BENEFITS OF REMOTE SENSING, ENVIRONMENTAL DATA AND IOT USAGE IN MANAGING SUSTAINABLE AGRICULTURAL SYSTEMS

Assoc. Prof. Dr. Krisztina Toth[1]
Assoc. Prof. Dr. Peter Miko[2]
Dipl. Ing. Claudiu Utoiu[3]
Prof. Dr. Ing. Mihai Gidea[4]
Dipl. Ing. Elena Utoiu[5]
Dr. Ing. Daniel Amariei[6]
[1, 2] Hungarian University of Agriculture and Life Sciences - MATE, Hungary
[3, 5] National Research and Development Institute for Food Bioresources - IBA Bucharest, Romania
[4] University of Agronomic Sciences and Veterinary Medicine of Bucharest, Romania
[6] Project Advisory and Management Experts Association - PAMEA, Austria

ABSTRACT

The purpose of this paper is to present the demarches performed and planned to be accomplished through the INSAC-AGRIS project (funded by EUREKA program) in regard to an integrated autonomous system able to correlate DAQ from ground and air and to design a pattern capable of triggering differentiated application of additives and/or water to proposed crops in order to achieve best-optimized harvesting yield. The debute phase of the study shows the steps and methodology of preparing the preliminary plot maps, soil sampling and soil characteristics maps. The very practical aspect of this research is to provide to farmers the opportunity for better supervision of plants by analyzing plant characteristics, plant population, weediness level, field health, growth problems, diseases, involved pest or insects, vegetation indices, all completing the necessary information portfolio for model creation and building the prediction algorithms, protecting in this way the nature and increasing soil protection as well as optimizing economic activities in the SMART agriculture area.

The experimental phase is developed in parallel in Hungary and Romania for a period of 4 years, using several experimental crops (wheat, rapeseed, green peas, corn, sunflower), the integrated system usability and scalability for later use being clear and proved.

Keywords: *remote sensing, crop management, harvest prediction, IoT, sustainability, extension*

INTRODUCTION

Precision agriculture has generated a very high profile in the agricultural industry over the last decades, but the fact of ‘within-field spatial variability’, has been known for centuries. The topic has been ‘technology-driven’ and so many of the engineering developments are in place, with the understanding of the biological processes on a localized scale lagging behind. Precision agriculture, as a crop management concept, can meet much of the increasing environmental, economic, market and public pressures on arable agriculture [1].

Precision agriculture refers to an emerging set of technologies to simultaneously help meet this demand and also promote sustainability. In this regard, Precision agriculture is a modern concept of agricultural management that allows decisions to be made assertively, fertilizers to be applied in the correct locations, and production costs to be reduced [2]. Precision agriculture uses intensive data collection, providing in this way high accurate tracking and helping to production adjustment by enabling the definition of management zones for the custom management of inputs [3].

Nowadays, after continuous development and evolution, precision agriculture aids in making more informed management decisions that may lead to greater profitability, being an alternative for reducing costs. Precision agriculture approach is multidisciplinary, involving multiple technologies and disciplines [4].

Traditional practices manage whole fields as a single unit, whereas in modern precision agriculture, the farm management unit is shifted from whole fields to small areas within fields, creating a systematic approach to managing variability by focusing on small areas within fields and involving the application of technology and agronomic principles to manage the spatial and temporal variation of all aspects of agricultural production to improve crop performance and environmental quality [5]. And success in precision agriculture is related to how well it can be applied to assess, manage, and evaluate the space-time continuum in crop production [6] that helps to overcome this threat in a smart way using modern information and communication technologies. It reduces the indecorous use of resources, pollution and hence improves the quality of life, which in turn helps to achieve sustainable development goals.

Existing trends are to reduce as much as possible human-work and replace it by robots - reflected in the final product costs. Thus, becomes imperative Sustainability - very strong related to carbon footprint, and Higher Production - world population is growing and hungrier. It is thus imperious to find solutions to increase, optimize and improve permanently the agricultural yield, being faster, more sustainable, more reliable and more efficient.

OVERALL CONCEPT

INSAC-AGRIS project objective aims to build an integrated autonomous system able to correlate DAQ from ground, plant and air and to design a pattern capable of triggering micro-differentiated application of additives and/or water to proposed crops in order to achieve best-optimized harvesting yield.

