"POLITEHNICA" UNIVERSITY of BUCHAREST

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DOCTORAL THESIS

Summary

RESEARCH ON THE SYNTHESIS OF OPTOELECTRONIC SYSTEMS FOR SCANNING SOIL PROPERTIES

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Content

INTRODUCTION

Spectrophotometry is an optical method of analyzing the properties and composition of materials, substances, soil, etc.

Spectrophotometers are commonly used to measure the absorbance, transmittance or reflectance of solid, liquid, transparent or opaque solutions and materials.

Spectral determination using a spectrophometer can lead to very good results in the quantitative and qualitative knowledge of the composition of these components in the food chain, which can generally consist of soil or food samples (vegetables, fruits, cereals or processed products).

In the paper I analyzed the principles of spectrophotometry, I studied the architecture and operation of spectrophotometers appropriate to the topic and a number of necessary sensors. Based on the analysis I established architectures and structures for the synthesis of optoelectronic systems for determining soil properties. I performed experimental determinations of the spectra of samples of some soil types and processed the acquired data (statistical analysis, spectral analysis, comparative analysis, etc.). I performed experimental determinations of the spectra of samples of some soil types and processed the acquired data (statistical analysis, spectral analysis, comparative analysis, etc.).

The realization of an optoelectronic system that determines the properties of the soil, correlated with their graphic location opens the way for the realization of maps with the properties of the soil on a large scale.

1. FIELD PRESENTATION

In the doctoral thesis I approached the following areas:

Spectrophotometry, Transducer systems, Command and control systems, Precision agriculture

2. ANALYSIS OF THE PRINCIPLES OF SPECTROPHOTOMETRY

2.1 Introduction

The use of spectrophotometry in determining the composition of soil samples is a complex and very useful problem by contributing to reducing the effects of soil pollution and human health.

The use of synthetic chemicals in agriculture to increase agricultural production and provide food to the world is a process that has negative effects on the environment and human health. According to research conducted on a large scale it has shown that these synthetic substances, which are sometimes toxic (pesticides, herbicides, etc.), have a negative influence on human health in the end and by polluting the environment, which contributes to the greatest human challenge in present - climate change.

2.2.5 Lambert - Beer law

For a given sample, the absorbance depends on six factors:

- identity of the absorbent substances;
- concentration of the substance;
- the length of the path;
- wavelength of light;
- solvent identity;

- temperature.

Lambert-Beer law links transmittance (and thus incident and transmitted intensities) to the distance that radiation travels through the environment, to molecular absorbivity and to the molar concentration.

According to [19]:

$$T = \frac{I}{I_0} = 10^{-\alpha l} = 10^{-\varepsilon l c} \tag{2.15}$$

Where α is the absorption coefficient of the substance, l is the distance traveled by light radiation through the substance, ε is the molar absorbance (extinction coefficient), and c is the molar concentration of the absorbing species in the material traversed by the light radiation.

If the transverse absorption coefficient is denoted σ , then (as in biology and physics), the Lambert - Beer law, is written:

$$T = \frac{I}{I_0} = e^{-\sigma l N} \tag{2.16}$$

where N is the density of the absorbent particles (number of particles per volume).

In [22], [23], the relationship between absorbance, transmittance and reflectance is given in the formula:

$$A + T + R = 1 \tag{2.18}$$

In the case of opaque materials (soil), T = 0, which results:

$$A + R = 1 \tag{2.19}$$

2.4 Considerations regarding the tools used in soil analysis

To determine the composition of soil samples, 2 types of spectrophotometers are required: one with visible and partially near-infrared CCD sensor (CCD sensor and one for near-infrared InGaAs sensor). They will have to work simultaneously to obtain a spectrum in the field of approx. 220-2500 nm.

Knowing the composition of unwanted substance but also all the elements that contribute to the human food chain and not only is very important. Spectrophotometric methods can be very useful in this regard. Spectral determination using a spectrophometer can lead to very good results in the quantitative and qualitative knowledge of the composition of these components in the food chain, which can generally consist of soil or food samples (vegetables, fruits, cereals, processed products).

On this basis, databases will be set up with spectra for different soil types and different samples to which their properties determined in the laboratory will be associated. The spectrum measured for a soil sample will be compared with that in the databases on various criteria.

The measured spectra can be compared with the spectra of soils supposed to be infested with synthetic products or toxic products due to the application of intensive agriculture (chemical, administration of synthetic fertilizers or other compounds, polluted soil, etc.) and their classification can be made.

Spectrum comparison methods can be of several types:

- Direct comparison (spectral correlation);
- New method based on the Fourier Transform (especially FFT), with the development of frequency spectra (FFT) for "good" soils as well as for those to be analyzed and their comparison ;
- Other methods of comparison are the PCA and PLS method, etc.

There are currently, for example, databases with soil spectra worldwide, which are not 100% adapted for soil spectrum recognition but can be processed and adapted. Similarly, databases can be set up for spectra by categories of soil samples and possibly geographical areas that can be used in future determinations. Fig. 2.4.1 shows the principle scheme of the analysis of soil samples.

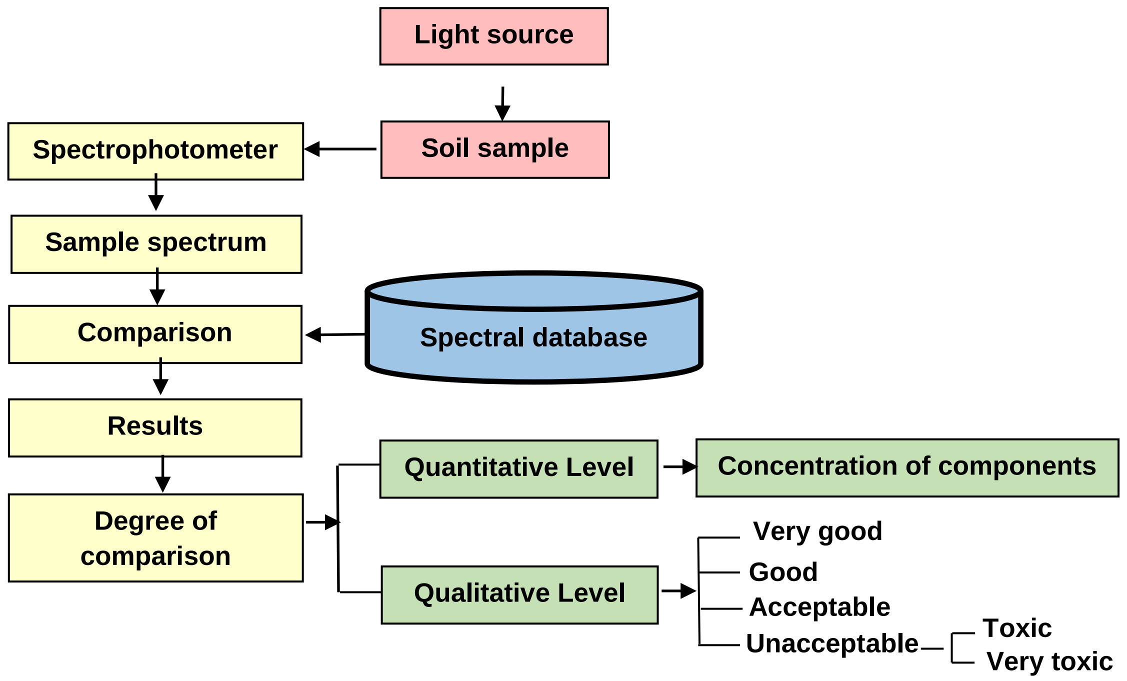

Fig. 2.4.1 Soil sample analysis diagram

The quality level can be established based on the degree of correlation by previous methods. In Figs. 2.4.2 a new approach based on Fourier analysis is presented [26].

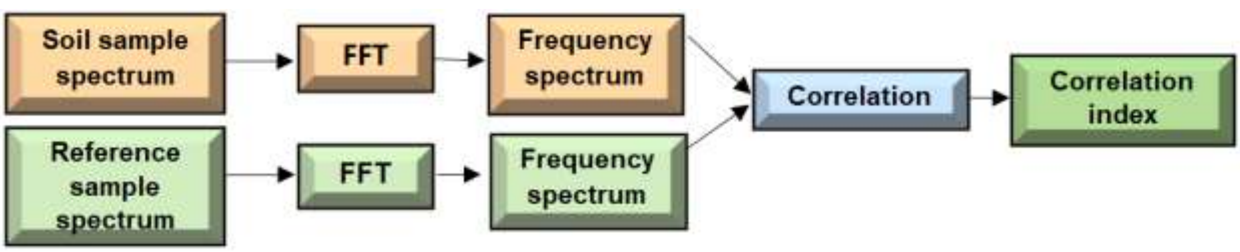

Fig. 2.4.2 FFT comparison method

3. ANALYSIS OF THE OPTOELECTRONIC SYSTEM FOR DETERMINING SOIL PROPERTIES

3.1 System structure

Mapping agricultural soils is the creation of maps that represent the characteristics of the soil or the amount of nutrients contained in it at various points with well-defined geospatial coordinates.

The complex system for mapping the properties of agricultural soils consists of: geostationary satellites “Global Positioning System” GPS or DGPS; computer equipment: PC or mobile computer for data processing; mobile equipment with: spectrometers covering the UV-VIS-NIR range, temperature sensor, optical sensor.

Software for processing data collected from the field: MATHCAD and MATHLAB for statistical and graphical processing of experimental data; MICROSOFT WORD for editing reports; MICROSOFT EXCEL for primary processing, statistics and graphics of experimental data; SOLO for data processing and chemometric data modeling; TransDatRO application for transforming the geographical coordinates corresponding to some points on the ground obtained with the help of GPS (Latitude, Longitude and Altitude) into x and y coordinates, respectively, for determining the 2D position of the points; MICROSOFT WINDOWS operating system; data acquisition software. Geographic Information System - GIS.

Determining the reflection or absorption of light radiation by the soil, materialized in spectra are useful for determining the main nutrients in the soil (nitrogen, phosphorus and potassium).

3.2 The main components of the system

3.3 Temperature and humidity transducer

Separate transducers or a single transducer that can measure both values simultaneously can be used to measure soil temperature and humidity.

The SM 300 Transducer from Delta-T Devices Ltd. (Fig. 3.3.1) can be used to determine the soil temperature and humidity with adequate accuracy for research work.

Fig. 3.3.1 Temperature and humidity transducer SM - 300 [29]

According to the description of the product on the website of the Romanian manufacturer and distributor [29] its main characteristics are: constant accuracy of ± 2.5%; stable to variations in temperature and salinity; maximum output voltage 1V.

How to convert read values in volts, temperature and humidity

The values read in volts are converted to temperature and humidity values according to the manufacturer's specifications, as follows: if the value read in [V] at the sensor output is V then calculate:

$$\sqrt{\epsilon} = 1.0 + 14.868V - 33.56V^2 + 51.223V^3 - 36.283V^4 + 9.715V^5$$

Using the table below the soil moisture can be calculated with the formula:

$$\theta = (\sqrt{\varepsilon} - a_0)/a_1$$

	a_0	a_1
Mineral	1.6	8.4
Organic	1.3	7.7

Tabel 3.2

and the desired values for soil, mineral or organic are obtained. Finally, the value is multiplied by 100 for an expression in%.

3.4.1 Inductive proximity transducers

Proximity transducers are non-contact displacement transducers and are used to detect the distance between two parts, to detect the presence of a body in the working area of the transducer, to detect the stroke ends of hydraulic or pneumatic cylinders, etc. [30].

