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Analysis and Protection of Soil in Controlled Regime Using Techniques Adapted to the Specifics of Precision Agriculture

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***Abstract*—**It is now unanimously accepted that conventional agriculture has led to the emergence and intensification of some forms of soil and environmental degradation, some of which are due to poorly applied or insufficiently substantiated technological measures. For this reason, the elaboration of any agricultural technology requires a deep knowledge of all the factors involved as well as of the interaction relations between them. This is also the way in which the research will be approached in this paper. Despite the fact that at European level the implementation of precision agriculture has a low level compared to some countries located on the American continent, it is emerging not only as an alternative to conventional agriculture but, as a viable way to preserve the quality of the environment in general, and the edaphic environment in particular. This gives an increased importance to the research in this paper through physical, chemical, biological, mineralogical and micromorphological analytical determinations, processing of analytical results, identification of processes, causes, factors, establishment of soil quality indicators and the perspective of measurements from distance by satellite techniques of some of these soil properties (humidity, temperature, pH, N, P, K and so on).

***Keywords*—**Conventional agriculture, environmental degradation, precision agriculture, soil.

I. Introduction

PRECISION agriculture has a completely new approach to the one we knew only a decade ago. It has managed to remain simple, easy to use, but in the same time much more accurate, and efficient from an economical perspective. The “self-orientation” technique, initially used on a small scale, was first implemented in 1970, year to be considered the reference year for precision agriculture. It is only in the last 15 years that reliable technologies have emerged that have had a significant impact on automation processes which enabled the development precision agriculture as it is known today. Tools that allow precise measurement of soil indicators are the base of precision agriculture, which allows farmers to streamline the agricultural process. In recent years, precision agriculture has become more popular among farmers, new technologies and offerings being available along the other benefits [1]. Some of the applications of this type of agriculture worth mentioning are the following. Firstly, GPS allows the precise tracking of any agricultural machine on the field. We can also have access to the detailed weather forecast, carefully dose the fertilizer and constantly monitor the condition of the crops. In agriculture, automation led to several types of data being collected based on which topographic maps were created, soil specific conditions monitoring, and accurate dosage of soil fertilizers [2]. Among the objectives of precision agriculture are: optimizing costs, increasing farm profits, and streamlining all resources allocated and used. Some of the key factors that need to be taken into account for maximizing the benefits of precision farming are the following.

A. Knowing and Fully Understanding the Properties of the Soil

Choosing the right cultivation technique can only occur after the soil characteristics are very well known. It is necessary for morphological, physical, hydro physical, agrochemical, biological analyzes to be performed in advance to any consideration and decision making for implementing precision technology [3]. Firstly, the soil needs to be divided into plots, and this can be achieved by measuring the surface via satellite or GPS systems. Soil samples from each plot are then required to be extracted, this action leading in the end to a complete, accurate view of the entire surface [4]. Once we know the properties of the soil, the data are introduced in the appropriate software that will aggregate all this information quickly and efficiently [5].

B. Carefully Dosing the Treatments for Each Plot

After obtaining data on soil quality, farmers can adjust the amount of fertilizers and plant protection products used more accurately. Another positive aspect of precision farming is the automation of individual treatments to save valuable time [6].

C. Monitoring the Crops

Constant monitoring is now possible thanks to new modern agricultural equipment connected to satellite systems such as GPS. An attractive option for many farmers is the use of drones, which facilitates effective monitoring [7].

Data can be collected in a variety of ways - for example by mounting sensors on tractors or other agricultural equipment equipped with GPS. The sensors measure everything in real time, from chlorophyll levels to plant water content.

It is also worth mentioning that even if the technologies used in precision agriculture may seem initially expensive, it is good to know that these costs can be high only at the beginning, the initial investment will pay off over time [8].

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II. Results Obtained

Until now, in Romania, GIS technology has been used in the following works in the field of soils and soils:

- Soils of the Danube Delta - RomSOTER-200, system that implements for Romania the SOTER methodology
- Geographic database of soils in Romania at 1: 1,000 scale .000, integrated in the European system EUSIS-SGDBE
- Spatial extrapolation of the results of agro-climatic modeling using GIS technology
- Geographic information system of soil resources "SIGSTAR-200".

SIGSTAR-200 was made on the basis of the information contained in about 50 map sheets that make up the "Soil Map of Romania at a scale of 1: 200,000", sheets published over a long period of time, whose information was updated according to a unique legend. The methodology for carrying out this GIS is presented first and then it continues with the main types of applications developed so far, namely: obtaining derived maps related to soil degradation processes (water erosion, wind erosion, siltation, pseudo gleization, salinization and alkalization) - characterization of the diversity of podocytes based on special quantitative indices - integration of data acquired by remote sensing.

