by using a cabinet with keyed door, open door detection and alert, and vibration sensor for SysAgria base station.

Due to the specificity of the application, tests in an electronics laboratory can cover only a small part of the system's functionality, so that real-time testing activities have been initiated. Five SysAgria systems were tested in different places, with different types of soil and plant cultures (*figure 2, figure 3*). The configuration of the SysAgria systems under test is presented below (*table 1*).

The purposes of the testing were:

- to verify the capability of monitoring from the distance the main parameters for agricultural lots;

- to test the integration of the system within other automation systems (e.g.: ventilation);

- to verify the system's energy independence.

- to improve the data analysis algorithm in accordance with the specific conditions;

- to observe the expected positive impact of the system on the monitorized cultures.

Figure 2 **SysAgria cabinet installed in a field**

Figure 3 **SysAgria cabinet installed in a greenhouse**

The particularity of the #1 system is that it has the option of automation implemented: according to the air temperature, the system may command the open/close of the curtains and the start/stop of a fan.

Table 1

The configuration of the SysAgria systems under test

No.	Location	Culture	Type	Sensors (total)
1	Cocorastii Colt	Chinese cabbage	greenhouse	Soil humidity, soil temperature, air temperature, relative humidity, wind speed, wind direction (6)
2	Chirnogi	corn	field	Soil humidity, soil temperature, soil pH, air temperature, relative humidity, wind speed, wind direction, rainfall, barometric pressure, solar radiation, leaf wetness, electroconductivity (29)
3	Calarasi	soybean	field	Soil humidity, soil temperature, soil pH, air temperature, relative humidity, wind speed, wind direction, rainfall, barometric pressure, solar radiation, leaf wetness, electroconductivity (24)
4	Turda	wheat	field	Soil humidity, soil temperature, soil pH, air temperature, relative humidity, wind speed, wind direction, solar radiation, leaf wetness, electroconductivity (14)
5	Arad	hazelnut tree	orchard	Air temperature, relative humidity, solar radiation, leaf wetness, rainfall, soil temperature, humidity, pH and electroconductivity (9)

The particularity of the #3 system is the ability to measure some parameters at three different levels: the air temperature and relative humidity at the heights of 0.3m, 0.7m, 1.1m, evapotranspiration and temperature on the leaf at 0.25m, 0.7m, 1.1m, soil moisture, temperature, pH and electroconductivity at depths of 0.15m, 0.25m, 0.35m. Due to the IoT facilities, data from the 5 locations could be retrieved and viewed also on a computer located at the company's headquarters in Bucharest in order to supervise SysAgria systems behavior *(figure 4)*. These prove the capability of SysAgria system to cover large areas. Along with the data on monitored parameters, information is also provided about the equipment that is useful for maintenance such as battery voltage, RF signal power, GPRS battery charging status, the last transmission time and system’s ID. Data can be stored locally or in the cloud on the Syswin Solutions server.

Figure 4 **The territorial locations of the SysAgria systems under test**

RESULTS AND DISCUSSIONS

Five systems were installed between June and August and they are still under testing, totaling 14,237 hours of operation. Communication was sometime lost due to telecom operators. There are differences between the technological levels of national operators: the system #5 worked better on 2G offered by an operator than on 3G from another. However, during the loss of communication, the system is still working and able to control the automation.

At the system #1, the wind sensors detect its speed and the direction; if the speed is higher than 8m/s the system will command the closing of the curtain from the wind. This will prevent a sudden change in temperature within the greenhouse. On the other side, if the speed is 1 – 2 m/s, the movement of the wind vane has a random move and the direction of the wind is unusable. The wind sensor support is located at a height of approximately 6 m (*figure 5*). Probably it should be placed higher in order not to be affected by the air flowing from the roof. The functionality of the automation is proved using the monitoring data from August 11, 2018, from 08:30:20 to 20:00:30. Every minute after reading the air temperature the microcontroller computes the mean value of the last 10 measurements and compares to a pre-set threshold (27.5°C). If the value is greater, the system will command the opening of the curtain up to 10%.

Figure 5 **Wind sensors installation in a greenhouse**

If the temperature increases, the opening will continue up to 100%. In this situation, the temperature is compared to another threshold (29°C) in order to start forced ventilation using a fan. However, the forced ventilation can be initiated whenever necessary (*figure 6*), but the air temperature in the greenhouse cannot be less than the ambient temperature without using a cooling agent. During the 11 hours of monitoring, the temperature in the greenhouse varied between 23.93°C and 34.43°C, while the AccuWeather site reported 30°C for that day. During the testing period, the algorithm was improved several times; for example, in order to reduce power consumption; if the fan should be working continuously, it will be commanded intermittently: 15 min on, 5 min off.

Certain parameters do not change quickly, such as soil pH. Usually, farmers do testing of the soil pH once, twice or even several times a year and they have to call a specialized lab. SysAgria allows reading anytime is needed. However, account must be taken of the operation principle of the pH sensor. Even if the manufacturer says the pH sensor can stay indefinitely in the field, the readings should not be trusted indefinitely: only when the probe is immersed in a solution prepared in the soil with the same water used for irrigation. After three hours from the installation of the system #3 (July 19), when the reactions were stabilized, the readings at a depth of 0.15m in the soil were performed and remained stable within the range 6.69pH ±0.25pH almost 10 days. This is a good value since soybean can be grown in soils with a pH between 5 and 8.5 (optimum 6.7pH, Serban D., 2008). During this time (July - August) there were no fertilization operations, but only a pest treatment that had no effect on the measurements.

