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MAXIMISING PRECISION AND ACCURACY IN SOIL SAMPLING USING AUTOMATED TECHNOLOGICAL PROCESSES

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Abstract: Precision and accuracy are essential components of soil sampling, as reliable data is necessary for informed decision making in agriculture and research. The advent of automated technology has revolutionized the way soil sampling is conducted, allowing for greater precision and accuracy in data collection. This article explores the role of automated technology in soil sampling, including the calibration of automated soil samplers, data management and analysis, and limitations of the technology. By understanding these key components, farmers and researchers can improve the quality of their soil sampling data, ultimately leading to better crop management decisions and more productive agricultural systems.
Keywords: agriculture, soil sampling, precision, accuracy, automation

1. INTRODUCTION

Soil sampling is an essential component of soil analysis in many fields, including agriculture, environmental science, and geology. The accuracy and precision of soil samples are crucial in generating reliable data for analysis. Traditional soil sampling techniques can be time–consuming and prone to human error, resulting in inconsistent and inaccurate results. Automated soil sampling equipment offers an efficient and precise solution to these issues. (Marin, E., et al, 2017).

In Romania, there has been some progress in the development of automated soil sampling technology. A few companies offer soil sampling services using automated tools, such as robotic soil probes and GPS mapping systems. However, the adoption of this technology is still limited, and most farmers still rely on manual soil sampling methods (Bulandra, M., et al, 2020).

In other countries, the use of automated soil sampling technology is more widespread. For example, in the United States, there are several companies that offer soil sampling services using automated tools. These companies use various technologies, such as GPS mapping systems, robotic soil probes, and remote sensing tools, to collect soil samples and analyze soil properties.

Similarly, in Australia, there has been significant investment in the development of automated soil sampling technology. Several companies offer soil sampling services using robotic soil probes and other tools, and the technology is widely adopted by farmers and agronomists.

2. MATERIALS AND METHODS

Components of an automated soil sampling machine

An automated soil sampling machine typically consists of several key components, which work together to collect soil samples efficiently and accurately.

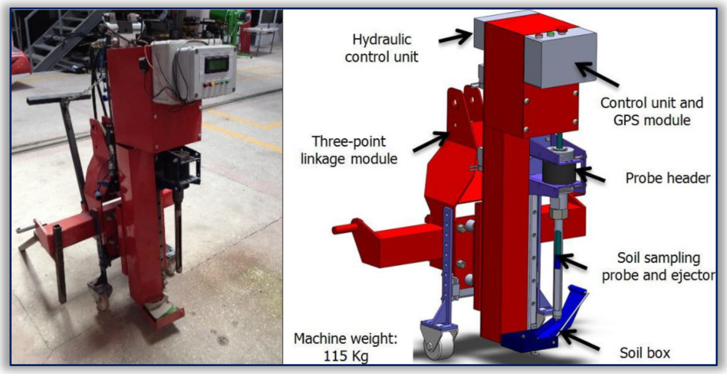

Figure 1 – Automated soil sampling equipment and its components (Dalmis, I.S et al, 2016)

- Sampling Head: The sampling head is the part of the machine that physically collects the soil samples. It can take many different forms, depending on the design of the machine. Some common types of

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sampling heads include augers, core samplers, and probes. The sampling head is typically designed to be inserted into the soil to a specified depth, and then to collect a sample of the soil at that depth.

Figure 2 – Sampling heads (GENEQ inc., 2023)

- Sampler Control Unit: The sampler control unit is the electronic control system that manages the operation of the sampling head. It typically consists of a microcontroller or computer that controls the movement of the sampling head, records data on the sampling process, and communicates with other components of the machine. The sampler control unit may also include sensors to measure parameters such as soil moisture, temperature, and nutrient levels.

Dalmış et al., 2016, developed a system that consists of a PLC micro controller, accumulator as a power supply, 2 relays for controlling solenoids, 2 switches for setting the limits of the machine, a start button and an emergency stop button in the system. There is also a GPS unit working independently from the main control unit in the system. The logical diagram is shown in Figure 3.