In Figs. 3.4.1.3 an inductive proximity transducer is shown that is frequently encountered in practice and which can also be used in the optoelectronic system.

Fig. 3.4.1.3 Industrial inductive proximity transducer manufactured by Pepperl + Fuchs, USA, (45mm length, 8 mm working distance, 18 mm diameter)

The inductive proximity transducerwill be used in the project to transmit to the command and control unit the vertical position of the sampling system for determining humidity, temperature and pH. With the help of a cutting board the transducer will indicate three positions "UP" (the soil sample is in contact with the transducers and soil determinations are made), "DOWN" (the sampler is 5-15 cm in the ground) and "MIDDLE" (wash the pH sensor).

3.5 PH transducer

For the pH transducer used in the project, the WQ201 transducer (Fig. 3.5.1) from ENVCO [31] can be used.

The main features of the transducer according to the presentation on the ENVCO website are:

1. The WQ201 transducer is a fully encapsulated electronic component, 4-20 mA output;
2. The pH sensor can be replaced;
3. It is an accurate device for measuring the uneven pH of water. The sensor probe is mounted on a 25-foot (7.62 m) extensible cable that can reach lengths of up to 500 feet (152.4 m) as needed;
4. The output of the pH transducer is 4-20 mA, with a three-wire configuration. The electronic components are completely encapsulated in a stainless steel casing. The transducer also consists of a removable shield and a pH element for easy maintenance.

The voltage produced by the complete probe is a linear function of the pH, generally about 60mV per unit pH.

3.6 Global Positioning System GPS

I briefly present the GARMIN 17X HVS equipment according to the technical specification of the GARMIN manufacturer [32]. This equipment can be used in applications for soil properties determination systems.

GPS 17x HVS is water resistant is not affected by rain, it is generally resistant to environmental conditions in agriculture.

GPS 17X is available with the NMEA 2000 interface.

Refresh rate: 1 record / second;
Accuracy: Standard GPS (SPS): <3 meters; Differential WAAS / EGNOS / MSAS: <1 meters.
Interfaces: RS-232;

4. STUDY OF ARCHITECTURE AND PRINCIPLE OF OPERATION OF SPECTROPHOTOMETERS ADEQUATE TO THE TOPIC APPROACHED

4.1 Vernier SpectroVis Plus Spectrophotometer (SVIS-PL)

SpectroVis Plus is a portable visible and near-infrared spectrophotometer and is further presented according to the manufacturer's specifications [33].

Table 4.1 lists the main specifications.

Fluorescence support	Central excitation at 405 and 500 nm
Light source	Incandescent with LED support
Detector	Linear CCD
Wavelength range	380 nm–950 nm
Wavelength reporting interval	~1 nm
Characteristic scan time	~ 2 s

Tabel 4.1 Specifications of the Vernier SpectroVis Plus Spectrophotometer [33]

4.2 USB4000 Ocean Optics spectrophotometer

The Ocean Optics USB4000 Spectrophotometer is manufactured by Ocean Optics. It has a USB and serial port. When connected via USB, the spectrophotometer is powered from the host computer without the need for an external power source. USB4000, can be controlled with OceanView software based on the Java programming language.

Fig. 4.2.1 USB4000 Ocean Optics Fiber Optic Spectrophotometer [34]

4.2.1 Features of the USB4000 Ocean Optics spectrophotometer

Below are the characteristics of the USB4000 Ocean Optics Fiber Optic Spectrophotometer: works in the range of 200-1100 nm, adaptable depending on the diffraction device and the selections of the input slot; an optical resolution of 0.1 to 10 nm (FWHM); 16-bit built-in microcontroller; 3MHz A / D converter, 22-pin connector for interface.

USB4000 has both USB and serial port connectors (used with an adapter) and allows the spectrophotometer to be connected to a computer via a USB or serial port

4.3 The Hamamatsu C9914GB minispectrophotometer series TG

The Hamamatsu C9914GB TG series minispectrophotometer is described below according to the manufacturer's technical documentation [35].

Fig. 4.3.1 Hamamatsu C9914GB TG Series Minispectrophotometer [35]

Table 4.7 and Table 4.8 show the optical and electrical characteristics of the HamamatsuC9914GB TG series minispectrophotometer:

Parameter	TG-cooled NIR-II C9914GB	Unit of measure
Spectral response range	1100 to 2200	nm
Spectral resolution (FWHM)*2	8 max.	nm

Tabelul 4.7 Optical characteristics of the Hamamatsu C9914GB TG series minispectrophotometer [35]

Parameter	C9914GB	Unit of measure
A / D conversion	16	bit
Integration time	5 to 1000	ms
Interface	USB 1.1	-

Tabelul 4.8 Electrical characteristics of the Hamamatsu C9914GB TG series minispectrophotometer [35]

4.4 NIRQuest spectrophotometer

Brief description of the NIRQuest spectrophotometer [36]:

It is available in several models covering the range 900 - 2500 nm with different options for grills, slots and mirrors.

Features: High signal-to-noise ratio: 15,000: 1 to 7500: 1, depending on the model. Combined with a high dynamic range, this means that the highest accuracy, important for modeling, can be obtained; Deep TEC cooling from 35 ° C to 50 ° C under ambient. This means that the black current has decreased and the RSZ has improved; High resolution: 2nm - 12nm (dependent on slots and detectors); Configurable with a range of detectors, grilles and slots; Fast data transfer via USB and optional RS-232; Hamamatsu matrix linear detector; 16-bit converter, 500 kHz A / D; Integration times from 1 ms to 120 seconds (depending on the spectrometer model); Encapsulated microcontroller; 10 inputs / outputs;

4.5 FLAME spectrophotometer

The Flame spectrophotometer is part of the latest generation of "Ocean Optics" equipment. Its characteristics are presented according to the technical documentation of the manufacturer [37].

Fig. 4.5.1 Flame spectrophotometer

The Flame spectrophotometer has high thermal stability, low variation from unit to unit, is flexible and easily configurable, has interchangeable slots, LED indicators and simpler connectors, can be used both in the laboratory and in the field. It communicates via USB and can be programmed for serial communication.

Specifications in brief in the following table (table 4.15):

Specification	Variant 2048 pixels	Variant 3648 pixels
SPECTROSCOPY		
Optical resolution	Up to 10.0 nm (depending on configuration)	
Signal-to-noise ratio	250:1	300:1
ELECTRONIC		
A / D resolution	16 bits	
Inputs / Outputs	8 x programmable digital GPIO	
DETECTOR		
Detector	Sony ILX511B CCD silicone linear matrix	CCDToshiba TCD1304AP Silicone Linear Matrix
Detection range	0.19-1.1 µm	

Tabel 4.15 FLAME specifications

5 STUDY OF ARCHITECTURE AND PRINCIPLE OF OPERATION OF COMMAND AND CONTROL UNITS ADEQUATE TO THE TOPIC APPROACHED

5.1 ARDUINO DUE command and control unit

Arduino Due is a 32-bit ARM Cortex-M3 microcontroller board that uses the Atmel SAM3X8E processor. It can be implemented on both Windows and Linux (using the related drivers for installation).

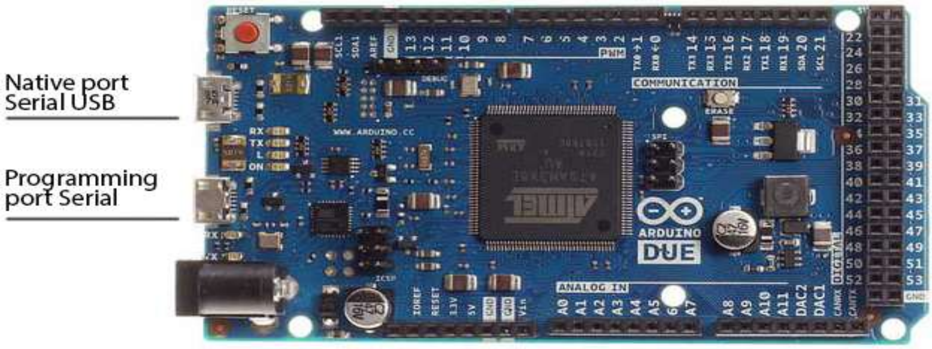

Fig. 5.1.1 USB ports for the Arduino Due board

The board has four UART channels. They are used for serial communication with external devices where TX is the serial transmission pin, while RX is the serial receive pin. Arduino Due contains 4 pairs of RX and TX serial pins.

This device is equipped with a serial peripheral interface (SPI) that plays a vital role in the communication between the microcontroller and other peripheral devices, such as travel registers and sensors. There are two pins used for SPI communication. The first is used to receive data, and the other helps the data to be sent by the microcontroller.

5.2 NI myRIO encapsulated controller

NI (National Instruments) **myRIO** is an encapsulated hardware device from National Instruments (NI). This is a reconfigurable and controllable I / O device. NI hardware is usually programmed with NI Labview, NI's graphical programming interface

Fig. 5.2.1 NI myRIO-1900©

NI myRIO © from National Instruments is equipped with a programmable Xilinx Zynq - 7010 FPGA device, which includes a dual-core ARM Cortex-A9 processor. The block diagram is presented in Figure 5.2.1. The FPGA has 28,000 programmable logic cells, 10 analog inputs, 6 analog outputs, 1 I / O audio channel and up to 40 digital input / output lines. The NI myRIO also has WiFi, a three-axis accelerometer and several programmable LEDs. NI myRIO is a tool used to implement engineering concepts as well as complex projects.

5.3 Raspberry Pi 3

The Raspberry Pi 3 board has a quad core / 64 bit / 1.4 Ghz / 1G RAM. A dedicated controller is also used.

Fig. 5.3.1 Raspberry Pi 3

Raspberry Pi 3 has the following important specifications: WiFi connection; Bluetooth connection; Ethernet network connection; USB communication (4); GPIO 40 pins; Memory stick;

5.4 DsPIC33FJ128GP804 MICROCHIP microcontroller

The dsPIC33FJ128GP804 microcontroller is part of the dsPIC33Fs series. This series is designed to run digital filter algorithms and high-speed digital control loops, ideal for applications that need to operate at high load. General purpose digital signal controllers (DSC) with advanced analog and perfect migration options to PIC24F, PIC24H MCU and dsPIC30F DSCs. Selective features present: modified Harvard architecture; compiler-optimized instruction set C; 24-bit long instructions, 16-bit data path; linear program memory addressing up to 4M instruction words; linear data memory that addresses up to 64 Kbytes; two 40-bit batteries with rounding options; indirect, modulo and bit-reverse addressing modes; 16 x 16 fractional / whole multiplication operations; 32/16 and 16/16 division operations; multiplying and accumulating a single cycle (MAC) with battery rewriting and dual data retrieval; on-chip Flash and SRAM; Up to 35 programmable digital I / O pins; analog-to-digital converters (ADC);

6. SYNTHESIS OF THE OPTOELECTRONIC SYSTEM FOR DETERMINING SOIL PROPERTIES

6.1 Introduction

The optoelectronic system for determining soil properties scans soils properties in real time to provide decision support for the development and maintenance of agricultural crops on various agricultural areas of farmers, administrators or their users.

Scanning involves sampling the soil with a resolution of a few meters to tens of meters by taking samples and determining their properties in real time.

The properties that can be determined are: pH, humidity and soil temperature at depths of 5 to 15 cm by sampling and data acquisition together with the geographical position of the equipment provided by GPS. Simultaneously the system acquires soil spectra with the help of spectrophotometers with a temporal resolution of one second or more depending on needs.

To perform soil properties scanning, the system must be mobile, able to move to the surface of the soil, take soil samples, or somehow scan the soil surface to retrieve data that is preprocessed and then stored with the help of an electronic memory that can be of several kinds depending on the volume of data.

