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Spring-Summer 2024

Environmental management, land use, biodiversity

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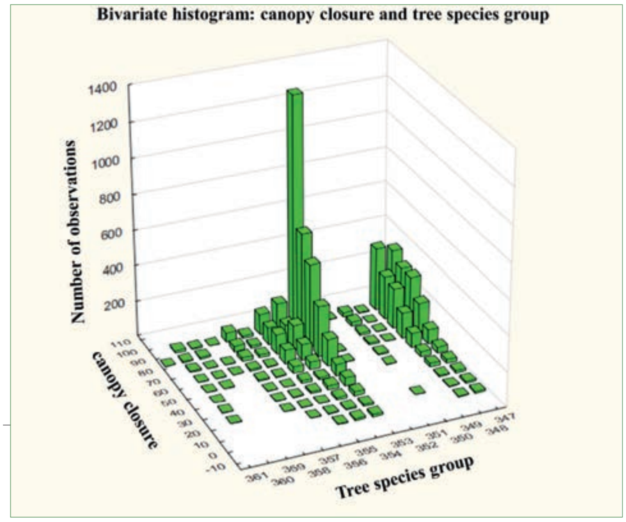

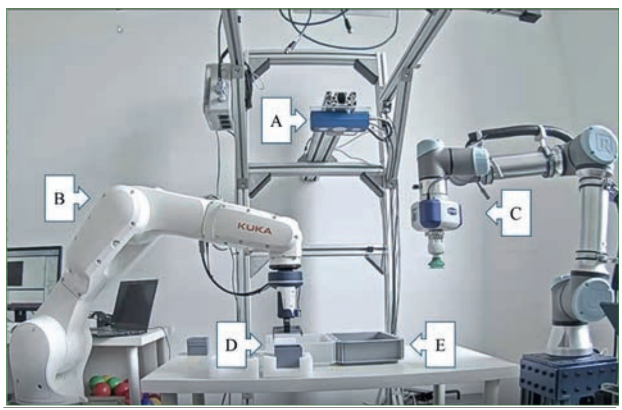

PREPARATORY STUDY FOR CARBON SEQUESTRATION MODELLING OF AGROFORESTRY IN HUNGARY – THE ASSESSMENT OF THE AVERAGE CANOPY CLOSURE OF WINDBREAKS

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ABSTRACT

A significant part of the climate change mitigation potential of the land use sector is inherent to agroforestry, windbreaks are important agroforestry elements of Hungariaqan agricultural landscapes. The improved agroforestry subsidy system in Hungary makes it relevant to model the carbon sequestration of windbreaks. In the frame of the ForestLab project we plan to develop a carbon sequestration model specific for Hungarian windbreaks. In this study we assess the average canopy closure of Hungarian windbreaks by tree species group based on the data of the National Forestry Database as a preparatory step of the model development. Our results show that the canopy closure of windbreaks under forest management planning in Hungary is relatively high, ranging between 74-96%. Among the examined effects the most important one is the age of the stand, which has the highest impact on the value of the canopy closure. Tree species group and production capacity are also important predictors of canopy closure.

keywords: windbreaks, shelterbelts, climate change mitigation, carbon sequestration, modelling

INTRODUCTION

In the light of the Paris Agreement and the European Green Deal climate change mitigation by means of nature-based solutions is becoming increasingly relevant (IPCC 2022). The Land Use and Forestry (LULUCF) sector has a crucial role in offsetting inevitable emissions of the Agriculture, Energy and Industry sectors. Agroforestry practices are key in upscaling carbon sequestration and storage in croplands (Borovics et al. 2017, Borovics and Király 2022, Honfy et al. 2023).

The International Centre for Research in Agroforestry (ICRAF) defines the term agroforestry as a dynamic, ecologically based natural resources management system that, through the integration of trees in farmland, diversifies and sustains production for increased social, economic and environmental benefits (Mosquera-Losada et al. 2009). The World Agroforestry Centre (WAC) highlights that in agroforestry systems woody perennials (trees, shrubs etc.) are deliberately used on the same land management unit as agricultural crops, animals, or both, either in some form of spatial arrangement or temporal sequence (Mosquera-Losada et al. 2009). Following the definitions given by the Association for Temperate Agroforestry (AFTA 1997) and Alavalapati and Nair (2001) there are currently five basic types of agroforestry practices in temperate areas: windbreaks, alley cropping, silvopasture, riparian buffers and forest farming. Nair (1993) defines windbreaks as narrow strips of trees, shrubs, and/or grasses planted to protect fields, homes, canals, and other areas from the wind and blowing sand. In Hungarian agricultural landscapes, windbreaks (i.e., field protection tree rows and field protection forest strips) are common elements that protect agricultural fields from wind and soil erosion. In response to the goals of the Carbon Farming directive, new incentives have been introduced in the Hungarian agricultural subsidy system. An important innovation starting in 2023 is that the agricultural land occupied by agroforestry systems remains eligible for direct area-based subsidies, and agroforestry systems can be counted as agroecology program elements and as landscape elements as well (NAK

2023). Windbreaks and trees planted on grasslands are subsidized in Hungary (NAK 2023). Considering the favourable changes in the subsidy system we can foresee that these landscape elements will become important means of land-based climate change mitigation. In our previous study (Király et al. 2024) we assessed the area of windbreaks, and the carbon sequestration realised in windbreaks in Hungary. According to our estimate, the weighted mean annual carbon sequestration in the aboveground biomass of windbreaks was –2.4 tCO_2/ha/year in the 2010–2020 period (Király et al. 2024). This value is very close to the average mean annual carbon sequestration per hectare value of all forests, as reported by the Hungarian Greenhouse Gas Inventory (NIR 2023). This means that planting a given area of windbreaks in between agricultural fields can have similar climate change mitigation effects as planting forests in the same given area (Király et al. 2024).

