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HUNGARIAN AGRICULTURAL RESEARCH

Spring-Summer 2024

Environmental management, land use, biodiversity

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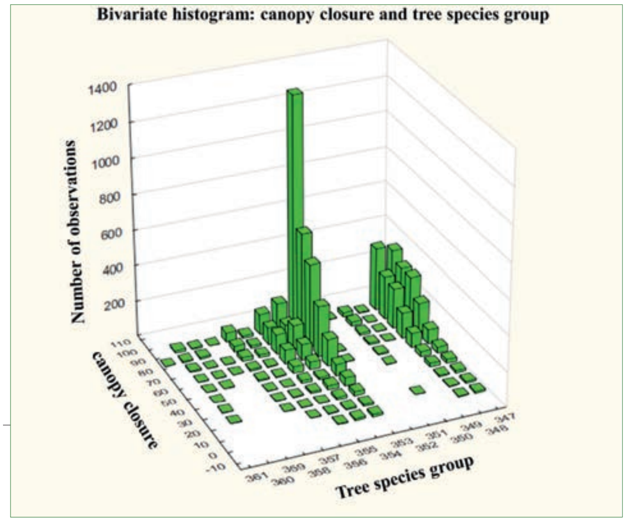

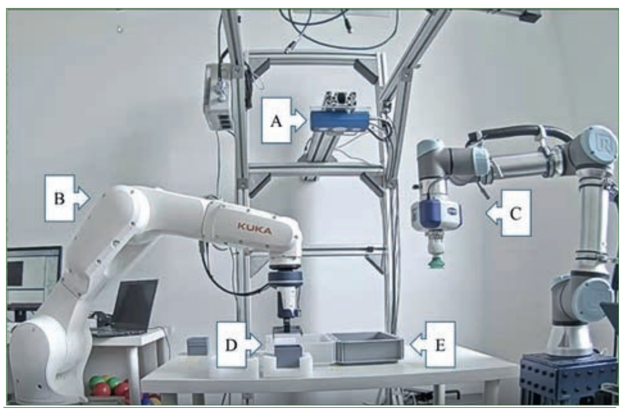

RESEARCH ACTIVITIES AND DEVELOPMENTS AT THE AGROTECHNOLOGY NATIONAL LABORATORY

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ABSTRACT

Establishing the Agrotechnology National Laboratory is crucial for the domestic adaptation of environmentally conscious, climate-friendly, and digitally supported agricultural practices and for aligning with international trends. The laboratory's activities include integrating national soil test results into a unified database, standardising laboratory applications of spectral analytical methods, developing test methods for organic micropollutants, and creating the first national soil spectral library. With its multidisciplinary approach, the laboratory focuses not only on soil science, but also on energetic analysis of biomass materials, monitoring their environmentally friendly use in combustion units, and innovative development strategies for plant protection technologies to minimise environmental impact.

keywords: National Laboratories Programme, soil analysis, spectral library, organic micropollutants, plant protection, biomass energy, combustion technologies

INTRODUCTION

The Agrotechnology National Laboratory (ANL) aims to develop three data-based knowledge bases (soil, plant protection, bioenergy) related to natural resources such as soil, water, and air. The primary focus is to create and operate a uniform national, high-resolution soil database. This national, central database will contain test results measured in Hungarian soil laboratories, supplemented by a national soil spectral library. A modern laboratory testing methodology conforming to uniform international standards and necessary infrastructural and equipment developments will be developed. The goal is for the Agrotechnology National Laboratory to serve as a relevant knowledge base available to all actors of the agricultural knowledge and innovation system (AKIS) proposed to be established by the new KAP (2023-2027). This support helps producers to meet society's sustainability expectations and regulations. Furthermore, using soil data is crucial in assessing the value of machinery and inputs.