In this way the system allows the collection of these properties (data) at distances per row from about 10 m to 100 m or even more for the sampling system and for the optical system of 5-10 m. The distance between rows can take values from a few meters to tens of meters, adjusting manually, with the help of adjustable markers or with the help of GPS.

6.2 System description

The main component parts of the system which due to its structure is a mechatronic system (mechanical - electronic) are: the pH transducer washing installation; mechanical system; electrohydraulic system; electronic command, control and data acquisition system; VIS-NIR spectrophotometer; GPS equipment; mobility insurance system (self-propelled) [38].

To these is added a portable computer for data processing, data interpretation and decision support with performance that allows the running of GIS programs, graphical representation of data, development kits for the command, control and data acquisition system, as well as followed by Office programs. It will also ensure communication with GPS for testing it as needed, communication with the central unit for the installation of command and control programs and reading or downloading the purchased data.

6.2.1 PH transducer washing system

For proper operation, the pH transducer must be washed before use. In order to determine the pH which is an important indicator of the properties of the soil, it is necessary to make an installation to ensure its washing after the analysis of a sample.

The main components of the installation according to Fig 6.2.1.1 are: 1) Water tank; 2) Faucet; 3) Water filter; 4) Pump; 5) “T” water dispenser; 6) Washing nozzles; 7) pH transducer; 8) Battery. The pumps are powered by the self-propelled system battery and are started by the command and control system for 1.5 - 2 seconds for washing the pH transducer. The command is given when the sampler is in the middle position (inductive transducer in the middle position, before sampling) [39].

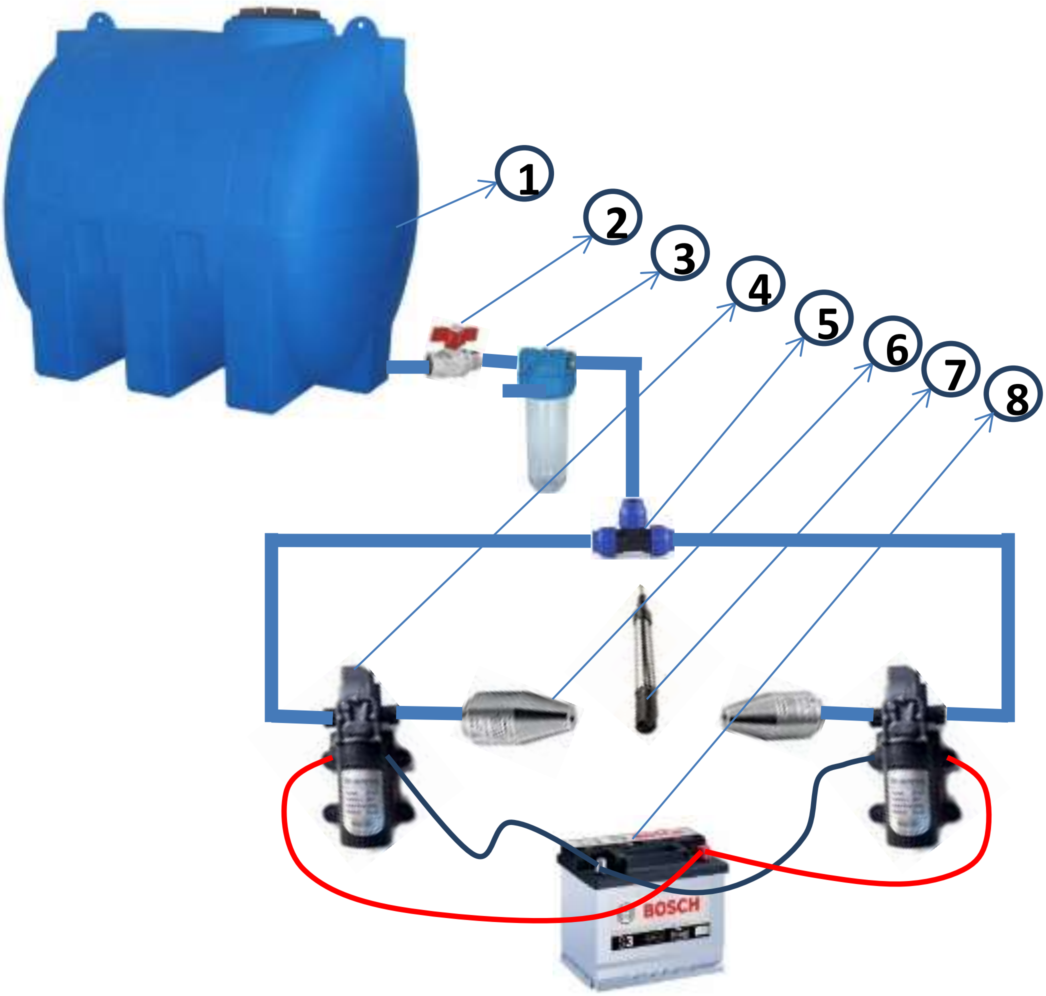

Fig. 6.2.1.1 Washing installation

6.2.2 The mechanical system

The main component parts of the mechanical system are:

- **Load-bearing structure** on 2 wheels with tires, which is coupled to the tractor or other means self-propelled in a classic manner by a bolt, on which the washing system, the hydraulic system, the transducer support and the inductive transducer are mounted.
- **The sampling system** consists of a bar structure of various profiles in the form of a parallelepiped, articulated in all the vertices of the parallelepiped in a vertical plane on which the sampler is mounted, which can be a coulter-like device that is hydraulically controlled according to Fig. 6.2.2.2 being driven by the hydraulic installation (hydraulic cylinder).

Also, on this structure which is mobile is mounted the **guide plate** which is integral with the bar structure. An inductive transducer is mounted on the coulter, which follows its movement vertically. The guide plate has cutouts and determines, depending on the position of the inductive transducer, the various commands for operating the cylinder (raising, lowering, stopping).

The main component of the sampling system is the sampler consisting of a coulter with a cylinder-shaped cutout through which the soil enters during travel and is stored in the rear tank where the sample is formed which is lifted by the hydraulic system so that the translators can enter it for measurements. The soil sample is held in this position for 1-2 seconds to analyze the sample.

In fig. 4.3 the elements of the sampler are presented: 1 - deformable parallelepiped; 2 - hydraulic cylinder (part of the electrohydraulic system); 3 - support bar for the coulter (rigid with the face of the parallelepiped on which it is mounted); 4 - coulter in the shape of a cylinder with a cup in the back for soil sample retention; 5 - pH transducer; 6 - temperature and humidity transducer.

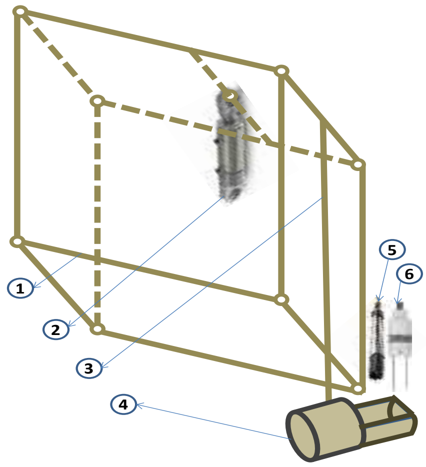

Fig. 6.2.2.2 Sampling system with deformable parallelepiped

6.2.3 Electrohydraulic system

The electrical component of the hydraulic system is supplied from the tractor battery and the hydraulic power is ensured by connecting it to the tractor's hydraulic system.

The main components of the hydraulic system according to Fig. 6.2.3 are: 1 - electrohydraulic servovalve; 2 - hydraulic cylinder that connects to: the command, control and data acquisition system; tractor hydraulic installation.

The electrohydraulic system acts by means of the hydraulic cylinder on the deformable parallelepiped and implicitly on the sampler ensuring its positioning in the three positions dictated by the guide plate by means of the inductive transducer.

In the top position the soil sample is in contact with the transducers and soil determinations of pH, humidity and temperature are performed.

In the middle position the sampler is at ground level and in this position the pH transducer is washed.

In the lower position the sampler is in the soil at a depth of 5-15 cm.

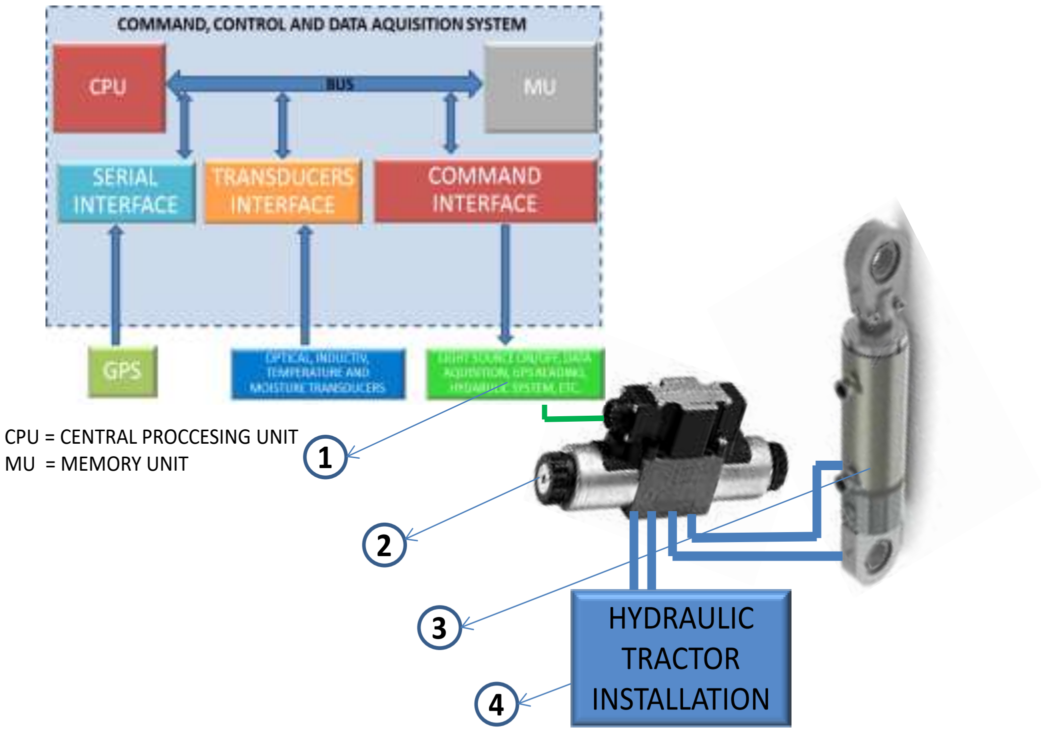

Fig. 6.2.3.1 Electrohydraulic system

6.2.4 Electronic command, control and data acquisition system

The command, control and data acquisition system is in interaction with the elements presented in Fig. 6.2.4.1 and shall be mounted on the load-bearing structure being powered by the tractor battery.

It performs:

- Command and control of the hydraulic installation by means of the inductive transducer, the guide plate and the valve actuating electromagnet;
- Defining the moments for washing the pH transducer, acquiring translator data and taking soil samples;
- Acquisition of data from the humidity, temperature and pH transducer and their storage;
- Acquisition of geospatial coordinates and GMT time from GPS (via the GPS satellite network) and their storage;
- Calculation of travel speed based on coordinates and GMT time provided by GPS, as well as distances between two samples.

In Fig. 6.2.4.2 the architecture of the optoelectronic system is presented. The main elements of the system architecture are: Command control system and data acquisition; Laptop; GPS; Transducers (pH, humidity and temperature, inductive); Coulter with optical sensor; spectrophotometers; Light source.