In the frame of the ForestLab project (Borovics 2022) which is a climate change mitigation and adaptation project carried out by the University of Sopron we plan to develop a carbon sequestration model specific for Hungarian windbreaks. This study is a preparatory step of the model development. In this paper we assess the average canopy closure of Hungarian windbreaks by tree species group based on the data of the National Forestry Database (NFD). Canopy closure is a necessary parameter for the use of yield tables to be able to predict future volume stock and increment of the windbreak stands.

MATERIAL AND METHODS

In our study we used the NFD, which is the official database of the Hungarian Forest Authority. NFD stores detailed data on each forest stand subject to forest management planning (Tobisch and Kottek 2013, Kottek et al. 2023). Forest management planning is based on field surveys during which the main stand attributes (such as the height, diameter, basal area, age, and canopy closure) are measured (Tobisch and Kottek 2013). Data on the standing volume are stored in tree species

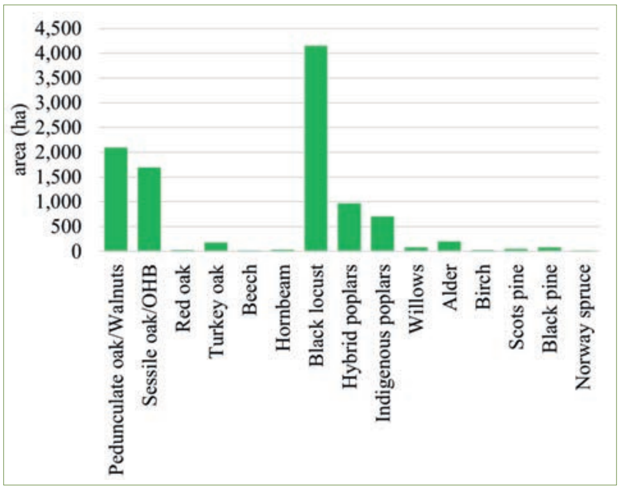

Figure 1: Area of windbreaks by tree species group as of the 2020 state of the NFD. ***(OHB: other hard broadleaved species).***

Table 1: Weighted means of canopy closure by tree species grou

Cell No.	Weighted means of canopy closure by tree species group Current effect: F(14, 6700)=14,684, p=0,0000 Effective hypothesis decomposition					
	tree species group	canopy closure (Mean)	canopy closure (Std.Err.)	canopy closure (-95,00%)	canopy closure (+95,00%)	Number of observations
1	Pedunculate oak	77.79	0.52	76.76	78.81	1221
2	Sessile oak	79.78	0.53	78.74	80.81	1114
3	Red oak	88.64	4.11	79.49	97.79	11
4	Turkey oak	80.36	1.76	76.85	83.87	81
5	Beech	96.00				2
6	Hornbeam	80.40	2.80	74.55	86.25	20
7	Black locust	83.53	0.32	82.89	84.16	2950
8	Hybrid poplars	74.49	0.90	72.71	76.26	588
9	Indigenous poplars	76.64	0.87	74.92	78.35	473
10	Willows	76.20	2.81	70.57	81.83	55
11	Alder	81.99	1.42	79.19	84.79	129
12	Birch	75.20	6.76	56.42	93.98	5
13	Scots pine	83.21	2.83	77.34	89.07	24
14	Black pine	77.76	3.07	71.54	83.97	41
15	Norway spruce	85.00				1

Table 2: Results of the multiple regression analysis. *(Numbers highlighted in red denote significant effect.)*

Regression Summary for Dependent Variable: canopy closure R= ,34841950 R²= ,12139615 Adjusted R²= ,12074135 F(5,6709)=185,40 p<0,0000 Std.Error of estimate: 17,304						
N=6715	b*	Std.Err. (of b*)	b	Std.Err. (of b)	t(6709)	p-value
Intercept			263.188	26.249	10.027	0.000
age	-0.345	0.013	-0.304	0.011	-27.593	0.000
tree species group	-0.083	0.013	-0.496	0.075	-6.650	0.000
mean annual increment of total production	0.100	0.012	0.546	0.063	8.672	0.000
mixture rate	-0.020	0.012	-0.016	0.010	-1.625	0.104
stand area	0.013	0.012	0.154	0.137	1.120	0.263