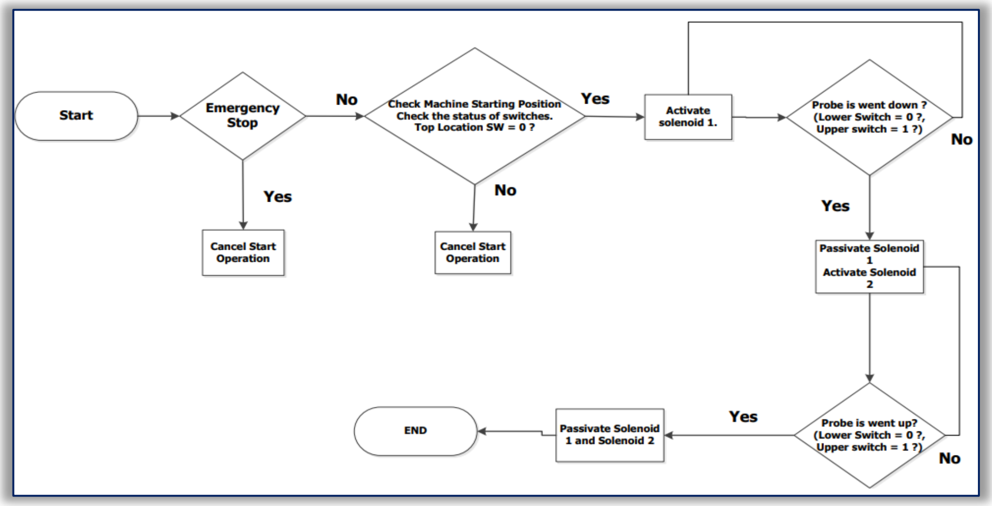

Figure 3 – Logical diagram (Dalmis, I.S et al, 2016)

- Power Source: The power source for an automated soil sampling machine can vary depending on the design of the machine. Some machines are battery–operated, while others may require an external power supply such as a generator. Machines that are used in remote locations may need to be designed to operate on solar power.

Figure 4 – Microcontroller by Mitsubishi (Mitsubishi Electric, 2023)

- Sensors: Many automated soil sampling machines include sensors to measure various parameters related to soil health. The data collected by these sensors can be used to inform decisions about crop management and soil health. A frequently type of sensor used are soil moisture sensors, which can measure the amount of moisture in the soil. They can be used to detect areas where the soil is dry or where it is too wet, which can be helpful in determining where to take soil samples. Another type of sensor are pH sensors. These sensors measure the acidity or alkalinity of the soil. They can be used to determine the pH level of the soil and identify areas that may require lime or other amendments.

Conductivity Sensors can measure the ability of the soil to conduct electricity. Their role is to determine the salinity of the soil and identify areas where the salt content is too high. Temperature sensors are frequently used in soil sampling equipment for being able to detect areas where the soil is too hot or too cold, which can affect plant growth.

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Figure 5 – pH sensor

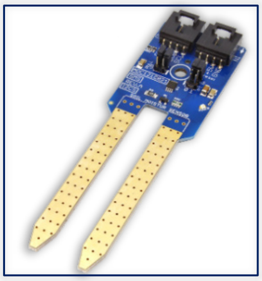

Figure 6 – Moisture sensor

Figure 7 – Temperature sensor

- GPS: Some automated soil sampling machines include GPS technology, which allows users to collect geospatial data on the location of soil samples. This data can be used to track changes in soil quality over time, and to identify areas that may require special attention in terms of crop management.
- Data Collection and Analysis Software: Many automated soil sampling machines come with software that allows users to collect and analyze data on soil quality. This software can be used to create detailed maps of soil properties, identify areas of concern, and make informed decisions about crop management and soil health. Currently there are being used a variety of software programs, depending on the context.

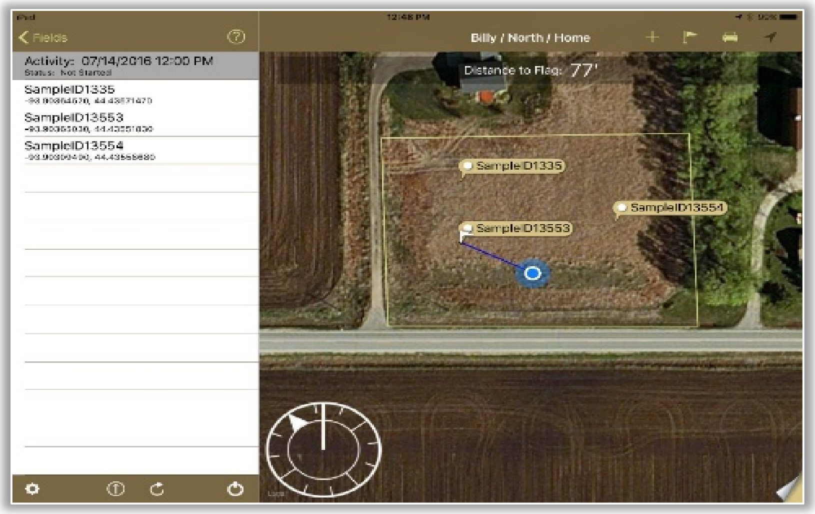

Figure 8 – FieldX Software user interface (FieldX, 2023)

For example, FieldX is a software package designed for use in agriculture. It includes a mobile app that can be used to collect data on soil health and crop management practices in the field. The app is designed to work with a range of different soil sampling machines, and the data collected can be analyzed using the FieldX software platform.