To these are added the execution elements (the ordered ones) made up of the electrohydraulic system and the washing system of pH transducer.

The VIS-NIR spectrophotometer is connected to the laptop via a USB interface, which picks up the absorbance or reflection spectra of the ground (depending on the spectrophotometer used) through the optical transducer which is mounted on a coulter that can penetrate the ground a few centimeters to take samples (spectra) at predetermined distances or time points (settable). The optical transducer is activated by light from a light source and reflected by the ground.

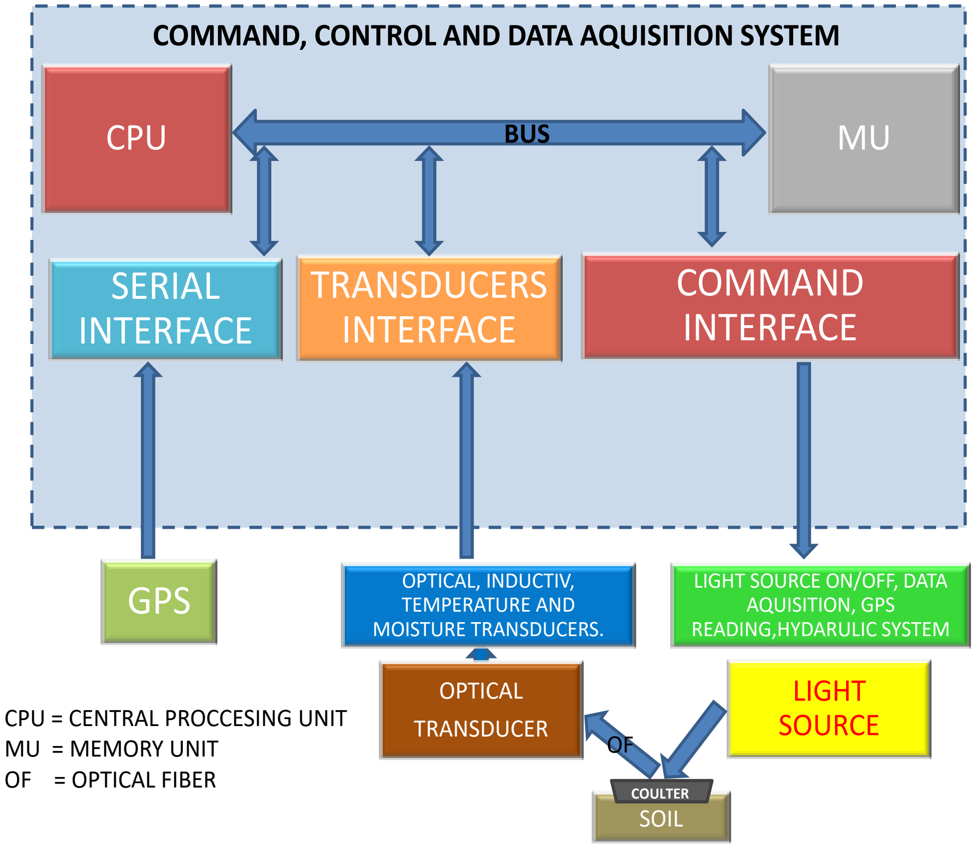

Fig. 6.2.4.2 Optoelectronic system architecture

6.3 Multifunctional section for reading soil parameters

During the research, new patentable solutions for scanning soil properties were identified. One of these is to change the way samples are taken using a device called a “Multifunctional section for reading soil parameters” [40]

The multifunctional section for reading the soil parameters mounted on a towed agricultural machine consists of the coulter 1 in the shape of a lying "V" , with the tip towards the direction of advance, from the support 2 for fixing on the frame, the tube 3 with spherical head provided with mouth for taking the soil samples, the shutter 4 which stops the soil inside the coulter for reading the parameters and allowing the taking of the soil sample, the gutter 5 through which the soil circulates or stops from which the samples are taken, the linear actuator 6 which acts vertically the shutter 4 between the ends of a slit on stroke c, the transducer 7 for determining the soil temperature and pH through the sensors S1 and S2, mounted jointly with the shutter 4, as well as an electronic data processing and storage system (Command and control unit - UCC, GPS, portable computer etc.).

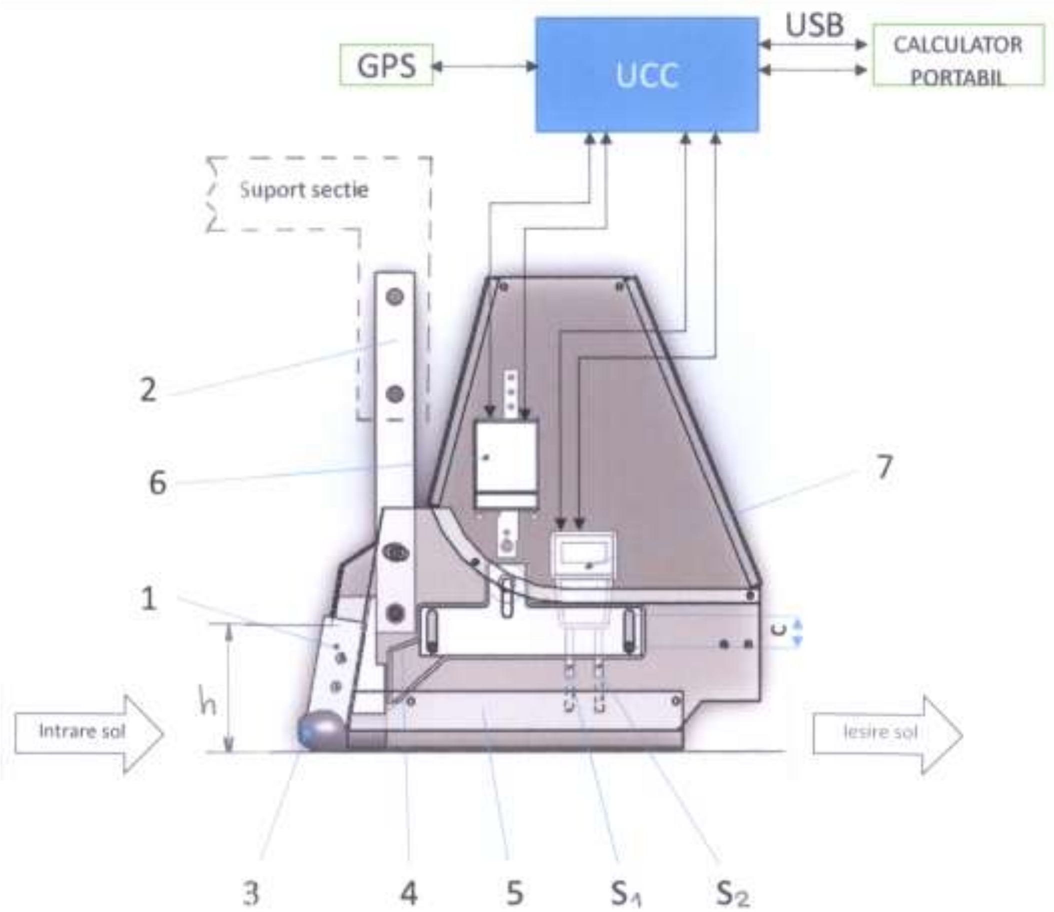

Fig. 6.3.1 Multifunctional section for reading soil parameters - general scheme

6.4 Intelligent soil sampling device

I present below an innovative solution to improve the positioning accuracy of the soil sampler and the sampling depth [41].

An intelligent soil sampling device contains an element called a command and control unit (UCC) and which commands and controls a number of other elements (servomechanism, sensors, etc.) for the purpose of uniform sampling and from the desired depth of soil samples in a short period of time.

For the uniform distribution of sampling points, the device has in its structure a displacement measuring transducer consisting of a gear wheel 5 which is mounted on the wheel hub of the mapping equipment and an inductive proximity transducer 6. Impulse signals from the transducer output 6 are transmitted to the command and control unit 9 and processed by it for the calculation of the displacement Lc. The distance Lref between two sampling points can be changed in real time by the operator via the operator console 10 or the system command and control unit and transmitted to the command and control unit 9 via the system communication bus. The command and control unit 9 compares the values of the signals Lref and Lc and when the difference between them is less than a required value it transmits a command signal for sampling the soil.

When sampling the soil, the command and control unit reads the values of the X, Y, Z coordinates of the point where the equipment for mapping the soil properties is located as well as the time t when the readings were performed via GPS. The values of the quantities X, Y, Z, t, Hc and Lc are transmitted through the system bus to the command and control unit of the equipment for processing and archiving.

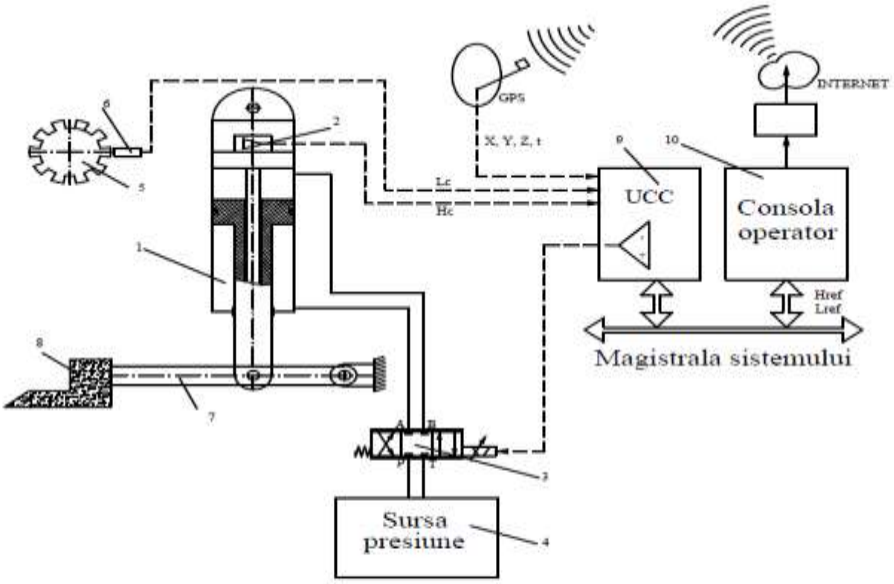

Fig. 6.4.1 - Intelligent soil sampling device - principle scheme

6.4.1 Device for driving soil property scanning platforms

Another innovative solution is presented below. This refers to the intelligent electronic command and control device that is intended for optoelectronic soil property scanning (DEC) platforms [42].

For the control of optoelectronic platforms for scanning soil properties, the intelligent electronic command and control device shown in fig.6.2.7.1 is provided with a distributive power supply module 1 for powering the device components, a serial interface (UART) 2 for communication with the module GPS c) and WiFi module b) that communicates with the graphical control interface (laptop, tablet, etc.) a), analog-to-digital converter ADC 3, logic-arithmetic unit 4, GPIO relay control module 5 for inputs and outputs of electrohydraulic equipment, RS485 6 serial interface for reading electroconductivity sensor measurements, RS485 7 interface for monitoring and reading pH-meter results, RS232 8 interface for controlling and retrieving data from the infrared spectrometer, RS232 9 interface for controlling and retrieving data from the spectrometer to the visible range.

The device commands and controls the hydraulic circuit for operating and washing the pH measuring system, the spectrometers necessary to determine the soil spectra, the electrical conductivity of the soil and the correlation of the data obtained with the position of the platform, provided by a GPS module c). Thus, the data obtained can be presented in GIS maps made with the help of specialized programs (ArcGis, Google Earth, etc.).