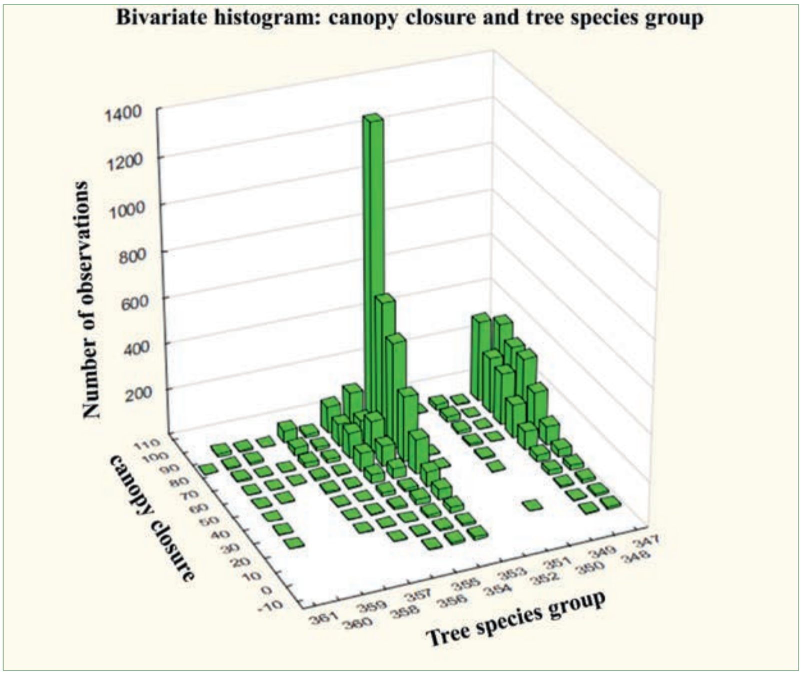

Figure 2: Bivariate histogram of the tree species group and canopy closure of windbreaks. (Tree species group codes are the following: 347 Pedunculate oak, 348 Sessile oak, 349 Red oak, 350 Turkey oak, 351 Beech, 352 Hornbeam, 353 Black locust, 354 Hybrid poplars, 355 Indigenous poplars, 356 Willows, 357 Alder, 358 Birch, 359 Scots pine, 360 Black pine, 361 Norway spruce.)

rows, which are the basic units of the database (Tobisch and Kottek 2013). The NFD stores data on the primary function (i.e., timber production, windbreak, nature protection, etc.) assigned to each forest sub-compartment (Király et al. 2024). We queried all stands with windbreak as the primary function from the 2020 state of the NFD at the country level. This way we obtained a whole country's windbreak forest stand group for further analysis. Thereafter we queried the tree species, area, age, canopy closure, mixture rate, and production capacity (defined as the mean annual increment of total production at the reference age of the stand) data of all stands and analysed the data using Statistica software (Version 14.0.1.25, Tulsa, OK, USA). The primary goal of the data analysis was to obtain mean canopy closure values by tree species group for the parametrisation of the carbon sequestration model under development. In addition, we also assessed the canopy closure by age, and we conducted a multiple regression analysis in order to identify variables that have significant effect on canopy closure.

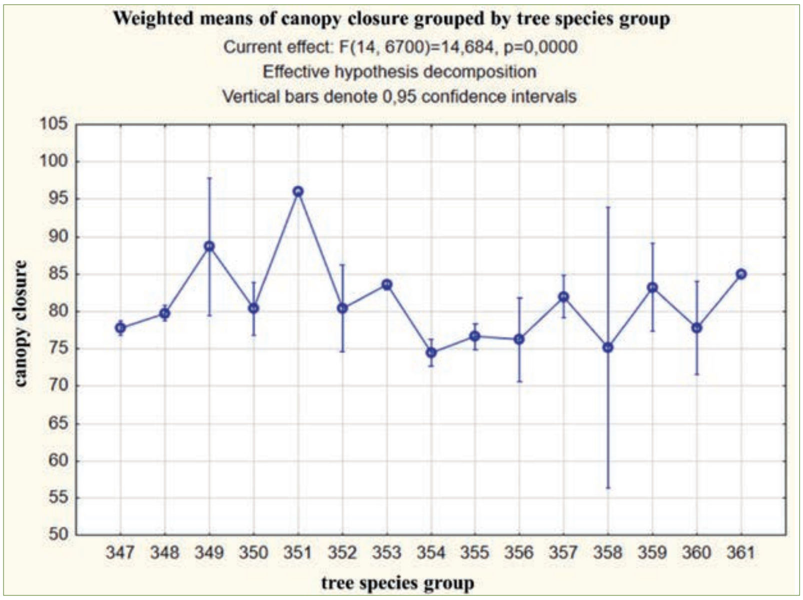

Figure 3: Weighted means of the canopy closure of windbreaks by tree species group. (Tree species group codes are the following: 347 Pedunculate oak, 348 Sessile oak, 349 Red oak, 350 Turkey oak, 351 Beech, 352 Hornbeam, 353 Black locust, 354 Hybrid poplars, 355 Indigenous poplars, 356 Willows, 357 Alder, 358 Birch, 359 Scots pine, 360 Black pine, 361 Norway spruce.)