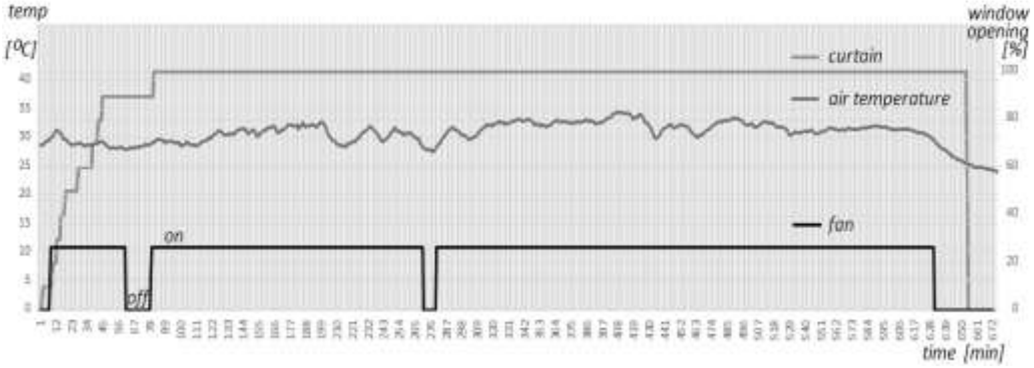

Figure 6 **The correlation between air temperature and the automation of ventilation in the greenhouse**

Although the measurement procedure requires a minimal intervention, the great benefit is that the result of the pH measurement is automatically transferred to the remote system database and processed. SysAgria allows monitoring of parameters, storing data in a database and consulting it for analysis at any time. Information can be tabulated or graphical. *Figure 7* presents the variation of air temperature, soil temperature and soil humidity in a greenhouse. It can be observed that the soil temperature is lower than air temperature during the day and becomes greater during the night confirming the capacity of heat accumulation by the soil. The system installed in the greenhouse allows to maintain a certain air temperature by controlling fans (forced cooling) or curtains (natural cooling), even it cannot be lower than outside air temperature.

Figure 8 presents the variation of soil moisture expressed in water volumetric content at three different depths, 0.15m, 0.25m and 0.35m, during a period of two months, June 1 – July 31, 2018 (system #3). The soil moisture at 0.35m depth is approximately constant (49%), decreases at 0.25m, and increase again at 0.15m from the surface, (~40%). The tendency of decreasing humidity at 0.25m under the ground can be attributed to water absorption by the roots - knowing that soybean develops about 75% of its root mass at 0.30m depth – and to a poor ascending stream of water to the roots of the plants. The soil at site #3 is recovered from a pond in the Danube meadow very rich in shellfish and snail and snail residues (figure 9).