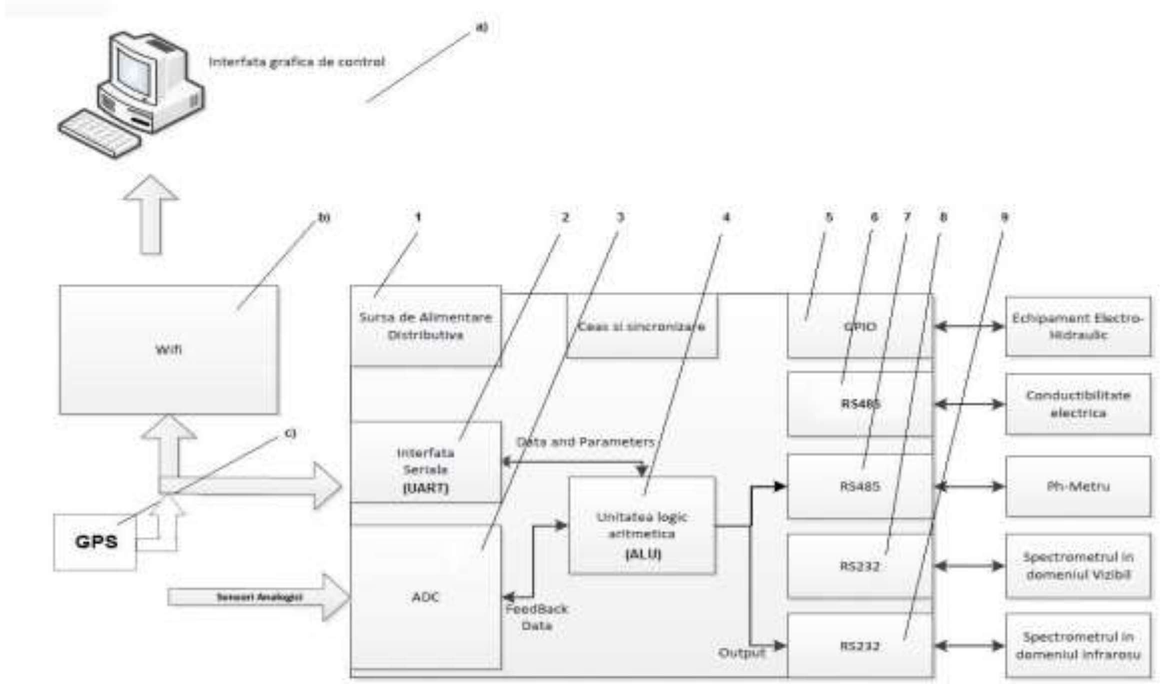

Fig. 6.2.7.1 Device for driving soil scanning platforms - the general scheme of principle

7. SIMULATION OF OPTOELECTRONIC SYSTEM OPERATION FOR DETERMINATION OF SOIL PROPERTIES

The simulation was performed using the LabVIEW program.

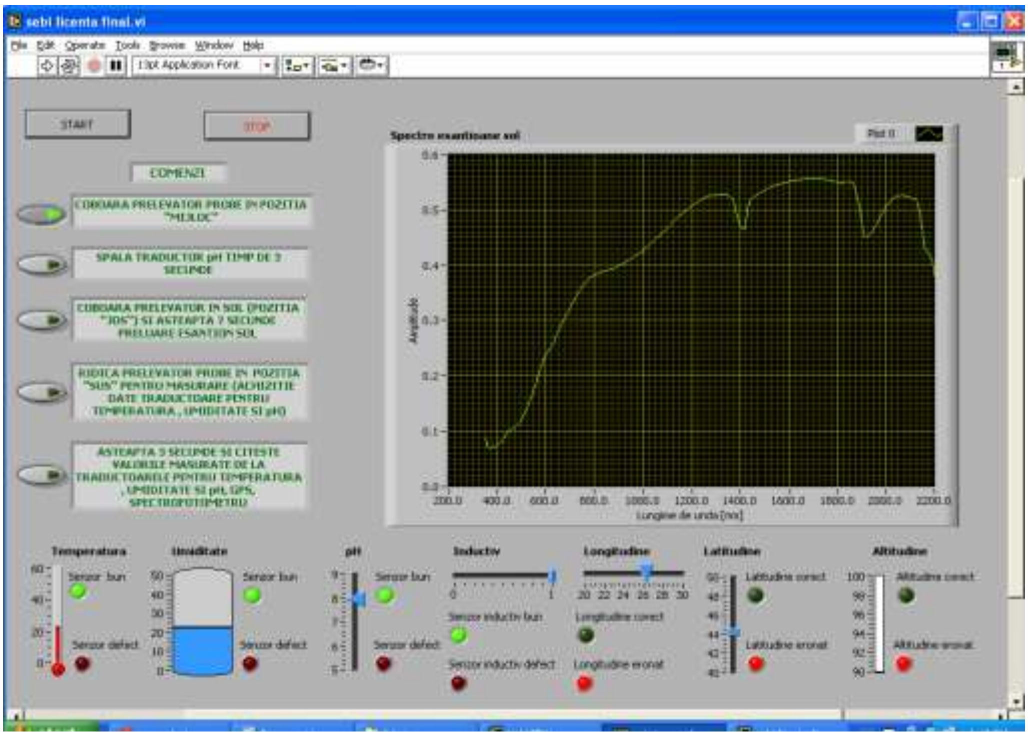

Fig. 7.1 Front panel for optoelectronic system simulation

The front panel design is intuitive and easy to use. Within the front panel the system elements are presented:

- The main commands of the optoelectronic system in their succession with the waiting times necessary to perform certain operations;
- The values measured by the transducers and associated indicators including the inductive transducer, as well as indicators of the correct operation of the transducers;
- Graph of the spectra of the soil samples measured by the spectrophotometer;
- Buttons to start the simulation process.

8. EXPERIMENTAL RESEARCH ON SOIL PROPERTY SCANNING

8.1 Experimental stand for determining the properties of soil properties

8.1.1 Components of the measuring system for the analysis of soil samples

The experimental stand for the determination of soil properties consists of the following components:

- Computing equipment: PC for storing and processing data with WINDOWS;
- Field sample spectrum processing software collected from the field:
  - MATHCAD and MATHLAB for statistical and graphical processing of experimental data and WORD for editing reports;
  - EXCEL for primary processing, statistics and graphics of experimental data.

In Figs. 8.1.1.1 the architecture and the information flow of the experimental stand is presented.

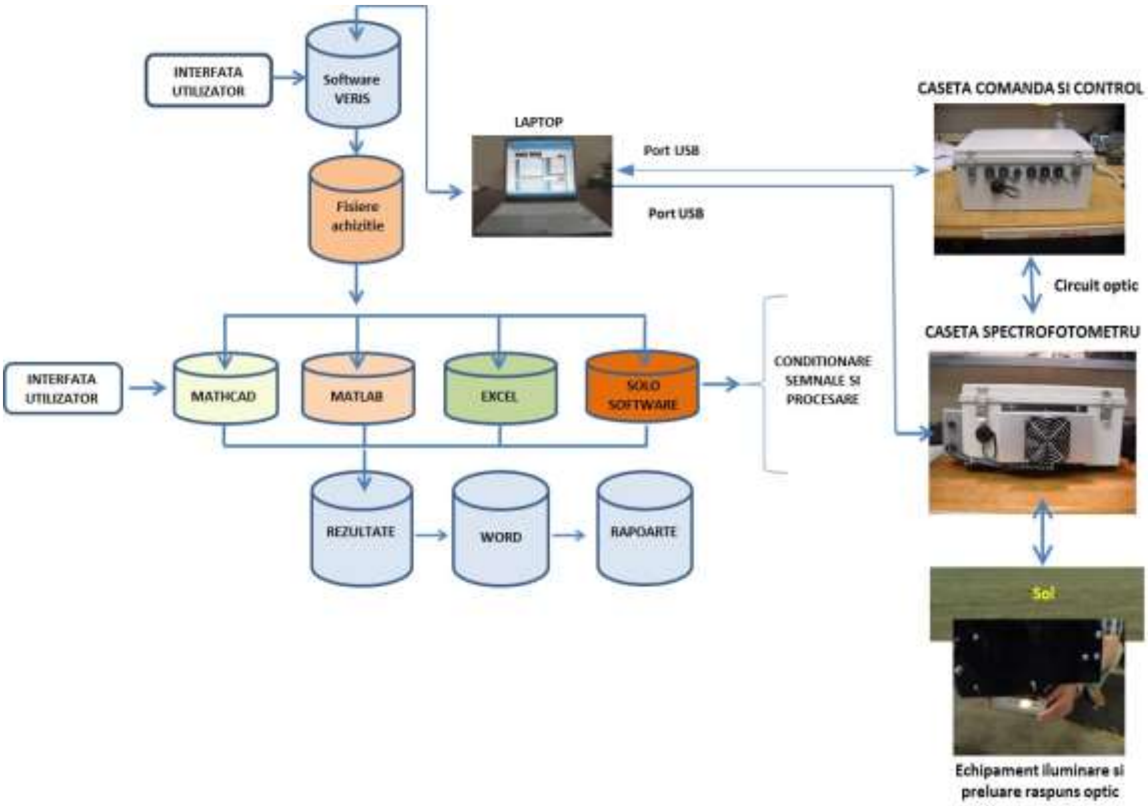

Fig. 8.1.1.1 Information flow within the measurement system for the analysis of soil samples

10. ANALYSIS AND IDENTIFICATION OF SOIL COMPONENTS

10.1 UV-VIS and NIR absorption spectra for soil analysis

By definition, visible and near-infrared spectroscopy is a spectroscopic method that uses the visible (200-1000 nm) and near-infrared region of the electromagnetic spectrum (limited to 800 nm and 2500 nm), for example between 200 nm and 2500 nm, approximately, field used in the experimental determinations, possible to cover and the use of two spectrophotometers Ocean Optics USB 4000 and Hamamatsu C9914GB series TG or Flame and NirQuest from Ocean Optics.

10.5.2 Database spectra

To analyze a spectrum taken in the field or laboratory, a spectral database of similar samples with known physicochemical properties is required. Certain statistical characteristics of the sample spectrum are estimated in comparison with each component of the spectral database, each of these characteristics being a measure of the "proximity" of the sample to each component of the spectral database.

The “proximity” of the sample spectrum is then ranked according to categories of characteristics or combinations of them, and then it is decided which is the spectrum in the database “closest” to the sample spectrum. After that, the physico-chemical characteristics of the “closest” component of the sample in the database are assigned in existing form or (if there are correction principles), corrected, to the sample.

10.5.4 Algorithm for processing the data of the samples taken

The spectra that will go through the process of processing and extracting information are the spectra harvested in the field either manually or automatically.
The basic algorithm of the comparison is not complicated, the operations being performed are:

1) storing the spectral sample data and choosing the comparison database;
2) both categories of spectra are passed in their minimum resolution, in order to be able to be compared in vector-accessible computer language;
3) comparison of each sample spectrum with each base spectrum by calculating the operators for estimating “recognition” or “approximation”, simultaneously forming one or more vectors (their number is equal to the number of recognition criteria used) with the values of the recognition characteristics.

For example, the sample spectrum from Fig. 10.5.4.3 is chosen and is compared with the spectra of the ISRIC - ICRAF database (passed in transmittance). The correlation estimator gives as the closest spectrum from the database the spectrum no. 2759 with a very high correlation coefficient of 0.9999, the same result being given by the distance recognition criterion. Therefore the soil corresponding to the spectrum of Fig. 10.5.4.3 can be attributed the soil properties with no. 2759 from the spectral database. At this step, in order to facilitate the understanding, I also give the variation of the recognition estimators, the estimator expressed by correlation, respectively the one expressed by distance, both in Fig. 10.5.4.4.