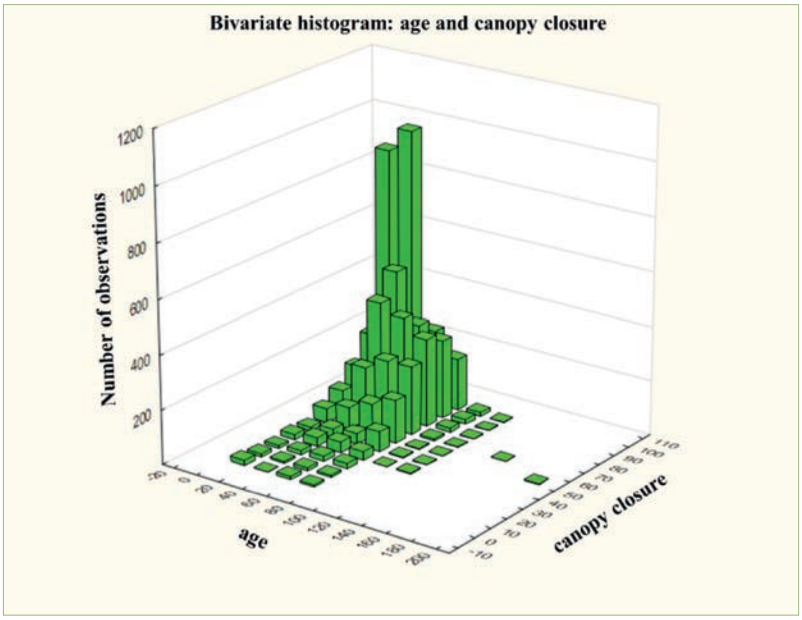

Figure 4: Bivariate histogram of the age and canopy closure of windbreaks.

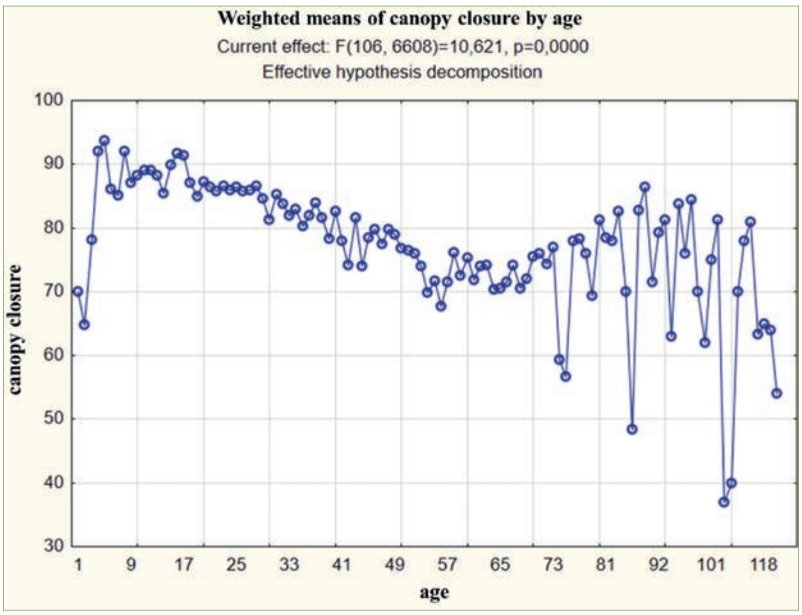

Figure 5: Weighted means of the canopy closure of windbreaks by age.

RESULTS

According to our results the majority of windbreaks are composed of black locust (*Robinia pseudoacacia*) stands, followed by pedunculate oak (*Quercus robur*), sessile oak (*Quercus petraea*), hybrid poplars, and indigenous poplars (Figure 1).

The weighted means of canopy closure by tree species group are detailed in Table 1. The highest canopy closure value was observed in beech (*Fagus sylvatica*) and red oak (*Quercus rubra*) stands. In the case of pedunculate oak, sessile oak, poplars, willows (*Salix*), birch (*Betula*) and black pine (*Pinus nigra*) the mean canopy closure was below 80%.

According to the results of the multiple regression analysis (Table 2) age, tree species group and production capacity had significant effect on canopy closure.

Our results show that tree species has a significant effect on canopy closure. Black locust, oaks and poplars represent the majority of the area of windbreaks (Figure 2). In the case of tree species represented by small area the confidence intervals of the mean are much wider (Figure 3).

According to our results the canopy closure of the windbreaks decreases with the age, however in the 1-10 age class a temporal increase was observed (Figure 4–5).

DISCUSSION

Our results show that the canopy closure of windbreaks under forest management planning is relatively high, ranging between 74-96%. Among the examined effects the most important one is the age, which has the highest impact on the value of the canopy closure. Tree species group and production capacity are also important predictors of canopy closure.

These results are in line with our previous findings related to the carbon sequestration of windbreaks which also varied highly depending on age and tree species (Király et al. 2024).

CONCLUSIONS

In this study we assessed the average canopy closure by tree species group for all windbreaks under forest management planning in Hungary. These results will be used in the parametrisation of a carbon sequestration model specific for windbreaks. As not all windbreaks are under forest management planning in Hungary it would be important to assess the canopy closure of those windbreaks which are not registered in the NFD. For this remote sensing-based assessment would be the most appropriate, as filed surveys would be too costly.