The system will be able to offers services able to collect, to correlate data acquisition systems from ground, plant and aerial levels and to predict crop properties from aerial collected imagery. Predicted data are able to trigger micro-differentiated or corrective application of additives or irrigation to crops in order to achieve one precision agriculture system for best-optimized harvesting yield.

The developed methodology stands on the following steps related to crop management & physical-chemical characteristics:

1. Preliminary aerial image-acquisition (VIS, UV, NIR);
2. Elaboration of orthophoto-maps;
3. Elaboration of ground sampling plan;
4. Elaboration of ground sensor typology and network;
5. Creation of a GIS system, based on parameters Database;
6. Algorithm/software development for data correlation;
7. Development of a map for variable distribution of inputs.

In terms of ground evaluation, data will be collected from soil sensors, validated by typical soil analysis, followed by plant monitoring, in vegetation and after harvesting. Data taken from mapping, consolidated with analyses and continuous monitoring, correlated with climatic parameters will constitute the patternable not only to suggest differentiated inputs application or micro-irrigation, but also to be able to predict the harvesting yield and production costs.

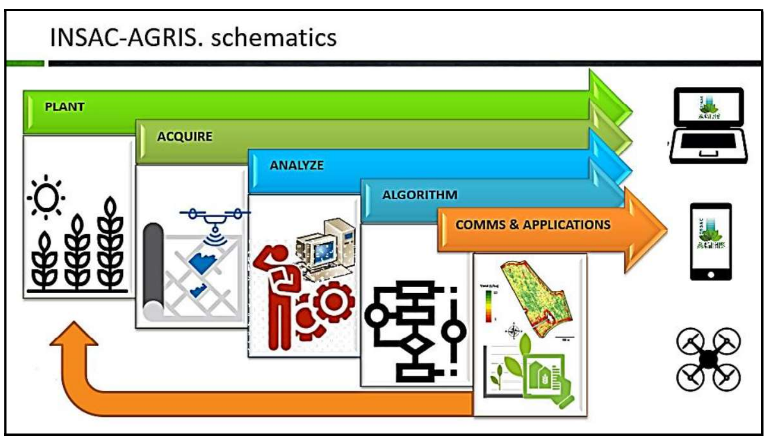

Fig.1. *INSAC AGRIS concept*

The proposed integrated system will provide farmers with the opportunity for better supervision of plants. So, the Consortium will develop a system able to analyze plant characteristics, plant population, weediness level, field health, growth problems, present diseases, involved pests or insects. Adding to the database the aerial imagery and ground data, analysis of soil and plants and adjust accordingly to climatic collected data, will create the base of the prediction system from only aerial data. Also, using a multi-spectral camera, several vegetation indices (e.g. NDVI, SAVI, etc.) and other plant physiology can be determined, completing the necessary information for building the prediction algorithms.

METHODOLOGY REPRESENTATIVE FOR SOIL SAMPLING

Soil analysis is a key practice to increase the efficiency of nutrient management in agriculture. Since the early 20th century, increasingly sophisticated methods have been developed to describe and manipulate the inherent spatial variability in soil chemical properties within the realms of classical and spatial statistics [7].

Soil sampling helps producers to develop management zones and prescription maps in precision agriculture, increasing the accuracy of rate and placement of necessary inputs (primarily fertilizers and lime to adjust pH) [8].

The total nutrient contents of the soil represent a sum of shapes with different degrees of mobility and accessibility, from the hard to mobilize form (present in minerals and compounds stable humic), to the relatively accessible one (present in altered minerals and organic matter in mineralization course) and to easily assimilable forms (elements changeable and solubilized in water from sol). Between these forms there is a dynamic, continuous balance, maintained by the continuous absorption of to plants of easily assimilable nutrients. Of the nutrients, N, P and K are frequently added to cultivated soils in the form of mineral and organic fertilizers, in various quantities, depending on the soil content in these nutrients and requirements of the cultivated plant. Also, in cases of occurrence of some phenomena micronutrient deficiencies in some cultivated plants, such as Zn deficiency in corn, deficiency of B to sugar beet and some trees, the lack of Mo to sunflower, completes the dowry natural micronutrients by administering mineral fertilizers with such elements chemicals. But to properly determine the need for macro- or microelements of soils, it is necessary evaluated (determined) the nutrient content of the soil. This operation is done within agrochemical mapping activity. It comprises three phases, one field, one laboratory and finally, an office one.