III. SIGSTAR-200 Concept

The SIGSTAR-200 concept was developed in order to have a tool to help implement the strategy of sustainable use of natural resources and the practice of precision agriculture. This strategy consists in the development of a viable agriculture and agri-food industry, both economically and from an environmental point of view, as well as in the sense of achieving an ecologically stable infrastructure, while preserving biodiversity and promoting local natural differences.

Sustainable use of natural resources and soil protection are part of the global concept of sustainable development of society, which aims to "meet current requirements without compromising the ability of future generations to meet their own requirements" [11]. SIGSTAR-200 is designed so that decisions can be made at any time on the basis of outdated data and models. From a functional point of view, the system is divided into two major modules:

- MODULE I (operational) implements what is known theoretically, but not practically realized in Romania. It is continuously improved based on the results provided by the Module II.
- MODULE II (research) keeps pace with the evolution of the concept of sustainable management of environmental resources, focusing on soil and land resources. The development of GIS technology for soil protection and the practice of precision agriculture involves new methods of spatial analysis and the development of remote sensing technology involves: new sensors, new physical and biophysical models.

The development of information technology involves: the use of concepts and techniques in the field of neural networks, fractal theory, logic, the use of textural and morphological analysis of images; advanced visualization techniques.

The SIGSTAR-200 geographic information system addresses both decision-makers at the level of central governing bodies of agricultural and county policies, as well as researchers and farmers, being a specific tool for implementing the strategy of sustainable use of land resources and implementing precision agriculture in Romania.

The first step in making SIGSTAR-200 was to move the older map sheets (28 out of 50), made according to a legend, into the new legend published in 2015. As there was no correspondence between the two legends - old and new - this operation led not only to the change of the name of the cartographic units of soil, but sometimes of the boundaries of some territorial units of soil. Therefore, for older map sheets, the updated version was introduced in the SIGSTAR200 according to the new legend and not the printed version. Cartographic data were entered into GIS by two methods:

(1) scan-thin-vectorization, for the map sheets elaborated in the nine legends and in which there were the original editions of the printed maps;
(2) digitization according to a specially elaborated calculus, for the sheets that needed updating according to the new legend, or for which the original edition was not available. After the introduction and construction of the topology, the cartographic data were transformed into Gauss-Krüger and Stereo coordinates on the Krasovsky ellipsoid.

As descriptive data, for each territorial unit of soil, the three existing characteristics on the printed map were introduced: the cartographic unit (type or subtype of soil), the texture of the surface horizon and the skeleton.

From a computer point of view, SIGSTAR-200 was made with Arc/Info software packages. Currently, the database is maintained both in the vector format of Arc/Info GIS and in a standard exchange format in order to make these data compatible with other types of GIS. The hardware configuration on which the SIGSTAR-200 was developed included a network of high-performance computers and various peripherals: digitizer, scanner, plotter and printer. Since 2010, high-performance GPS devices have been added to this configuration, with which it is currently mandatory to position in the field in mapping studies.

A. The Main Types of Applications for SIGSTAR-200

SIGSTAR-200 is mainly used for obtaining derivative maps of degradation processes. In order to turn the SIGSTAR-200 into a decision-making tool, in the spirit of a sustainable use strategy for and for precision farming, a number of "standard end products" have been defined. These refer to maps of the following soil degradation processes: water erosion, wind erosion, siltation, pseudo gleization, excess moisture, salinization and alkalization. As a result, descriptive data were added to the SIGSTAR-200 by "expert" rules, which correspond to the classification of the soil cartographic unit in degradation classes defined as follows:

- water erosion classes: below 5%, between 5-25%, between 25-50%, between 50-75%, over 75% - affected area of the soil cartographic unit.

- wind erosion classes: below 5%, between 5-25%, between 25-50%, between 50-75%, over 75% - affected area of the soil cartographic unit.
- glaze intensity classes: zero (no danger of excess water), very low (danger of excess water in case of uncontrolled irrigation).
- moist groundwater, moderate excess moisture (danger of excess water only in rainy years - glazed subtypes), strong (danger of excess water if there is no artificial drainage).
- phreatic hydromorphic soils, strong excess moisture (quasi-permanent excess of water - swampy subtypes).
- pseudogley intensity classes: zero (no risk of excess water), low (low risk of excess water in rainy years) - chernozems from crovs; vertex subtypes of non-pseudogleyed soils, moderate (moderate danger of excess water in rainy years - pseudogleyed soils, vertisoils, flat soils, clinomorphic soils), very strong (prolonged excess of water - swampy soils).
- salinization intensity classes: zero, weak moderate, strong very strong
- alkalization intensity classes: zero, weak-moderate, strong-very strong.
- areas with a real risk of moisture deficit (see Fig. 1).