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DEVELOPMENT OF BIN PICKING SYSTEM FOR OBJECTS WITH VARIOUS FORM

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ABSTRACT

Bin picking is important step in the industrial and agricultural robotics, where several challenges had to be handled. During the object moving speed is a crucial factor as it influences productivity of the system. Also, the reliability of the system is a critical point i.e. pick and move all objects from the box even if those have various shape, size, softness. In this study we developed and tested a system to pick and place different form of objects. We involved 3 different robotic arms and 2 end effectors. Results showed that some of the objects, in more particular the curved cylinder and torus had to be repositioned in some cases 2 times before the pick, while in the case of the cylinder the maximum number of repositioning was 1. Mean number of repositioning per run was the higher in the case of torus while if we count repositioning per object, it was the higher in the case of curved cylinder. Maximum robotic arm movement time was counted, where the shortest maximum interval needed in the case of the plate, while the longest for the curved cylinder. In this study we introduced a new methodology for bin picking provides the possibility to use different types of arms and end effectors, with reducing the number of objects repositioning and time for path planning.

keywords: digitalization, bin picking, robotics, machine vision, object recognition, artificial intelligence, sensor, logistics

INTRODUCTION

Caused by multiple factors including labour shortage, climate change and increased demand for environmentally friendly agricultural technologies moreover population growth we can observe an intensified spread of precision farming solutions (Vougioukas, 2019; Duckett et al., 2018). Robotics are involved in multiple sectors of agriculture. Aravind et al. (2017) reviewed the agricultural mobile robotics concerning cereals (maize, wheat, rice etc.), industrial crops (cotton, tobacco, sunflower etc.) and other crops (e.g.: vegetables, flowers and ornamental plants etc.) and grouped the operations in 5 groups as tilling, soil analysis, seeding and transplanting, crop scouting and control moreover harvesting. Later Fountas et al. (2020) gave a more detailed classification and involved weeding, disease and insect detection, spraying plant management and multi-purpose robotic systems into the main operations. Livestock production also involves robotic solutions, where the focus is on the dairy farms (Shvets et al., 2024), while other sectors such as poultry production also applies advanced technologies (Ren et al., 2020). Duong et al. (2020) reviewed the robotic and autonomous systems from the perspective of the supply chain of the food industry. Their thematic analysis included studies concerning food quality, food safety, food waste, supply chain efficiency and supply chain analysis. Among the most important examples Iqbal et al. (2017) highlighted the picking, placing, palletizing, quality detection, bottle arrangement and filling, applications and showed the main requirements against these advanced technologies such as kinematics, dynamics, and control; hygiene; productivity and safety. Robotic solutions have several tasks in the above-mentioned sectors, and some of them requires complex motion planning. Bin picking is one of the main challenges in computer vision and robotics where the robotic arm/manipulator must pick up objects with various softness, form, shape, and material from different position. The bin-picking task becomes even more complicated and complex when the materials in the crate must be unloaded to the last piece without human intervention, when wedged and jammed objects must be freed for safe handling, when everything has to be done in short interval and without collision. Zhu et al. (2022) showed the complexity of bin picking benchmark in food handling, later Raja et al. (2024) evaluated the performance indicators during deformable material pick-and-place.

The aim of this study was to develop a robotic system that could handle robotic arms from various manufacturers and reduce time of object identification and picking moreover to provide technology for the 100 % object movement.

MATERIAL AND METHODS

Robotic arms and end effectors: Six-axis robotic arms were tested in these experiments: UR5e (Unchained Robotics GmbH); KUKA KR 6 R900 (KUKA Deutschland GmbH), and Yaskawa GP7 (Yaskawa America, Inc.). Two different end effectors were involved: a ROB-SET ECBPi

Figure 1: Four different objects included in this study: curved cylinder, cylinder, plate and torus from left to right

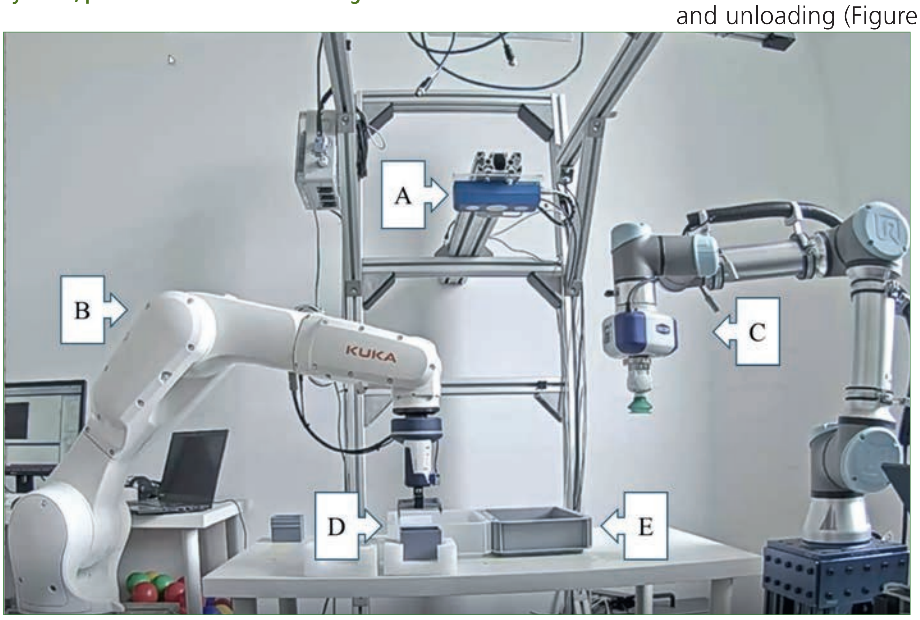

Figure 2: Robotic platform for the pick and place experiment. A: Ensenso N35-604-16-bl 3D-Camera; B: KUKA KR 6 R900 with Schunk Co-act EGP-C 40-N-N-UREK two-finger parallel gripper; C: UR5e with ROB-SET ECBPi UR vacuum effector; D: pick up box; E: place box

UR vacuum effector (Schmalz Vacuum Technology Ltd.) and a Schunk Co-act EGP-C 40-N-N-UREK two-finger parallel gripper (SCHUNK SE & Co.) (Figure 1). These experiments aimed to evaluate compatibility. Detailed test with different objects was run with UR5e.