One of the functions of the soil is to produce phytomass, which is used as a matter basis for the production of food, clothing, fuels, etc. This function is set in value by appropriating the soil to be a continuous reservoir and supplier of water and nutrients, which are confers the general property of fertility. For plant growth, the soil provides many chemical elements necessary for development vegetation and crop formation. Of these, 14 are considered nutrients or essential nutrients. Depending on the quantity needed by the plants and their physiological and biochemical functions, nutrients are divided into macronutrients and micronutrients. In turn, macronutrients are divided in primary macronutrients (N, P and K) and secondary macronutrients (S, Ca and Mg). The group of micronutrients includes: Fe (a chemical element whose soil level is considered macroconstituent), Mn, Co, Cu, Zn, B, Mo, Cl. Soils contain different nature reserves of nutrients depending on nature parental material and soil type.

On another hand, soil testing is an integral part of a soil fertility management program. An effective soil testing planning provides information on the fertility status of soils within a field that can be used for making fertilizer recommendations, monitoring changes in soil fertility over time and even identifying and targeting low fertility soils within larger fields. The informative soil sampling highly improves on-farm nutrient efficiency, leading to increased return on investment for fertilizer and decreased risk of off-site nutrient movement. Regardless of the goal, reliable soil testing has to start with proper soil sampling and testing. In this regard, a proper soil sample collection relies on three principles, which constituted the basis of our methodology design, namely:

- ***Organization***: an orderly system for soil sample collection and handling simplifies the collection and minimizes the chance of human errors such as mislabelling or misplacing soil samples;
- ***Consistency***: collecting each sample in a uniform manner between the 3 years of project lifetime will greatly improve the quality and reliability of the results;
- ***Simplicity***: last, but not least, following simple procedures helped us to ensure sample collection which is consistent and easily organized.

But, in order to have a proper environment for digitalizing the reference data, first step to be taken is the experimental plots georeferencing and establish of the location of collection points for soil sampling.

RESULTS OF INVESTIGATION

The experimental plots are located one in Romania, the southern part of the country and exploited by AGROVET SA, having Mr. Laurentiu BERCA as leading the reasearches on their behalf and, the second in Hungary, the central part of the country and exploited by Kuspermezo Kft, Mr. Attila NAGY leading the reasearches and activity for this.

In the following are presented the results obtained after laboratory analisys for the experimental plot depictured in figure 2.

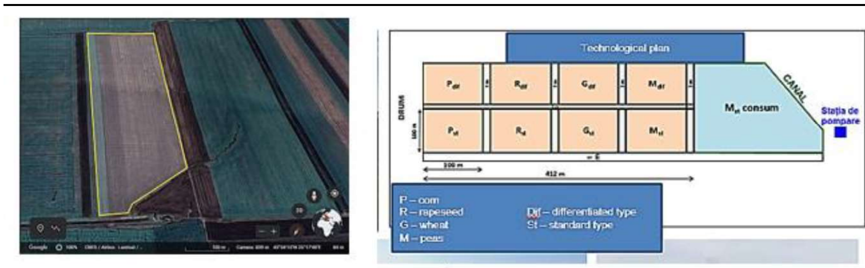

Fig. 2. *Georeferenced plot and crop planing*

The very practical aspect of this research is to provide to farmers the opportunity for better crop management by analysing plant characteristics, plant population, weediness level, field health, growth problems, diseases, involved pest or insects, vegetation indices, all completing the necessary information portfolio for model creation and building the prediction algorithms, protecting in this way the nature and increasing soil protection as well as optimizing economic activities in the SMART agriculture area.

The first stage of INSAC-AGRIS is to set up the parameters, analyse conditions and to adjust the triggers for the next year's stages. From this point of view, both teams from Romania and Hungary ran out of complementary field activities together with lab and office operations.

1. First step was to identify the parcels into a GIS software, measuring the borders and building the dimensional characteristics;
2. After identifying the experimental parcels, the soil samples map was built, using a grid of 50 m x 50 m and setting-up the GPS coordinates of the sampling points;
3. In the field, accordingly to the specific procedure, the soil samples were collected and labeled from the already mapped points using a GPS sensor;
4. Soil samples were minced and prepared in ampules for the lab, in order to keep the soil characteristics until the lab analyses;
5. Using the lab results, nutrients maps were made, loaded in the tractor computer and differentiated nitrogen soil enhancing was made;
6. The last operation made was sowing using the built maps introduced in the tractor computer.