3. CURRENT STATE OF THE AUTOMATED SOIL SAMPLING EQUIPMENTS

There are several types of automated soil samplers available on the market, ranging from portable hand–held devices to large automated machines. These samplers use a range of techniques, including augers, coring, and vacuum extraction, to collect soil samples quickly and efficiently.

The most affordable available commercial solution is hand–held soil sampler, being a commonly used device for collecting samples at the surface. After collecting the soil, it is examined in the laboratory, which is a time–consuming process. These methods are not enough for large farms located on hundreds of hectares.

The SonicSampDrill is a fully automated soil sampling system produced by Eijkelkamp, a Netherlands–based company that specializes in soil and water research equipment. The system uses sonic drilling technology to collect high–quality soil samples quickly and efficiently.

Another example comes from Estonian University of Life Sciences (Leemet, T., et al, 2018), who managed to implement an articulated steering UGV platform prototype with soil sampling mechanism. While being somewhat similar to fullsize unmanned tractor platforms (Oksanen, T. et al, 2015), et al, this UGV is classified as mid–size and weights 470 kg. It suits perfectly for automating repeated light tasks usually carried out by humans like automated measurements and sampling.

The soil sampling and collecting system is integrated into separate body module (Fig. 11, left). For robotic sampling, often drilling is used, especially in harder or variable grounds (Zhang, T., et al, 2017). However, for soft field soils, sample probing with 25 mm diameter and 300 mm length tubular probe (pink in Fig. 11) is simple and durable.

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Figure 9 – SonicSampDrill (Eijkelkamp, 2023)

Figure 10 – Collecting the soil samples (Eijkelkamp, 2023)

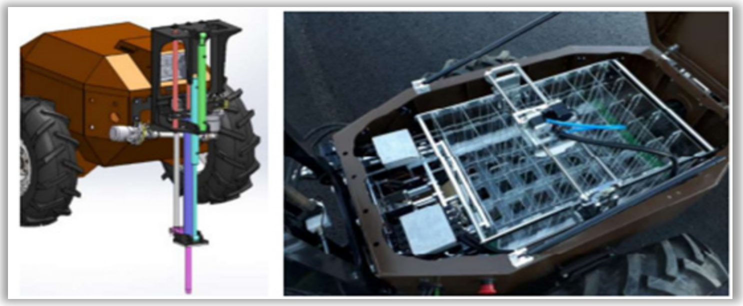

Figure 11 – CAD–model and sample storage system from the prototype (Leemet, T., et al, 2018)

Figure 12 – Articulated platform prototype with soil sampling mechanism (Leemet, T., et al, 2018)

As for software, the input for creating the work tasks is GeoJSON data file with pre–agreed attribute marking. This file is used for creating area borders, restrictions and calculating the path segments for driving between sample points. The software is divided into two separate independent systems: firmware for driving the hardware and remote management system in server, including user interface (UI) for operator (Fig. 13).

For achieving the maximum flexibility, the software uses service–oriented architecture. The remote management system software in server is based on NodeJS run–time environment and AngularJS framework. Using the separate library for communicating with operator, the server software manages robot tasks, work process, analyses telemetry and enables also manual control. Software system for the soil sampling device developed in this research is able to work with maps and spatial data.

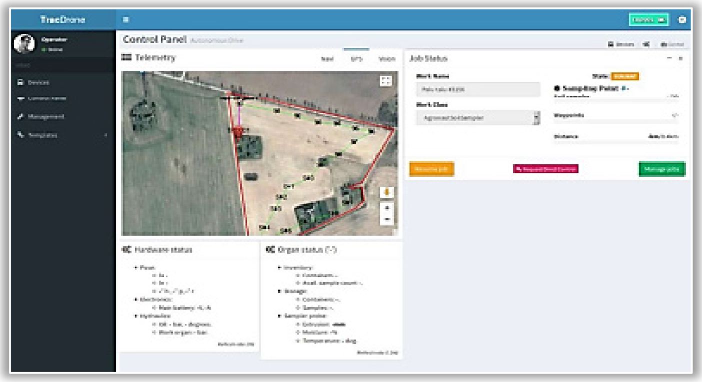

Figure 13 – Soil sampling UI for work plan configuration view (Leemet, T., et al, 2018)

4. CALIBRATION OF AUTOMATED SOIL SAMPLERS

Calibrating automated soil samplers is crucial for ensuring precision and accuracy in soil sampling. Calibration involves ensuring that the sampler is collecting the correct amount of soil and that the depth of sampling is consistent. This can be achieved through the use of calibration weights and markers to ensure that the sampler is collecting the correct volume of soil at the desired depth.