Camera: Object detection was carried out with an Ensenso N35-604-16-bl 3D-Camera with 330-1100 mm lens (IDS Imaging Development Systems GmbH) (Figure 1).

Objects and test: In this study 4 type object with different form were picked and place with UR5e: curved cylinder (n=5), torus (n=25) with Schunk Co-act EGP-C 40-N-N-UREK two-finger parallel gripper and cylinder (n=6) and plate (n=10) with ROB-SET ECBPi UR vacuum effector to the tests and evaluate the interval of picking

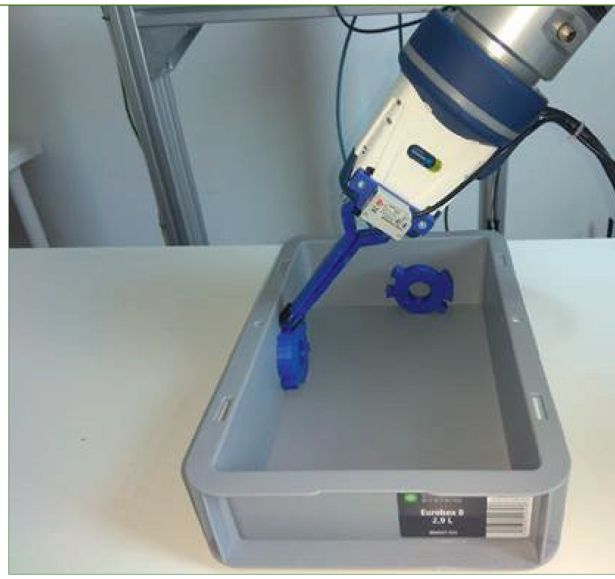

Figure 3: Object repositioning when the end effector is not able to pick the object

and unloading (Figure 2). The tests were carried out for each form individually, when the total numbers of objects had to be picked and placed 10 times. The objects were placed in a plastic box with the size of 300 mm × 200 mm × 70 mm (length×width×depth), and samples had to picked and placed to another box with the same size. If the object was not possible to be picked the system planned and implemented the repositioning the object (Figure 3). During the test minimum, maximum and average number of repositioning, total number of repositioning during the 10 run and maximum robotic arm's movement time were recorded.

RESULTS AND DISCUSSION

Ellekilde and Petersen (2013) emphasized that object moving is important part of the industry but as this operation do not add value to the product it should be performed as fast and seamlessly as it is possible, therefore optimal motion planning is essential. The result of the study is showed on the flowchart (Figure 4) that represents and process of defining the task to be performed by the robotic arms. As an initial step an RGB-D image of the contents of the box is generated. This step is critical in object recognition and pose estimation therefore the test of several 3D cameras is already available (Grenzdörffer et al., 2020), and applied in various environments for example in greenhouse and orchard (Botta et al., 2022). The image is segmented using a