The National Food Chain Safety Office (NÉBIH), in collaboration with the Hungarian University of Agriculture and Life Sciences (MATE), is responsible for soil analysis and developing a database. This collaboration also leads to innovative services, with the Institute of Agricultural Economics (AKI) support. The professional activities of the project are carried out within MATE by several departments: the Agro Environmental Science Research Center and the Department of Soil Science within the Institute of Environmental Sciences. Additionally, the Testing Group for Plant Protection Machines and the Testing Group for Energetics, both of which belong to the University Laboratory Center are involved in the project.

The critical elements of the research and development activities undertaken by the National Agricultural Technology Laboratory are described below.

RESEARCH ACTIVITIES AND DEVELOPMENTS OF THE PROJECT

Development of the National Soil Database

Our project involves the creation of a high-resolution, nationwide soil database in Hungary, a project that will be at the forefront of technological advancements. This process is achieved through an advanced IT system that automates the collection, quality control, organisation, and integration of data from soil laboratories in Hungary.

The proposed platform will establish a central database, gradually evolving into a time-series database, encompassing soil information for Hungary's agricultural and forestry areas.

Soil Research

Soil is an indispensable and hardly renewable natural resource for many human activities. There is an unprecedented demand for high-quality and adequate quantity of soil data and information nowadays. This growing interest in soil has exposed the spatial, temporal, and financial limitations of conventional soil analytical methods. Spectroscopic (dry chemistry) technologies, when used in parallel with conventional laboratory (wet chemistry) methods, provide the opportunity to make soil information provision more time- and cost-effective and environmentally friendly. Considering the rich information content of the spectra measured in the visible and near-infrared (VIS-NIR) and middle-infrared (MIR) spectral regions, it is possible to derive a great deal of information simultaneously from a single spectrum (Figure 1).
The methodological framework for the development is defined by the protocols of the Global Soil Laboratory Network (GLOSOLAN), one of the leading technical networks of the FAO Global Soil Partnership. Following the guidelines provided by the GLOSOLAN Soil Spectroscopy working group, we aim to integrate spectroscopic techniques into soil testing practices and create a nationwide soil spectral library using VIS-NIR and MIR spectroscopic measurements. Based on this database, we also aim to develop a soil property estimation service. The foundation of the spectral library is based on spectra acquired on soil samples collected from the genetic horizons of soil profiles in the first year (1992) of the Hungarian Soil Information and Monitoring System (TIM).
The reference soil parameters used are the values obtained from the TIM database for soil samples from the genetic horizons of the soils, determined by conventional laboratory methods (Table 1).

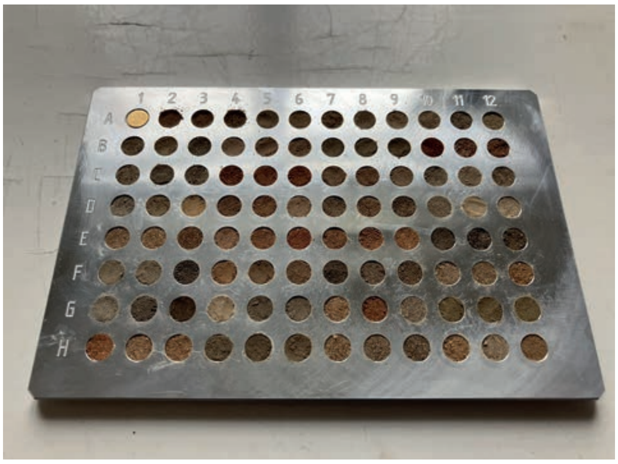

Figure 1: Soil samples prepared for middle-infrared spectral analysis

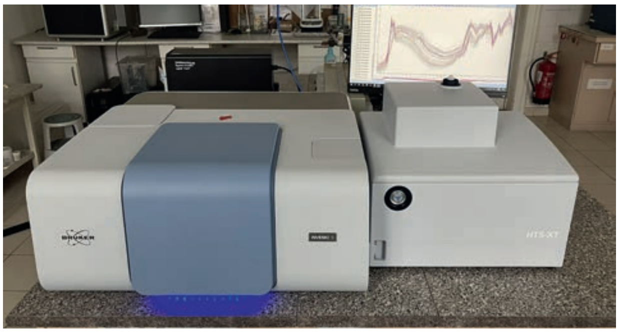

Figure 2: Bruker Invenio Fourier-Transform Infrared (FTIR) Spectrometer with Coupled HTS-XT Sample Changer