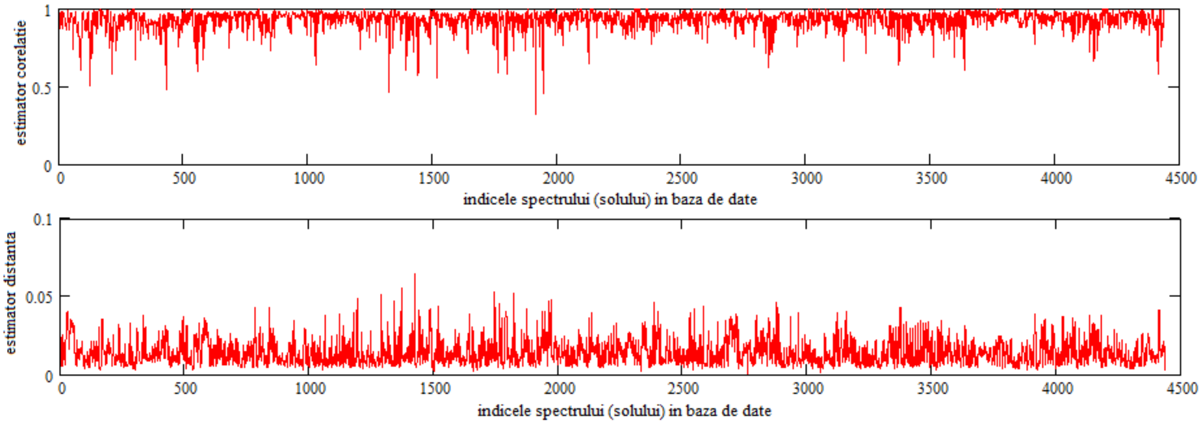

Fig. 10.5.4.4 Variation of recognition estimators with the spectral (soil) index in the spectral database, for a spectral sample

Physical and chemical data, mineral composition, classification and many other data about this soil as well as other soils from the ISRIC-ICRAF database can be extracted directly from the file in which this database is organized.

In Fig. 10.7.1 spectra of the reference base are given on the same graph, precisely to highlight the differences between them.

In Fig. 10.7.2 the correlation matrix between the components of the basic spectrum is given. It is observed that there are no fully correlated spectra.

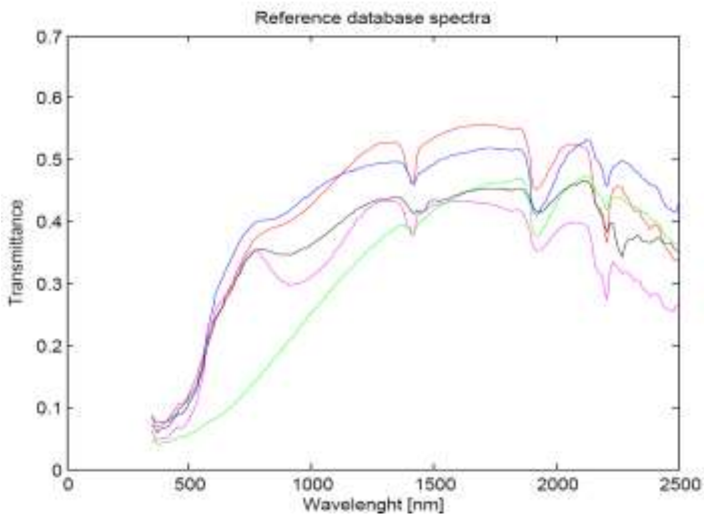

Fig. 10.7.1 Spectra of the reference base represented on the same graph

	s1	s2	s3	s4	s5	s6	s7	s8	s9	s10
s1	1	0.983	0.95	0.973	0.925	0.979	0.888	0.908	0.883	0.983
s2	0.983	1	0.991	0.997	0.859	0.961	0.955	0.966	0.805	0.987
s3	0.95	0.991	1	0.996	0.805	0.938	0.984	0.99	0.743	0.972
s4	0.973	0.997	0.996	1	0.853	0.963	0.965	0.976	0.798	0.987
s5	0.925	0.859	0.805	0.853	1	0.956	0.695	0.736	0.994	0.907
s6	0.979	0.961	0.938	0.963	0.956	1	0.872	0.9	0.921	0.979
s7	0.888	0.955	0.984	0.965	0.695	0.872	1	0.998	0.621	0.92
s8	0.908	0.966	0.99	0.976	0.736	0.9	0.998	1	0.665	0.937
s9	0.883	0.805	0.743	0.798	0.994	0.921	0.621	0.665	1	0.866
s10	0.983	0.987	0.972	0.987	0.907	0.979	0.92	0.937	0.866	1

Fig. 10.7.2 Matrix of correlations of the spectra in the reference base

Obtaining maps of the distribution of components in the soil

25 samples were taken at an equal distance from an area of about 80x80 sqm, which were analyzed using the experimental installation presented above.

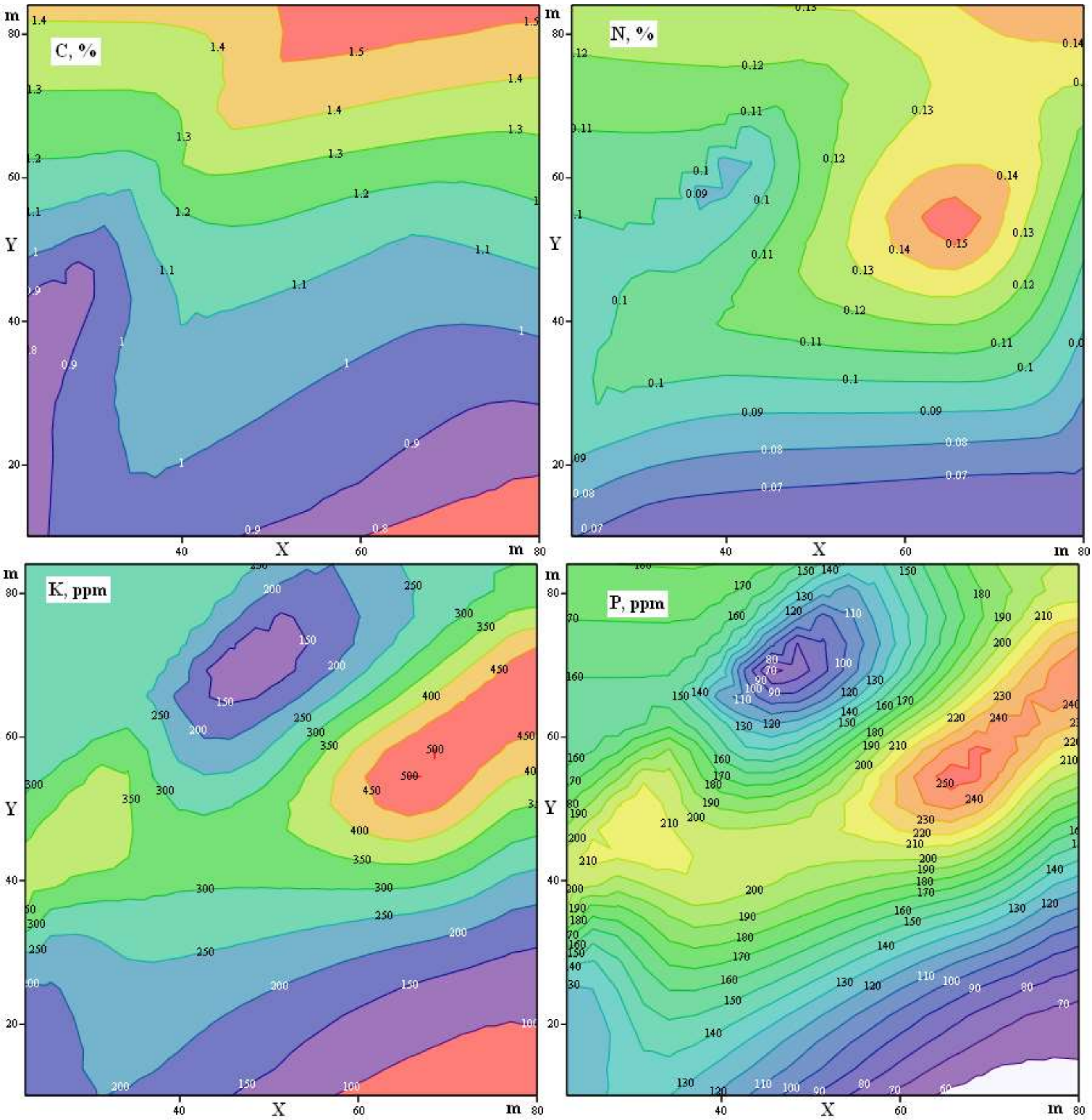

Fig. 10.8.1.1 Distributions of concentrations of organic carbon, nitrogen, potassium and phosphorus in the analyzed area

10.9 Program for calculating nutrient requirements based on soil properties

Fertilization is an agricultural work that aims to improve the soil in terms of macroelements (nitrogen, phosphorus, potassium, sulfur, calcium and magnesium) as well as microelements (molybdenum, boron, chlorine, copper, iron, manganese, nickel and zinc), by applying specific fertilizers.

10.9.3 Results

Based on the developed algorithm, a database was created together with the related software for its management [100] and the calculation of nutrient requirements based on measurements or estimates of nutrients and existing agrotechnical requirements for the crop.

The structure of the database contains tables and system tables with information for fertilization for each crop and main nutrients: N-nitrogen, P-phosphorus and K-potassium.

The software ensures the maintenance of the database using line commands or menu commands (fig. 10.9.5).

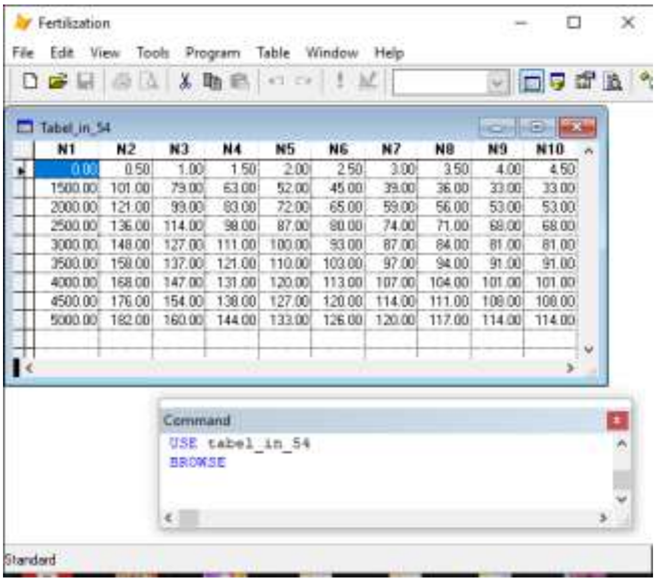

Fig. **10.9.5** Navigation of table in the command window

Input data is entered directly from an application form. The main input data are shown in fig. **10.9.6**.