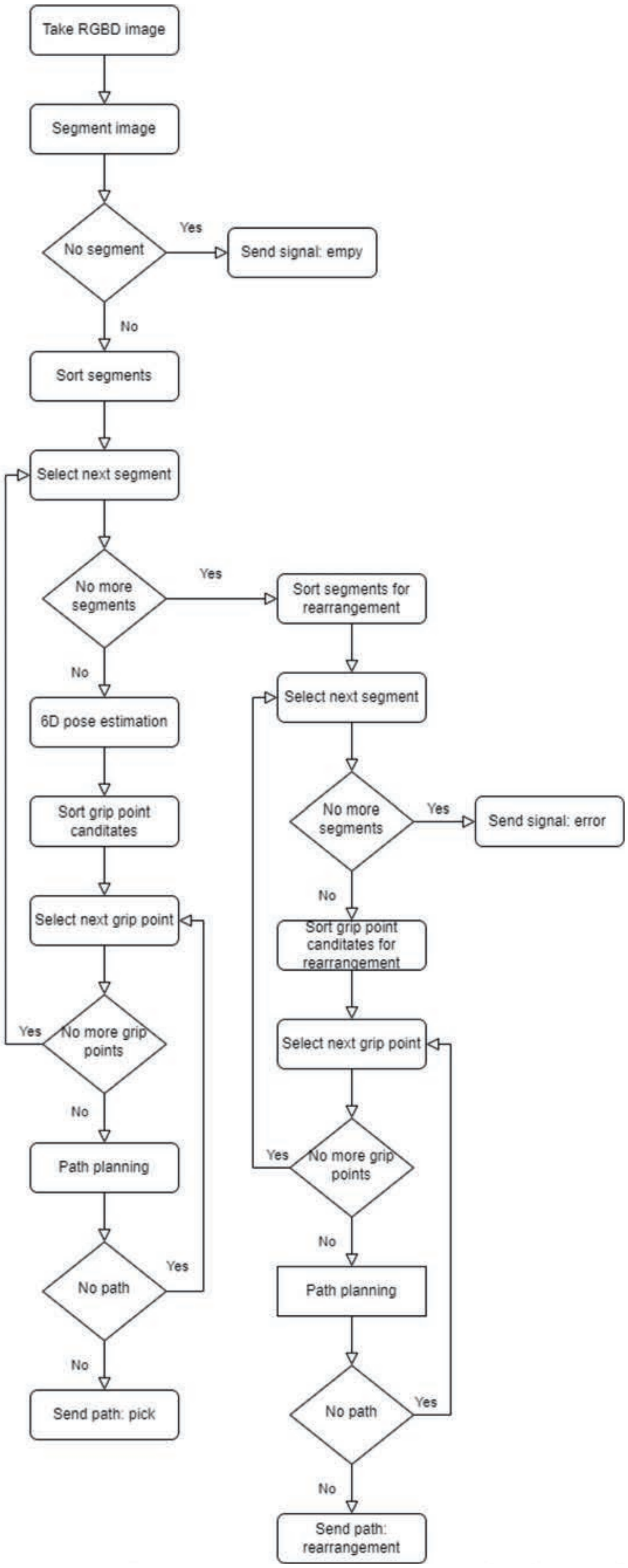

Figure 4: Flowchart represents the process of defining the task to be performed by the robotic arms.

neural network method to reduce the processing time. The segments are sorted according to a predefined criterion, for example size and position. The sorted segments are traversed. The position of the 6D is determined for a given segment. Based on the 6D position, possible grip points are determined. Then possible grip points are sorted (e.g.: position, orientation) and traversed. For a grip point the system searches for a collision-free robot arm path. If there is one, it is sent to the robotic arm, if not, it takes the next candidate grip point. If there are no more segments, then the system sorts the segments for reordering. For a given segment, we search for grip points, then possible grip points are sorted. We go through the sorted grip points. For a grip point, we search for a collision-free robot arm path to move. If there is one, we send it to the robotic arm, if not we take the next candidate grip point. If no more grip point candidates, then the next segment.

Former studies highlighted the importance of the form in robotic picking, also the distance of bins concerning the motion time (Solowjow et al., 2020) therefore during the test's different numbers of objects with different form were involved while robotic arm had to pick and place the objects from one box to other. Results were evaluated according to the individual boxes and according to the individual objects too. Minimum number of repositioning was 0 in all cases, meaning that irrespective to the form or the density of objects in the box there were runs where in one step any of the objects were possible to be picked by the effector. Maximum number of repositioning was lowest in the case of the plate. In all runs the plates were possible to be picked without any repositioning. In the case of the cylinder this number was 1 and only in 1 run was necessary to have a repositioning. The highest maximum numbers of repositioning were 2 in the case of curved cylinder and torus. Concerning the sum of repositioning (during the 10 runs) the highest value was observed in the case of the torus as in the 10 runs 9 repositioning was necessary, compared to the curved cylinder where this value was 6. It must be highlighted the numbers of object in the box concerning the different forms were not the same, for this reason the relative frequency of repositioning was also different. For this reason, even if the sum of repositioning of the torus was higher than in the case of the curved cylinder, the mean number of repositioning of the former one was lower (0,036 repositioning/object/10 run) compared to those of the later shape (0,12 repositioning/object/10 run). In this study maximum robotic arm's movement time was also evaluated. The results showed that the maximum robotic arm movement time was the shortest in the case of plate (1,2 second) while the longest in the case of the curved cylinder where it was 1,64 second. Based on various form movement in a long-term experiment Solowjow et al. (2020) according to the distance of the bins achieved 200-250 to 350 picks per hour with 90-95% success rate. In this study the aim

Table 1: Summary statistics of the pick and place tests with different form of objects				
Object form	curved cylinder (n=5)	cylinder (n=6)	plate (n=10)	torus (n=25)
Min. number of repositioning	0	0	0	0
Max. number of repositioning	2	1	0	2
Mean of the number of repositioning/run	0,6	0,1	0	0,9
Mean of the number of repositioning/object	0,12	0,016	0	0,036
Sum of repositioning	6	1	0	9
Max. robotic arm's movement time (seconds)	1,64	1,28	1,2	1,41

was to reduce the time under 2 seconds with 100% success rate which was achieved by our system.

CONCLUSIONS

Bin picking is important in many sectors of the industrial robotics within this agriculture and food technology. Some of the main challenges are the design the optimal motion planning, handling various object forms and provide high success rate. The bin picking solution we have developed and reported in this study offers highly efficient and time-saving operation. This system features fast object recognition technology and enables fast and accurate identification and handling of complex shaped objects.

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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).