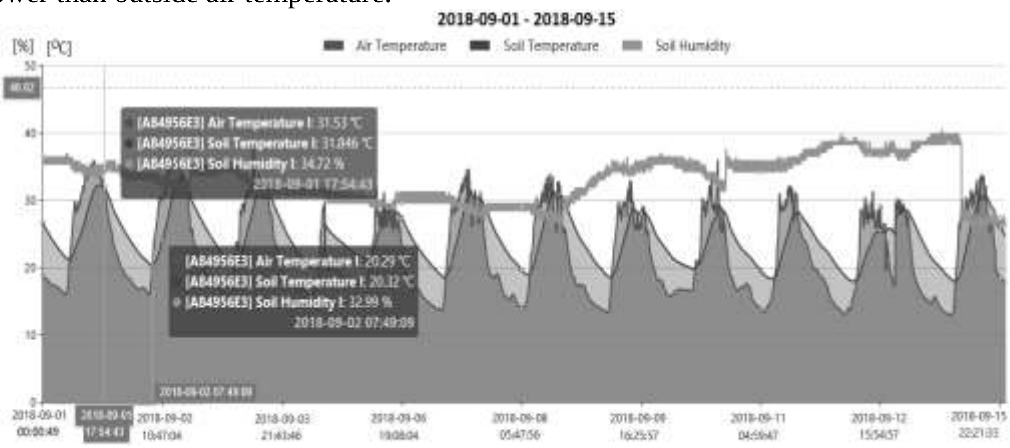

Figure 7 **Diagram of the variation of some parameters in the greenhouse**

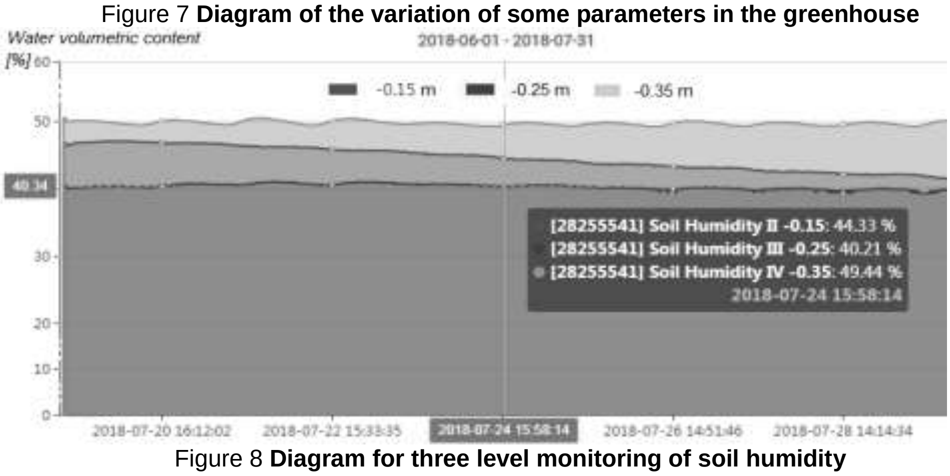

Figure 8 **Diagram for three level monitoring of soil humidity**

Figure 9 **Three level soil moisture measuring (site #3)**

The depths of the measurements have been established by the needs of the beneficiary, but it can be any depending on the type of culture; for example, sugar beet, in soils with the most favorable texture, develop deep roots that can reach up to 1.20m (Vatamanu V., 2014).

No failure of any system due to lack of energy was recorded. This proves that the systems were well-sized in terms of energy.

The system can offer Notification to the user if some conditions occur. However, the farmer is responsible to set the thresholds of the parameters according to local conditions. In the future, based on collaboration with agricultural specialists, SysAgria will be improved with an advanced data analysis in order to make predictions and to offer solutions to problems.

CONCLUSIONS

The system is available 24/24 hours, 7/7 days without the need for an external power supply. Temporary lack of communication due to radio wave propagation conditions does not affect the behavior of the system; the commands are sent to the automation system, data are stored locally and retransmitted when the connection is restored.

The efficiency of the system #1 was reported by the farmer itself: in a short time, the cabbage in the greenhouse grew very well and nice compared to those cultivated in the field and were not affected by the disease (*figure 10*). This is one of the positive impacts expected from SysAgria.

SysAgria enables the integration of automated control and command systems to function as a decision maker and timely operation on automated irrigation and fertilization systems, ventilation systems, dehumidification, lighting, especially for solariums and greenhouses.

Due to the many types of air sensors, the system can work as weather station too.

SysAgria was thought to be a tool in the service of the farmer based on electronic technology and knowledge in the field of agriculture. The ability to control different types of soil sensors placed on different depth, air and light sensors and supplied by a considerable computing power could make SysAgria a useful tool in research activities.

Figure 10 **The cabbage culture from the greenhouse**

ACKNOWLEGMENTS

This research work was carried out in the frame of the “Operational Program Competitivity 2014-2020” POC - A.1 – A.1.2.1. – D – 2015, COD SMIS 104238, supported by MECS - ANCSI, PRIAMM, ID p_39_360 project.

REFERENCES

Lozano Fernández T., Lignan A., Mejias A., Sanchez Garrido J., 2015 - *Potato-powered IoT,* available on-line at: https://www.hackster.io/4354/potato-powered-iot-947b69.

Lutticken R.E., 2000 - *Development of an internet-based communication and information network to progress the implementation of Precision Agriculture,* Proceedings of the 5th International Conference on Precision Agriculture, Bloomington, Minnesota, USA, 16-19 July, 2000, 2000 pp.1-14 ref.11.

Mazon-Olivo B., Hernándes-Rojas D., Maza-Salinas J., Pan A., 2018 - *Rules engine and complex event processor in the context of internet of things for precision agriculture,* Computers and Electronics in Agriculture, Volume 154: 347-360.

Petearson Anzola J., Garcia-Diaz V., Camilo Jimenez A., 2017 - *WSN analysis in grid topology for potato crop for IoT,* The 4th Multidisciplinary International Social Networks Conference, July 17-19, 2017, Proceedings of MISNC ‘17, Bangkok, Thailand, pp. 1-7.

Serban D., 2008 - *Tehnologii de cultura: generalitati in cultura de soia;* AgroRomania.ro; 28 Nov. 2008; available on-line at: http:// agroromania. manager.ro/articole/stiri/tehnologii-de-cultura-generalitati-in-cultura-de-soia-1268.html.

Vatamanu V., 2014 - *Individualitatea plantei si cresterea radacinilor,* Revista Agrimedia, 15 February 2014; available on-line at: https:// www.agrimedia.ro /articole/individualitatea-plantei-si-cresterea-radacinilor.

Zarnescu A., Ungurelu R., Macovei M. I., Varzaru G, 2018 - *Integrating soil pH measurement into an internet of things application,* The International Conference of the University of Agronomic Sciences and Veterinary Medicine of Bucharest – Agriculture for Life, Life for Agriculture, June 7 – 9, 2018, Proceedings.

Zhang N., Wang M., Wang N., 2002 - *Precision agriculture–a worldwide overview*, Computers and Electronics in Agriculture. 36 (2002): 13-32.