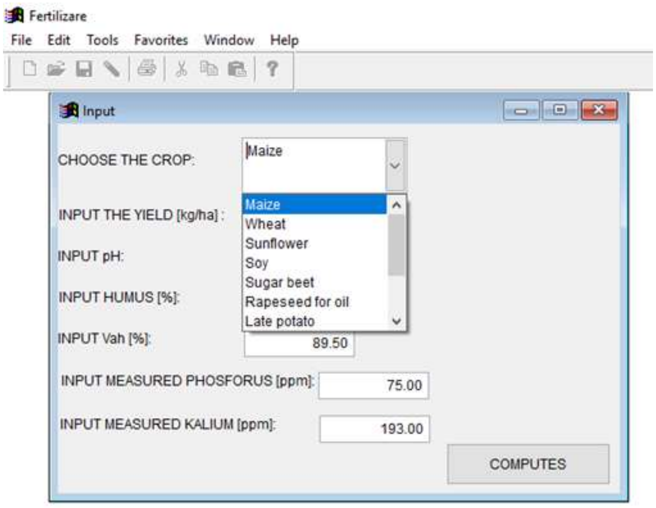

Fig. **10.9.6** “Input” dialog box

The application calculates the nutrient requirements for a location where soil samples were collected. The requirement is expressed in kg / ha.

Figure 10.9.9 shows examples of results obtained for maize and wheat crops when the data were entered correctly. These reports can be printed.

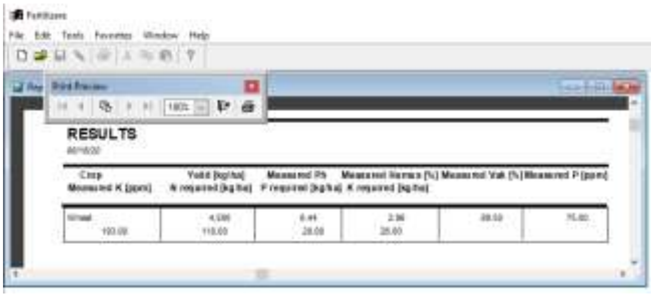

Fig. **10.9.9** Results obtained for wheat cultivation

The results obtained are stored in a table of results which contains the input data and the nutrient requirements. These are shown on the screen and can be printed or stored in a file.

11. ECO-NANO TECHNOLOGIES FOR SOIL CARTOGRAPHY

Following the research undertaken in a technology of fertilization of agricultural crops has resulted that is applied in the phase preceding the establishment of agricultural crops and continues with the other elements of fertilization of agricultural crops until harvest.

Fig. 11.1 Implementation and integration of eco-nano technologies for agricultural crop fertilization in the phase preceding the establishment of the crop

12. CONCLUSIONS

12.1 General conclusions

I selectively present general conclusions in the summary. Precision agriculture, more recently smart agriculture has opened up the possibility of widespread application of advances in electronics, information technology and GPS geographical location. The implementation of HIGH-TECH technologies in agriculture contributes to the increase of agricultural productions, simultaneously with the reduction of the impact on the environment. The main objective is the acquisition and processing with precision in time, space and information of the data obtained through measurement and geographical location systems on an agricultural land in order to obtain economic, agronomic and environmental benefits.

The development of an optoelectronic system for determining the properties of the soil requires a complex equipment that includes mechanical, electronic and information technology components. I have designed absolutely new solutions for the device for driving soil scanning platforms, the intelligent soil sampling device, multifunctional section for reading soil parameters.

I also implemented an experimental measurement stand for experimental determinations and measurements of soil sample spectra and experimental research was performed on their spectra. The acquired experimental data were processed by various means, techniques and methods. Based on the experimental results and numerical simulations, methods / techniques / algorithms were developed for identifying some components of the studied soil samples, with generalization possibilities.

I created a program to simulate the operation of the optoelectronic system in the LabVIEW program presented and the front panel of the process control was designed and realized through an interactive graphical interface.

For the local calculation of the necessary nutrients for each determination of soil properties, a software was developed for their calculation and a database associated with agrotechnical prescriptions.

Area of application of the system is wide due to the fact that agriculture is practiced globally and precision agriculture contributes substantially to the development of agricultural production and environmental protection. The use of precision agriculture and the development of electronic systems and sensors to contribute to its application have an upward trend.

Such systems are useful and necessary not only for Romanian agriculture, but also for world agriculture in general. The development of these systems and their large-scale integration at the level of specialized electronic components contributes to the application at the level of all farms, including small and medium-sized ones by ensuring profitability, due to the decrease in the cost price of the system.

The possibility offered to farmers to know the quality of their land (soil) with resolutions of a few meters or tens of meters is an essential element in approaching a sustainable agriculture that uses rational resources and at the same time achieves enhanced protection of the environment.

12.2 Specific conclusions (selective)

From the analysis of spectrophotometers appropriate to the topic, mainly the satisfaction of the requirement to cover the wavelength range (220-2500 nm) resulted the need to use 2 spectrophotometers that must work in parallel to cover the range.

The proposed recognition algorithm is able to sort the spectra by the spectra in the reference database. Also, the algorithm is simply extended until the elaboration of the distribution maps of the concentrations of some chemical elements in the case of geospatial determinations (the geodetic coordinate of the sampling location is also introduced - with GPS);

The accuracy of the determinations of the various elements depends essentially on the accuracy of the elements of the reference base. The elements must be selected so as to have as different concentrations as possible in the same element. As a result, two spectra of soils with the same concentration of all elements of interest, it is better not to be admitted in the same reference base.

Due to the wide market (globally) for such determinations, a potential direction of research consists in the realization of universal analysis systems for vegetables, fruits, soil, human and animal food, soil, etc.

The topic addressed in the paper is of interest and aims at a wide market for the system and methods resulting from research, due to the field with global impact - agriculture, as well as its high-tech component - spectrophotometry.

12.3 Original contributions

The original contributions are presented below:

- the study of the principles of spectrophotometry for the elaboration of the analysis methods and the determination of the properties of the soil samples;
- architecture and experimental stand configuration for determining soil sample spectra;
- elaboration of algorithm, method and software for identifying the composition of soil samples with generalization possibilities;
- generalizing the recognition of a spectrum from a database by identifying the correspondence between 2 collections of data series, articol “P. Cardei, S. Muraru, R. Sfiru and V. Muraru, "Identification of correspondents between a standard series collection and an experimental series collection," 2019 11th International Conference on Electronics, Computers and Artificial Intelligence (ECAI), Pitesti, Romania, 2019, pp. 1-6, doi: 10.1109/ECAI46879.2019.9042028”;
- design of equipment for scanning soil properties, articol “Sebastian Lucian Muraru, Vergil Muraru, Petru Cardei, Cornelia Muraru-Ionel, Laurentiu Vladutoiu, SCANNING EQUIPMENT TO ASSESS PHYSICAL SOIL PROPERTIES, Proceedings of the 45th International Symposium on Agricultural Engineering, Opatija, Croatia , 21 - 24 February 2017, ISSN 1848-4425, pag 25 – 34”;
- elaboration of a structural model of an intelligent farm, articol “Muraru S., Muraru V., Schiopu P., Pirna I., Cardei P., “THE STRUCTURAL MODEL OF THE SMART FARM TO IMPROVE ENVIRONMENTAL PROTECTION”, Oral presentation at The 18th International Multidisciplinary Scientific GeoConference SGEM 2018, 2 July - 8 July 2018, Albena, Bulgaria, vol. 18, Issue 5.1, ISSN 1314–2704,DOI: 10.5593/sgem2018/5.1, pp. 979 – 986”;

- the design of the device for driving soil scanning platforms, **patent application OSIM A/00501** from 19.08.2019;
- intelligent device design of soil sampling, **patent application OSIM A-00372** from 20.06.2019;
- the design of the multifunctional section for reading the soil parameters, patent application OSIM A/00734 from 13 11.2019;
- acquisition of well-determined surface soil spectrum samples and at regular spatial intervals and their analysis;
- elaboration of the new method of photometric spectrum analysis based on FFT analysis;
- elaboration of Matlab and MathCAD programs for the implementation of the original contributions and the processing of the experimental data;
- development of software and database associated with agrotechnical prescriptions for the local calculation of the nutrient requirement for each determination of soil properties;
- elaboration of eco-nano technology for soil fertilization.

12.4 Dissemination of results

Articles:

1. **Sebastian Lucian Muraru**, Vergil Muraru, Petru Cardei, Cornelia Muraru-Ionel, Laurentiu Vladutoiu, SCANNING EQUIPMENT TO ASSESS PHYSICAL SOIL PROPERTIES, Proceedings of the 45th International Symposium on Agricultural Engineering, Opatija, Croatia , 21 - 24 February 2017, ISSN 1848-4425, pag 25 – 34, **ISI article**;
2. **Sebastian Lucian Muraru**, Vergil Muraru, Paul Șchiopu, Petru Cardei, Cornelia Muraru-Ionel, RESEARCH ON SOIL PROPERTIES ANALYSIS USING SPECTROPHOTOMETRY, Proceedings of 17th International Multidisciplinary Scientific Geoconference SGEM 2017, Vol. 17, ISSN 1314-2704, DOI: 105593/sgem2017/32, Albena, Bulgaria, 29 June – 5 July 2017, pag. 461 – 468, **BDI- SCOPUS article**, **under ISI evaluation and indexing**;
3. **Sebastian Lucian Muraru**, Paul Șchiopu, Petru Cardei, Vergil Muraru, Cornelia Muraru-Ionel, ENVIRONMENTAL PROTECTION THROUGH HIGH RESOLUTION EVALUATION OF SOIL, Proceedings of 17th International Multidisciplinary Scientific Geoconference SGEM 2017, Vol. 17, ISSN 1314-2704, DOI: 105593/sgem2017/52, Albena, Bulgaria, 29 June – 5 July 2017, pag. 335 – 342, **BDI- SCOPUS article**, **under ISI evaluation and indexing**;
4. **Muraru S.**, Muraru V., Șchiopu P., Pirna I., Cardei P., “THE STRUCTURAL MODEL OF THE SMART FARM TO IMPROVE ENVIRONMENTAL PROTECTION”, Proceedings of the 18th International Multidisciplinary Scientific GeoConference SGEM 2018, 2 July - 8 July 2018, Albena, Bulgaria, vol. 18, Issue 5.1, ISSN 1314–2704,DOI: 10.5593/sgem2018/5.1, pp. 979 – 986, **BDI- SCOPUS article**, **under ISI evaluation and indexing**;
5. **Muraru S.L.**, Cardei P., Muraru V., Sfiru R., Condruz P., RESEARCH REGARDING THE USE OF DRONES IN AGRICULTURE, Proceedings of „19th International Multidisciplinary Scientific GeoConference SGEM 2019”, Albena, Bulgaria, Vol. 19, Issue 6.2, ISSN 1314-2704, pp. 683 – 690, **BDI- SCOPUS article**, **under ISI evaluation and indexing**;
6. P. Cardei, **S. Muraru,** R. Sfiru and V. Muraru, "Identification of correspondents between a standard series collection and an experimental series collection", *2019 11th International*

Conference on Electronics, Computers and Artificial Intelligence (ECAI), Pitești, Romania, 2019, pp. 1-6, doi: 10.1109/ECAI46879.2019.9042028", **ISI article**;