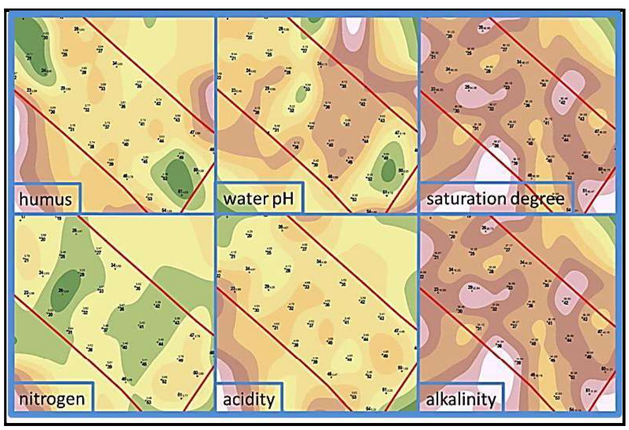

Fig. 3. *Soil composition characteristics for the Romanian experimental plot, before sowing*

CONCLUSION

Precision agriculture together with Internet of Things (IoT), can change the paradigm of agriculture from a manual and static approach to more dynamic and smart change, decreasing human efforts and leading to enhanced production.

The main conclusion following the activities made up until this moment in INSAC-AGRIS, is that keeping an organized approach of assessing the field, preparing for sowing with differentiated fertilization, brings an economy up until 80% of the sowing costs.

For the future research planned for the next two years, the benefit will be increased by including a cost-analysis evaluation for each sampling method used before sowing. This cost-analysis can include the time, money, and resources it takes to obtain the samples, as well as apply the recommended amount of material. This will help to further delve into the effect of soil sampling on management practices within farming operations.

The secondary conclusion is that automatized based agriculture machinery brings not necessarily a cost reduction, but an increase of agricultural works and more organized experimental plots.

The next step in the project is to bring the aerial assessment of the crops over the full vegetation period, before and after harvesting, so keeping regular feedback and allowing to intervene in a moment, when issues in soil quality or health status of the plant appear. In the future, INSAC-AGRIS plans to build a soil grid of sensors network able to alert in any moment the appeared issues.

This approach will become the basics of Agriculture 4.0, and building the framework for a sustainable agro-food system from Farm to Fork.

ACKNOWLEDGEMENTS

The activities described are supported by Eureka public network for international cooperation in R&D and innovation under the grant agreement E!13295-INSAC AGRIS.

REFERENCES

[1] Stafford, J. V. Implementing Precision Agriculture in the 21st Century, Journal of Agricultural Engineering Research, 76(3) 267-275, ISSN 0021-8634, 2000.

[2] Chang, J., Clay, D. E., Carlson, C. G., Clay, S. A., & Malo, D. D., Different techniques to identify management zones impact nitrogen and phosphorus sampling variability. Agronomy Journal, vol. 95(6), pp 1550–1559. https://doi.org/10.2134/agronj2003.1550, 2003.

[3] Lawrence P.G., Roper W., Morris T., Guillard K,. Guiding soil sampling strategies using classical and spatial statistics: A review, Agronomy Journal 2020;112:493–510 Soil Fertility & Crop Nutrition, https://doi.org/10.1002/agj2.20048 pp 493-510, 2020.

[4] Hedley C. The role of precision agriculture for improved nutrient management on farms. Journal of the Science of Food and Agriculture; vol 95: pp 12–19. 2015.

[5] Hengl, T., Rossiter, D. G., & Stein, A.. Soil sampling strategies for spatial prediction by correlation with auxiliary maps. Australian Journal of Soil Research, 41(8), pp 1403–1422. https://doi.org/10.1071/SR03005, 2003.

[6] Pierce, F. J., Nowak, P. Aspects of Precision Agriculture, Advances in Agronomy, Academic Press, 67 1-85, ISSN 0065-2113, ISBN 9780120007677, 1999.

[7] Lark, R. M., Towards soil geostatistics. Spatial Statistics, 1, pp 92–99. https://doi.org/10.1016/j.spasta.2012.02.001, 2012.

[8] Hausherr Luder, R.,Qin, R., Richner,W., Stamp, P.,&Noulas, C. Spatial variability of selected soil properties and its impact on the grain yield of oats (Avena sativa L.) in small fields. Journal of Plant Nutrition, 41(19), 2446–2469. https://doi.org/10.1080/01904167. 2018.1527935, 2018.