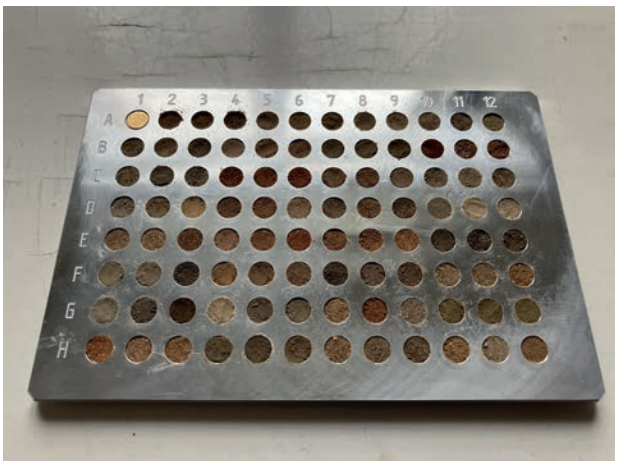

Figure 1: Soil samples prepared for middle-infrared spectral analysis

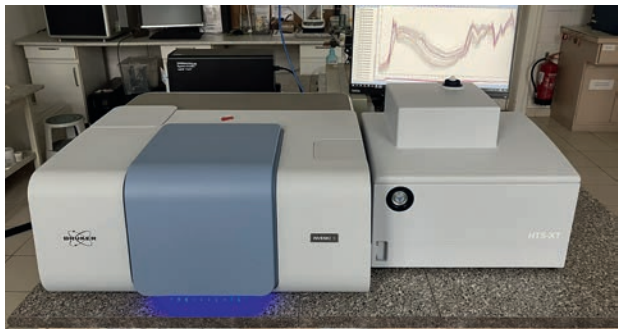

Figure 2: Bruker Invenio Fourier-Transform Infrared (FTIR) Spectrometer with Coupled HTS-XT Sample Changer

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.

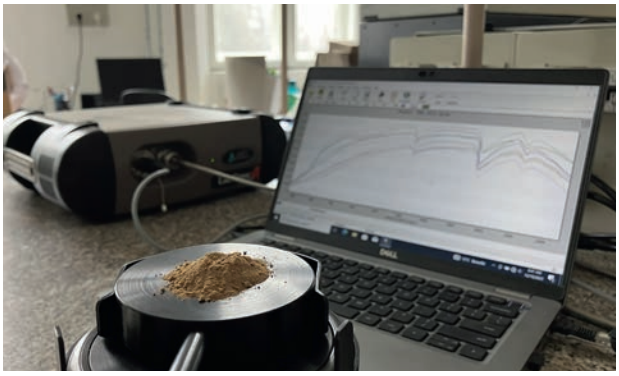

Figure 3: Malvern Panalytics ASD LabSpec 4 Hi-res Portable Spectrometer

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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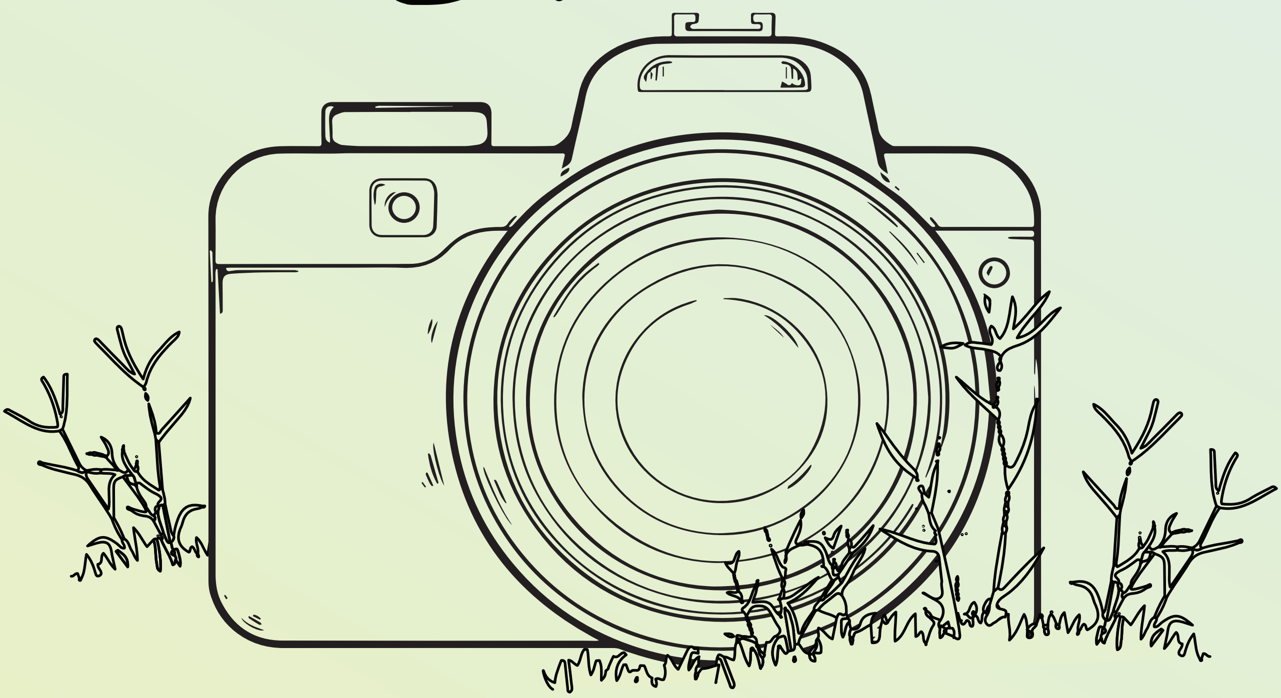

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