The MIR measurements are carried out using the high sample capacity Bruker Invenio Fourier-transform infrared (FTIR) spectrometer (Figure 2). This instrument is equipped with the HTS-XT sample changer, which allows for the simultaneous spectral characterisation of 95 soil samples. Additionally, VIS-NIR measurements are included in the spectral database and are obtained using the Malvern Panalytical ASD LabSpec 4 Hi-res portable

Table 1: The soil parameters used as reference data for developing spectroscopy-based soil property prediction models

Soil parameter	Test method	Reference/Standard
Organic matter content	Székely method	MSZ-08-0452-1980
pH in distilled water and KCl	Potentiometry	MSZ-08-0206/2-1978
$CaCO_3$ content	Scheibler (calcimeter)	MSZ-08-0206/2-1978
Exchangeable Ca, Mg, Na, K	modified Mehlich method	MSZ-08-0214/1-2/1978
Cation Exchange Capacity (T-value)	modified Mehlich method	MSZ-08-0215-1978
Sum of bases (S-value)	Calculated based on exchangeable Ca, Mg, Na, K	∑ Ca,Mg,Na,K
Texture (sand, silt, clay %)	Pipette method	MSZ-08-0205-1978
Maximum water retention (pF=0)	Saturation of undisturbed soil sample with water	MSZ-08-0205-1978
Field capacity (pF=2,5)	Várallyay pF box with kaolin sheet apparatus	MSZ-08-0205-1978
Wilting Point (pF=4,2)	Membrane compression	MSZ-08-0205-1978

spectrometer (Figure 3). Chemometric modelling is performed to build predictive models to estimate soil parameters based on spectral data. This approach integrates a rapid, cost-effective laboratory procedure into soil testing and reduces the need for environmentally harmful chemicals compared to conventional methods. Values obtained from traditional laboratory methods for soil samples in the TIM database serve as reference soil parameters. The continuously expanding spectral library and the soil property estimation service will provide a reliable method for estimating a wide range of physical and chemical soil properties. This will improve the current laboratory capacity without significant cost increases.

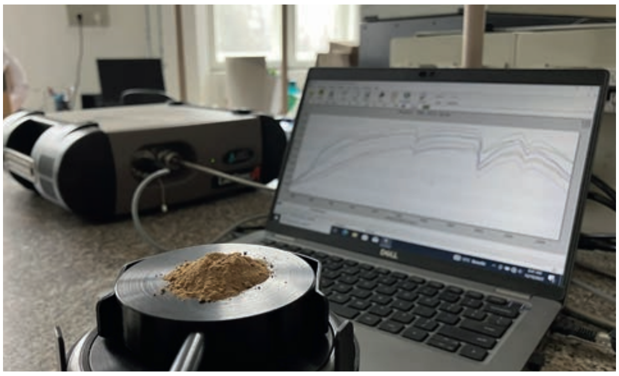

Figure 3: Malvern Panalytics ASD LabSpec 4 Hi-res Portable Spectrometer

Agro-Environmental Research

The Agro Environmental Research Center of the Institute of Environmental Sciences has acquired a gas chromatograph coupled to a mass spectrometer (GC-MS), an essential technique for identifying (semi)volatile micropollutants from agricultural or other sources. The methods for determining target compounds on this instrument are currently being developed, including optimising separation and detection parameters, creating a proprietary spectrum library and testing the performance of the instrument. Once we adapt our previously used methods, it will be possible to detect and monitor applied foreign organic compounds (such as pesticide residues, polyaromatic hydrocarbons, mycotoxins, etc.) in environmental samples (soil, surface water, groundwater, and plant matrices). This also includes testing application technologies e.g. to detect off-target pesticide drift, and studying these potential contaminants' environmental fate and dissipation pathways (degradation, leaching, absorption).