Direct use allows, for example, the measurement of soil moisture and roughness.

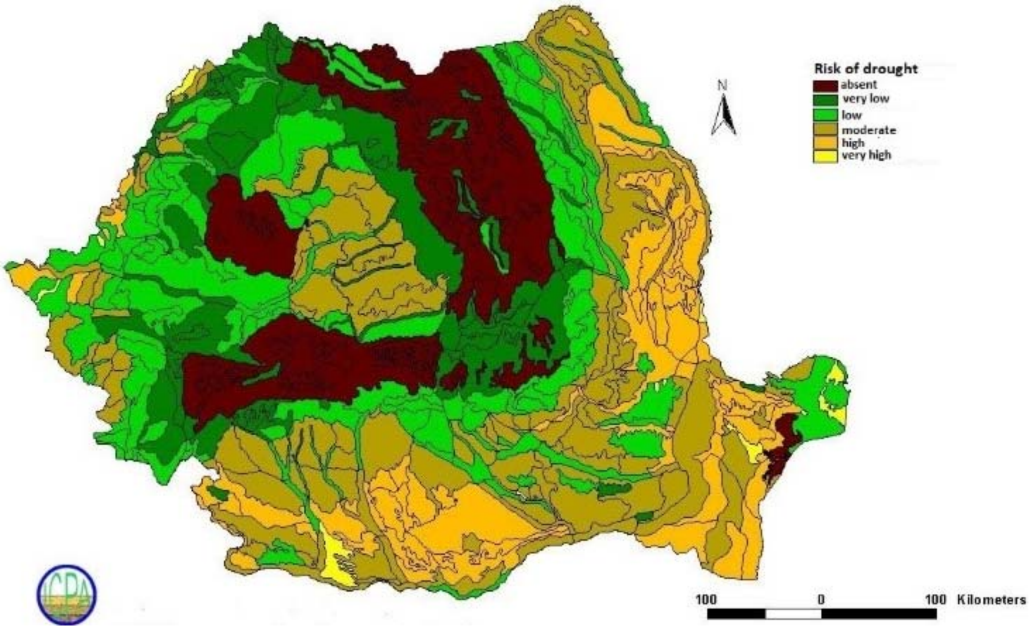

Fig. 1 Climatic risks taken into account when practicing precision agriculture

The corridor operated by ERS2 is 100 km, the one operated by RADARSAT varies between 50 and 500 km. An image covers a very large area in both cases, which is, in addition to the good correlation between σ ° and mv, a major advantage of using radar images purchased by satellites.

To estimate the parameters in the formula used for determining whether two pints are static independent which is used by the module, humidity and roughness measurements are required in representative areas of the site, areas that on the ground represent a disk that circumscribes the SAR pixel (ERS, respectively RADARSAT). The points where the measurements are made must be found in the radar image, therefore must be located in the field using GPS equipment.

The error must be below 1 pixel SAR, which means an error below 10 m. However, it is desirable that the accuracy be significantly better, i.e. the error is around 3 m, to meet the requirements of precision agriculture.

For humidity measurement at the selected points, soil samples shall be taken as close as possible to the surface time of the satellite, determining whether dew, haze, fog or rain are present at the time of sampling. It is also recorded whether such events occurred between the time of the satellite's passage and the time of sampling, when there is a significant gap between them (for example, one night).

Soil surface moisture can be determined based on the gravimetric method, on samples collected in cylinders, or with Time Domain Reflectometry (TDR) equipment. If it has 5 cm electrodes, they are inserted vertically; if they are longer, it is recommended to insert them obliquely, so that they integrate values also on 5 cm (valid for the C band, more precisely 5.3 GHz/5.6 cm) [9].

Roughness measurements are necessary because the retransmitted signal is significantly dependent on this feature. They are needed at least immediately after sowing, when the roughness is maximum, and towards the end of the phenological cycle, when the soil has a significantly lower and more constant roughness over time. In addition, it is good to make measurements even after exceptional climatic events, such as hail. The roughness profile is made perpendicular to the rows shown. The literature recommends additionally adding a roughness profile along the rows. Multiple repetitions are required for each point, the location of the repetitions within the disc being random [10].