7. Vergil Muraru, Petru Cardei, Sebastian Muraru, Cornelia Muraru-Ionel, Paula Condruz, CONVERGENCE OF DIFFERENT MODELS FOR THE SAME STRUCTURE IN COMPUTER AIDED ENGINEERING, Proceedings of the 46th International Symposium, "Actual Tasks on Agricultural Engineering", Opatija, Croatia, 27 February - 1 March 2018, ISSN 1848-4425, pp. 263-271, **ISI article**;
8. Vergil Marian Muraru, **Sebastian Lucian Muraru**, Cornelia Muraru-Ionel, Paula Condruz, Raluca Sfîru, EFFICIENT USE OF WATER IN AGRICULTURAL CROPS BASED ON SATELLITE INFORMATION, Proceedings of the 18th International Multidisciplinary Scientific GeoConference SGEM 2018, 2 July - 8 July 2018, Albena, Bulgaria, vol. 18, Issue 6.1, ISSN 1314–2704, DOI: 10.5593/sgem2018/6.1, pp. 615 – 622, **BDI- SCOPUS article**, **under ISI evaluation and indexing**;
9. V. Muraru, P. Cardei, R. Sfiru, **S. Muraru**, P. Condruz, IDENTIFICATION AND FORECAST OF DROUGHT STATUS FOR CLIMATE CHANGE MONITORING, 17th International Multidisciplinary Scientific GeoConference SGEM 2017, Vienna GREEN Conference Proceedings, ISSN 1314-2704, 27 - 29 November, 2017, Vol. 17, Issue 43, pp. 405-412, **BDI-SCOPUS article**, **under ISI evaluation and indexing**;
10. Vergil Marian Muraru, Petru Cardei, Cornelia Muraru-Ionel, **Sebastian Muraru**, Tania Țicu DATABASES AS SUPPORT FOR ENVIRONMENTAL MANAGEMENT AND PROTECTION, Proceedings of the 44th International Symposium on Agricultural Engineering, Actual Tasks on Agricultural Engineering, Opatija, Croatia, 23rd – 26th February 2016, ISSN 1848-4425, pp. 499 – 508, http://atae.agr.hr/44th_ATAE_proceedings.pdf, **ISI article**;
11. Vergil Marian Muraru, Cornelia Muraru-Ionel, Petru Cardei, **Sebastian Muraru**, Tania Țicu, SPATIAL DATABASE FOR IMPROVING THE PUBLIC AWARENESS ON ENVIRONMENTAL MANAGEMENT AND PROTECTION, International Multidisciplinary Scientific GeoConference: SGEM: Surveying Geology & mining Ecology Management, Vol. 1, 2016, pp. 843-850, **ISI article**;
12. Condruz P., Berevoianu B., Muraru V., Dulgheru A., **Muraru S.**, Sfiru R., FERTILIZATION ALGORITHM IN AGRICULTURE /ALGORITM DE FERTILIZARE ÎN AGRICULTURĂ International Symposium ISB-INMATEH Agricultural and Mechanical Engineering, 31 Oct. – 1 Nov. 2019, INMA Bucuresti, pp. 876 – 882, **BDI article**;
13. Muraru V., Cardei P., Muraru-Ionel C., **Muraru S.L**., Sfiru R., Radu O., Condruz P., CONCEPTION AND DEVELOPMENT OF TECHNICAL SYSTEMS FOR SUSTAINABLE AGRICULTURE, ISB-INMA TEH 2017, International Symposium, „ISB – INMA TEH AGRICULTURAL AND MECHANICAL ENGINEERING" Proceedings, Bucharest, Romania, 26 – 28 Oct. 2017, pp. 867 – 874, **BDI article**;
14. **S. Muraru**, P. Condruz and I. Calciu, "Development of software for optimizing the fertilization of agricultural crop", ECAI 2020 INTERNATIONAL CONFERENCE *12th Edition* Electronics, Computers and Artificial Intelligence, Pitești, Romania, 25-27.06.2020, **pending ISI publishing and indexing**;

Scientific communications

1. **Sebastian Lucian Muraru**, Vergil Muraru, Paul Șchiopu, Petru Cardei, Cornelia Muraru-Ionel, RESEARCH ON SOIL PROPERTIES ANALYSIS USING SPECTROPHOTOMETRY, Oral

presentation at The 17th International Multidisciplinary Scientific Geoconference SGEM 2017, Albena, Bulgaria, 29 June – 5 July 2017.

2. **Sebastian Lucian Muraru**, Paul Șchiopu, Petru Cardei, Vergil Muraru, Cornelia Muraru-Ionel, ENVIRONMENTAL PROTECTION THROUGH HIGH RESOLUTION EVALUATION OF SOIL, Oral presentation at The 17th International Multidisciplinary Scientific Geoconference SGEM 2017, Albena, Bulgaria, 29 June – 5 July 2017
3. **Muraru S.**, Muraru V., Șchiopu P., Pirna I., Cardei P., "THE STRUCTURAL MODEL OF THE SMART FARM TO IMPROVE ENVIRONMENTAL PROTECTION", Oral presentation at The 18th International Multidisciplinary Scientific GeoConference SGEM 2018, 2 July - 8 July 2018, Albena, Bulgaria;
4. **Muraru S.L.**, Cardei P., Muraru V., Sfiru R., Condruz P., RESEARCH REGARDING THE USE OF DRONES IN AGRICULTURE, Oral presentation at The 19th International Multidisciplinary Scientific GeoConference SGEM 2019", Albena, Bulgaria, 2019.
5. P. Cardei, **S. Muraru**, R. Sfiru and V. Muraru, "Identification of correspondents between a standard series collection and an experimental series collection ,oral presentation at " *2019 11th International Conference on Electronics, Computers and Artificial Intelligence (ECAI)*, Pitesti, Romania, 2019";
6. Muraru V., Cardei P., Muraru-Ionel C., **Muraru S.L.**, Sfiru R., Radu O., Condruz P., CONCEPTION AND DEVELOPMENT OF TECHNICAL SYSTEMS FOR SUSTAINABLE AGRICULTURE, sustinuta in cadrul "ISB-INMA TEH 2017", International Symposium, Bucharest, Romania, 26 – 28 Oct. 2017;
7. POSTER - Condruz P., Berevoianu B., Muraru V., Dulgheru A., **Muraru S.**, Sfiru R., ALGORITM DE FERTILIZARE ÎN AGRICULTURA, International Symposium ISB-INMATEH Agricultural and Mechanical Engineering, 31 Oct. – 1 Nov. 2019, INMA București;

Patent applications

1. **Muraru S.**, Constantinescu O, Device for driving platforms for scanning the soil property. Patent Application no. A-00734 / 13.11.2019;
2. V. M. Muraru, **S. L. Muraru**, C. Nicolae, C. Muraru–Ionel, I. Ganea-Christu, Patent Application no. A/00501/19.08.2019, "Multifunctional section for reading soil parameters";
3. **S. L. Muraru**, V. M. Muraru, I. Ganea-Christu, C. Muraru–Ionel, A. Dulgheru, B. Berevoianu, Patent Application no. A-00372 / 20.06.2019, "Intelligent device for sampling soils";
4. V. M. Muraru, **S.L. Muraru**, P. Condruz, C. Muraru–Ionel, T. M. Ţicu, G. Deák, L. A. Laslo, M. S. Matei, M. G. Boboc, A. Stan, Patent Application no. A/00632/ 03.09.2018, "Intelligent system for variable zonal irrigation";

Research projects

I selectively present research projects:

1. 2018 – present "Eco-nanotechnologies and intelligent equipment for soil properties mapping and evaluating the dynamics of the plant in order to improve agricultural production and environmental protection", **Responsible project partner** (Complex Projects PN-III-P1-1.2-PCCDI-2017-0560);

2. 2017-2018 – “Developing a technology to combat drought forecasted at national level by using satellite, observational and climate model data - DROUGHTSAT”, **Collaborator** (“STAR” Program);
3. 2017-2018 – “Advanced computer and digital research for conception and development in order to efficient the intelligent technological systems for agricultural works” - **Collaborator** (“NUCLEU” Program);

12.5 Future directions of research and activity

- Realization of encapsulated dedicated circuits for the command and control system related to soil properties scanning equipment due to the wide market (globally);
- Development of decision-making management systems within agricultural farms based on the results obtained in the paper;
- Improving spectrum recognition algorithms through the use of artificial intelligence;
- Realization by similarity of quantitative and qualitative analysis systems for vegetables, fruits, human and animal food in order to evaluate substances harmful to health;
- Creation of databases with soil spectra and their properties at national level with a resolution of tens of square meters;
- Patenting the original solutions of the thesis;
- Development of drone applications to cover the need for nutrients;
- Development of new standards for eco-nanotechnologies in agriculture;
- Real-time elaboration of nutrient prescription maps, automatic elaboration of maps after scanning;
- Development of print and online media support for farmers in the use of new technologies specific to smart agriculture.

BIBLIOGRAPHY

Selective

[19] http://en.wikipedia.org/wiki/Beer-Lambert_law.

[22] M.Y. Nadeem, Waqas Ahmed, Optical Properties of ZnS Thin Films.

[23] http://www.rasfoiesc.com/educatie/fizica/MATERIA-SI-RADIATIA-ELECTROMAG15.php.

[26] **Sebastian Lucian Muraru**, Vergil Muraru, Paul Schiopu, Petru Cardei, Cornelia Muraru-Ionel, RESEARCH ON SOIL PROPERTIES ANALYSIS USING SPECTROPHOTOMETRY, Proceedings of 17th International Multidisciplinary Scientific Geoconference SGEM 2017, Vol. 17, ISBN 978 619-7408 05-8, ISSN 1314-2704, DOI: 105593/sgem2017/32, Albena, Bulgaria, 29 June – 5 July 2017, pag. 461 – 468.

[29] http://www.delta-t.co.uk

[30] Bodea M., Mihut I, Turic l., Tiponuț L., Aparate electronice pentru măsurare și control, Editura Didactică și Pedagogică București, 1985.

[31] http://www.envcoglobal.com/catalog/product/analog-ph-sensors/wq201-ph-sensor.html

[32] Garmin International Inc., Technica Specification GPS 17X HVS, USA, 2011;

[33] Vernier, User's guide Vernier SpectroVis PLUS, USA, 2019

[34] Ocean Optics, Inc., USB4000 Fiber Optic Spectrometer Installation and Operation Manual, USA, 2019;

[35] Hamamatsu Photonics, Mini-spectrometers, Japan, 2009;

[36] Ocean Optics, Inc., NIRQuest Installation and Operation Manual, USA, 2018;

[37] Ocean Optics, Inc., FLAME Installation and Operation Manual, USA, 2019;

[38] **Sebastian Lucian Muraru**, Vergil Muraru, Petru Cardei, Cornelia Muraru-Ionel, Laurentiu Vladutoiu, SCANNING EQUIPMENT TO ASSESS PHYSICAL SOIL PROPERTIES, Proceedings of the 45th International Symposium on Agricultural Engineering, Opatija, Croatia , 21 - 24 February 2017, ISSN 1848-4425, pag 25 – 34.

[39] **Sebastian Lucian Muraru**, Paul Schiopu, Petru Cardei, Vergil Muraru, Cornelia Muraru-Ionel, ENVIRONMENTAL PROTECTION THROUGH HIGH RESOLUTION EVALUATION OF SOIL, Proceedings of 17th International Multidisciplinary Scientific Geoconference SGEM 2017, Vol. 17, ISBN 978 619-7408 09-6, ISSN 1314-2704, DOI: 105593/sgem2017/52, Albena, Bulgaria, 29 June – 5 July 2017, pag. 335 – 342;

[40] V. M. Muraru, **S. L. Muraru**, C. Nicolae, C. Muraru–Ionel, I. Ganea-Christu, Patent Application no. A/00501/19.08.2019, "Multifunctional section for reading soil parameters";

[41] **S. L. Muraru**, V. M. Muraru, I. Ganea-Christu, C. Muraru–Ionel, A. Dulgheru, B. Berevoianu, Patent Application no. A-00372 / 20.06.2019, "Intelligent device for sampling soils";

[42] **Muraru S.,** Constantinescu O, Device for driving platforms for scanning the soil property. Patent Application no. A-00734 / 13.11.2019;

[100] T. Teorey and S. Buxton, "Database Design: Know It All", USA, pp. 11-38, 2009.