Organic xenobiotics, or organic micropollutants, represent a significant type of potential environmental contaminants resulting from agricultural practices. These contaminants include organic compounds that do not occur naturally in the environment, such as residues of pesticides used for plant protection and mycotoxins produced by pathogenic microorganisms that may infect crops during cultivation or storage. Monitoring these contaminants is essential to ensure crop and food safety as well as environmental safety. Accurate monitoring of pesticide residues in soil and surface water is critical from an environmental safety perspective, particularly regarding their potential to contaminate water sources and the need to protect water basins. Regulatory laws governing pesticide authorization (Regulation (EC) No 1107/2009, Decree 43/2010 (IV. 23.) of the Ministry of Agriculture and Rural Development) exclude active ingredients and formulations that do not adequately degrade in the environment and tend to accumulate (persistent). Nevertheless, as required by the relevant legislation, preventing water contamination requires regulation and monitoring of pesticide application technologies. The analytical laboratory (Figure 4) within the Agrotechnology National Laboratory, which detects organic micropollutants, facilitates this monitoring activity. During its operation, the most frequently detected pesticide residues were primarily herbicides used in maize cultivation, reflecting current herbicide usage. Conversely, diffuse pollution at low residue levels (e.g., trifluralin) generally indicates persistence of pesticide active ingredients. Contamination levels measured in organically farmed areas were significantly

Figure 4: The newly acquired GC-MS instrument in the environmental analysis laboratory for the detection of organic micropollutants

lower than in intensively cultivated areas. However, pesticide residues are still present in organic farming, albeit at low levels, partly due to persistent organic pollutants in the soil and potential contamination of the irrigation water.

Bioenergy research

Thanks to the developments provided by the Agrotechnology National Laboratory, the modernised analytical infrastructure enables more accurate and faster determination of the energy properties of typical solid biomass-based samples (Figure 5). The Testing Group for Energetics has acquired an elemental analyser, allowing precise measurement of carbon, hydrogen, nitrogen, sulphur, and chlorine content in solid biomass fuels. Additionally, the laboratory now possesses a calorimeter to determine the gross calorific value of biofuels. These instruments collectively enable us to ascertain the net calorific value of the samples tested.

The project also encompasses the combustion and environmental assessment of equipment using these fuels. These test solutions include evaluations of thermal performance, efficiency, and environmental emissions, such as flue gas composition and particulate matter emissions (Figure 6). A mobile flue gas analyser was also purchased, designed specifically for examining combustion equipment and providing on-site measurement capabilities with the newly acquired measuring van.

Figure 6: Laboratory examination of combustion equipment

Figure 7: Testing of mounted sprayers in the laboratory

Figure 5: Biomass samples for energetic analysis

Testing of Plant Protection Machinery

Modernising testing capabilities for plant protection machinery is also being undertaken within the project framework. This includes the expansion of field test areas, the determination of objective work quality characteristics, the examination of spray drift, and the development of new methods *(Figure 7-8).* Additionally, a mobile testing laboratory was established to support tests conducted at the sites of agricultural producers. The testing method-

Figure 8: Field Testing of Spraying Drones

ology was aligned with international standards, and an environmental certification criteria system for plant protection technologies and machinery was developed as part of this effort.

Thanks to the infrastructure development achieved within the project, including the mobile laboratory, the facility can now conduct on-site testing of plant protection machinery. We can offer our partners a range of services related to machinery development. These services include examining cross-distribution uniformity, evaluating nozzle spray performance and droplet distribution, testing pump delivery performance, and conducting fieldwork quality assessments.

CONCLUSIONS

The project has resulted in establishing an IT system for automatically collecting, verifying, and organising data from Hungarian soil laboratories. In addition, a micropollutant analysis laboratory has been established to detect organic micropollutants. The project also supports research into the energy and combustion properties of solid biomass fuel samples and the testing of boilers using these fuels. Moreover, testing capacity has been developed to provide services to agricultural producers and companies for evaluating plant protection machinery and technologies. Furthermore, a soil spectral library has been established to facilitate the efficient determination of soil parameters, thereby supporting the application of international sustainable soil testing technologies.

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