Roughness is defined by two fundamental parameters: the standard deviation of the variation of the surface heights, σ ("rms height") and the surface correlation length, l ("surface correlation length"):

$$\tau = \left[\frac{1}{N-1}\left(\sum_{i=1}^{N}(z_i)^2 - N(\bar{z})^2\right)\right]^{1/2}$$

where Z = height "i" measured, N = number of measurements.

The surface correlation length is usually defined as the displacement for which the normalized autocorrelation function ρ is: ρ (l) = 1 / e, where ρ is for a spatial displacement x '= (j-1) Δx in the direction of the profile:

$$\rho(x) = \frac{\sum_{i=1}^{N+1-j} z_i x z_{i+j-1}}{\sum_{i=1}^{N} Z_i^2}$$

The correlation length of a surface provides a reference for estimating the statistical independence of two points on the surface. This means that if the two points are separated by a horizontal distance > l, then their heights can be considered statistically independent.

In order to be used in the processing of radar images, the roughness data must be measured with a special roughness meter so that:

- to allow the calculation of the correlation length, which means relatively long profiles (1.5 - 2 m)
- have a spatial sampling Δ x along the profile such that Δ x < λ / 10 (5), where λ is the wavelength of radar radiation.

B. Characterization of the Diversity of Ped Landscapes Based on Quantitative Indices

Several sets of quantitative indices have been defined in order to quantify the diversity and fragmentation of foot landscapes, to formalize the comparison between different foot landscapes and last but not least, to deepen the understanding of the structure, functioning and changes produced within foot landscapes. The area, the type of area and the pedestrian landscape were taken into account as hierarchical levels, defining indices of: surface, density, size and variability, shape, neighborhoods and diversity.