One common method of calibrating automated soil samplers involves using a set of calibration weights to ensure that the sampler is collecting the correct amount of soil. This can be achieved by placing the calibration weights in the sampler and running it for a set amount of time, then measuring the weight of soil collected. The weight of the collected soil can then be compared to the weight of the calibration weights to determine the accuracy of the sampler.

Another method of calibrating automated soil samplers involves ensuring that the depth of soil sampling is consistent. This can be achieved by using a depth marker or probe to ensure that the sampler is collecting soil at the desired depth. The depth of sampling can be adjusted as needed until the desired depth is achieved consistently.

Field testing is another important method of calibrating automated soil samplers. This can involve testing the sampler under a range of field conditions, including different soil types, moisture levels, and vegetation cover, to ensure that it is collecting accurate and consistent data. Field testing can also help to identify any issues with the sampler that may affect its performance.

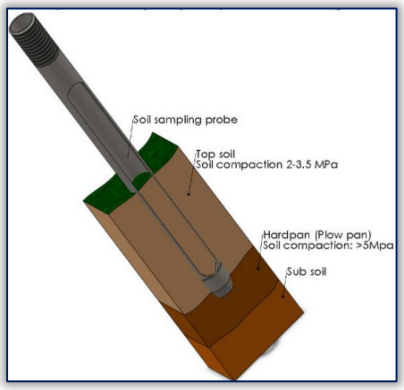

Figure 14 – Soil sampling probe and soil layers (Dalmis, I.S et al, 2016)

Comparing the results of automated soil sampling with traditional soil sampling methods is another effective way to calibrate automated soil samplers. This can involve collecting samples using both automated and traditional methods and comparing the results to identify any differences in data quality. Any discrepancies can then be addressed to ensure that the automated sampler is collecting accurate and consistent data.

By using these calibration methods, researchers and farmers can ensure that their automated soil samplers are collecting accurate and reliable data, ultimately leading to better crop management decisions and more productive agricultural systems.

5. RESULTS

Upon Leemet, T et al., 2018 studies, the control unit is set to operate in the manner shown on Fig. 15 in order to get the best performance out of the sampling mechanism. The aggregate sample taking times were determined by measuring mean acting times. Although the robot platform's navigation was still in the testing phase, its control unit can move the platform between the sampling spots about twice as slowly as an operator driving an ATV. However, a robot can gather 75 samples per hour due to a speedier process and outperform the conventional approach while traveling considerably more slowly, whereas a human operator using an ATV and a manual probe can only collect up to 50 composite samples per hour. Manual and automatic soil sampling methods each have their own advantages and disadvantages, shown in Table 1.

Vehicle act.	Driving		Stopped		Driving			
Turret act.	Turn to sampl. pos							Turn to transp. pos
Cleaner act.		Cleaner up				Cleaner down		
Probe act.			Probe into soil	Probe up				Probe down
Support act.		Support down		Support up				
Container act.					Container forward		Container back	
Duration, s	4.80	1.30	1.80	4.30	1.10	1.30	1.10	4.80

Figure 15 – Soil sampling mechanism tested action durations (Leemet, T., et al, 2018)

Table 1. Advantages and disadvantages of manual and automatic soil sampling

Sampling Method	Advantages	Disadvantages
Manual	Minimum equipment required	- Labor–intensive - Environment possibly dangerous to field personel - May be difficult to get personnel and equipment to the storm water outfall within the 30–minute requirement - Possible human error
Automatic	• Minimizes labor requirements • Low risk of human error • Reduced personnel exposure to unsafe conditions • Sampling may be triggered remotely or initiated according to present conditions	- Samples collected for oil and grease may not be representative - Automatic samplers cannot properly collect samples for volatile organic compounds analysis - Costly if numerous sampling sites requ ire the purchase of equipment - Requires equipment installation and maintenance - Requires operator training; May not be appropriate for pH and temperature - May not be appropriate for parameters with short holding times (for example, fecal streptococcus, fecal coliform, chlorine) - Cross–contamination of aliquot if tubing/bottles not washed

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6. CONCLUSIONS

The precision and accuracy of automated soil sampling systems can be affected by factors such as soil type, moisture content, and environmental conditions, and further research is needed to optimize these systems for different conditions. While automated soil sampling systems can be expensive to purchase and maintain, the long–term benefits in terms of precision, accuracy, and efficiency may make them a worthwhile investment for larger–scale agricultural operations.

Overall, this research suggests that automated soil sampling technologies have the potential to revolutionize the field of soil analysis, providing greater precision, accuracy, and efficiency compared to manual methods. By optimizing these systems for different soil types and environmental conditions, and integrating them with other agricultural technologies, it may be possible to achieve even greater benefits in the future.

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