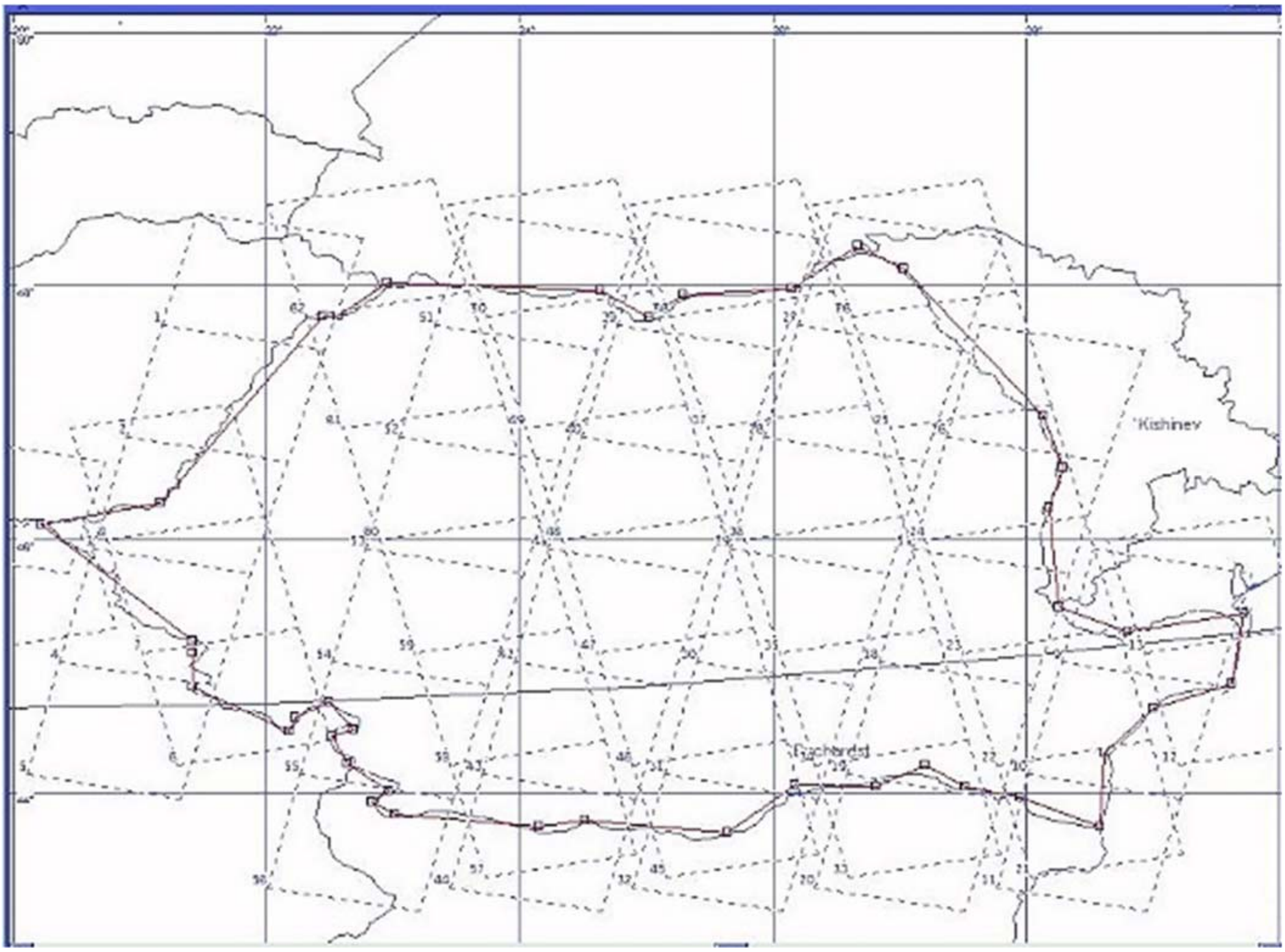

Fig. 2 Romania's satellite coverage mode taking into account the ascending and descending orbits of the satellite

C. Integration of Data Acquired by Remote Sensing

To explain the operation of the "vegetal carpet-pedological cover" system, the quantities accessible from data acquired by remote sensing are the following:

- for the hydric operation of the system.
- in the optical field: reflectance, albedo and structure of the vegetal carpet (% of ground cover with vegetation).
- infrared thermal field: surface temperature, water stress and evapotranspiration.
- in the field of microwaves (radar): surface humidity - for the function of assimilating carbon and nitrogen.
- in optical field: structure of the plant mat (leaf surface index and leaf tilt angle), chlorophyll pigments and nitrogen content, absorbed photosynthetic active radiation.

Fig. 3 SPOT-XS and ERS 2 satellite images from an agricultural area with fertile soils in southern Romania where precision agriculture is practiced

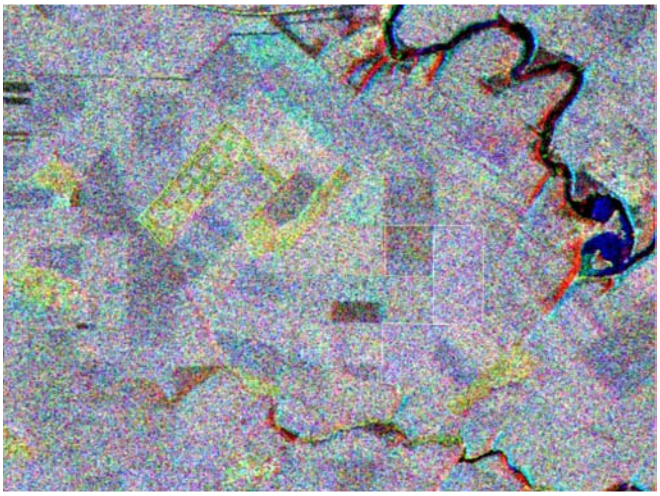

Fig. 4 SPOT-XS and ERS 2 satellite images from an agricultural area with fertile soils in southern Romania where precision agriculture is practiced

There are two approaches to the use of remote sensing data and precision agriculture:

- direct use in the form of vegetation indices or indices correlated with certain soil characteristics, an approach that has statistical or qualitative results, appropriate for regional or national scale through satellites (Fig. 2)
- indirect use, by assimilation in radiative transfer models coupled with agro physiological models, approach with quantitative results, suitable for both regional or national scale and local (plot) for precision agriculture (Figs. 3 and 4).

IV. Conclusion

The SIGSTAR-200 Geographic Information System on Soil Analysis and Protection has already proved its worth in assisting the decision-making process by providing standard end products in the form of thematic maps. In addition, the viability of the IT design has been validated, the system proving to be perfectly compatible with other GIS systems. Regarding the integration of remote sensing data and the practice of precision agriculture, this could be done with good results for a regional scale (drainage basin). The exposed methodology can be used as a case study for any area of the country.

The choice of the index for characterizing vigor or green biomass will be made mainly depending on the degree of soil cover with vegetation. The use of space remote sensing is conditioned by the cost of the images.

There are relatively inexpensive solutions for small-scale applications. Based on them, photosynthetic activity monitoring applications can be made at regional and national level. However, we notice a negative aspect, general at the level of our country, caused by the lack of a link in the research-development-extension activity, which has attributions of management and updating of GIS, after they have been made. However, the maintenance and development of geographical information systems, which are systems of great complexity and size and therefore very expensive, should be regulated in a medium to long-term vision, coordinated at European and national level so that precision agriculture to get us brave.

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