

Earth Observation hyperspectral remote sensing in agriculture: capacity building experience within the Horizon Europe EXPERT project between ASI, DLR and ROSA space agencies

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ABSTRACT

Missions such as DESIS, PRISMA, and EnMAP boost Hyperspectral (HS) Earth Observation (EO) applications, including agriculture. However, algorithms and methodological workflows are not yet fully shared outside the specialist scientific community and towards downstream applications. Furthermore, these developments may mostly remain unrealized opportunities for those countries without long-standing tradition of HS remote sensing or companies producing HS sensors. Within Horizon Europe "Reaching Excellence in Hyperspectral Remote Sensing" (EXPERT) project Grant Agreement No. 101160059, the Italian and German Space Agencies (ASI and DLR, respectively) are training Romanian Space Agency (ROSA) staff to build specialist competence and hands-on technical skills in HS. EXPERT foresees research use-cases focused on mining, agricultural and cultural heritage. To address the agriculture use-case, research activities are undertaken at Moara Domnească Didactic Farm, northeast of Bucharest. PRISMA and EnMAP image analysis is integrated with field measurements, including collections of relevant spectra using hand-held spectrometer and laboratory analysis on soil and vegetation samples. The first fieldwork campaign was carried out between the end of June and July 2025 and others are planned throughout the crop cycle. While these activities serve to set up the experiment, they are also opportunities to undertake capacity building on field spectroscopy and generation of applications products from hyperspectral satellite imagery. The EXPERT capacity building will prepare towards data exploitation of future spaceborne missions such as the Copernicus Hyperspectral Imaging Mission (CHIME).

Keywords: Hyperspectral Remote Sensing, Earth Observation, PRISMA, EnMAP, agriculture, capacity building.

1. INTRODUCTION

Hyperspectral (HS) remote sensing is a well-established Earth Observation (EO) domain, which has matured over the last 40 years by means of various airborne (AIS, AVIRIS, CASI, HyMAP, HySPEX) and spaceborne instruments (Hyperion, HICO, CHRIS). Owing to a number of current and upcoming HS sensors and missions, its relevance over the next decade is expected to increase even further.

To summarize the recent history of HS EO development, it is worth recalling that several missions were launched over the past 25 years [1]. Launched by the National Aeronautics and Space Administration (NASA) in 2000, Earth Observing-1 (EO-1) was the first non-military satellite mission equipped with a HS instrument called Hyperion. The instrument acquired 220 spectral bands (30 m spatial resolution) in the visible-near-infrared (VNIR) and shortwave-infrared (SWIR) spectrum. Next, the Compact High Resolution Imaging Spectrometer (CHRIS) on board of Project for On-Board Autonomy-1 (PROBA-1) was launched by the European Space Agency (ESA) in 2001. Onboard of a scientific mission, CHRIS represented the second hyperspectral spaceborne instrument. After a few years of lack of HS missions, with the exception of the Hyperspectral Imager for the Coastal Ocean (HICO) that focused on imaging the oceans from the International Space Station (ISS) from 2009 to 2014, starting from 2018 new missions have been launched.

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Currently operational, the German Aerospace Center (DLR)'s Earth Sensing Imaging Spectrometer (DESI), the Italian Space Agency (ASI)'s PRecursores IperSpettrale della Missione Applicativa /Hyperspectral Precursor of the Application Mission (PRISMA) and the DLR's Environmental Mapping and Analysis Program (EnMAP) are advanced hyperspectral missions that acquire data across more than 200 spectral bands, with a spatial resolution of 30 m.

More recently, in 2024, the first Tanager satellite was launched by PLANET private company. Future missions are already planned, including the Copernicus Hyperspectral Imaging Mission for the Environment (CHIME) that represents one of the Copernicus Sentinel Expansion Missions (planned for launch by ESA in 2028).

In this lively and evolving upstream context, a growing amount of HS imagery is disseminated across the international science and commercial community and, in the near future, an increase in data flow is expected. Therefore, it is of paramount importance that investments are made to create a distributed network of scientific (researchers and academia groups) and commercial (developers, SMEs and geospatial services companies) users capable of analyzing these data, also through novel processing algorithms, testing of prototype products workflows, and delivery of application products and services.

One of the application domains where HS proves most beneficial is agriculture [2-3]. However, while there is an increasing literature on algorithms development for estimating key parameters of croplands and arable land (e.g. soil organic carbon, canopy chlorophyll content, total nitrogen, leaf area index) and demonstrating prototypes products (e.g. quantification of non-photosynthetic cropland biomass, crop yield prediction, and crop traits retrieval) (e.g. [4-6]), there is still a lack of evidence that such algorithms and methodological workflows are shared outside the specialist scientific community and towards downstream applications.

The risk is that these developments may mostly remain unrealized opportunities for those countries where, in absence of a long-standing tradition of HS remote sensing or companies producing HS sensors, there is no yet a consolidated and distributed community with HS satellite remote sensing technical and hands-on expertise (except for sparse individual scholars or groups already working with these technologies or with prior expertise on airborne data only). For example, this scenario can be found at the moment in Romania and, more widely, across Eastern Europe countries. While several academia and research organizations have strong competences in various strands of remote sensing – first of which multispectral optical and Synthetic Aperture Radar – and commercial companies exist and deliver applications and downstream services, HS satellite remote sensing has not yet reached maturity across the country. To stimulate an acceleration in this EO domain at national level, one of the most effective strategies is to identify a national champion (or a group of them) that can act as a technological innovator hub. This may start creating in turn a competence basis, and promote further dissemination across the reference community through training initiatives.

It is with this scope that the Romanian Space Agency (ROSA) promoted the application for and is coordinating the Horizon Europe "Reaching Excellence in Hyperspectral Remote Sensing" (EXPERT) project (<https://www.expert-project.rosa.ro/>), with ASI and DLR as project partners. ROSA is the ideal candidate to take the role of technological innovator hub described above, as the national space body in charge of coordinating the national space research and application programs, promoting Romania's development in the space field, and representing the Romanian Government in international cooperation programs and undertaking research oriented on space matters. EXPERT is funded in the framework of HORIZON.4.1 "Widening participation and spreading excellence" program, "HORIZON-WIDERA-2023-ACCESS-02-01 - Twinning Bottom-Up" topic, "HORIZON Coordination and Support Actions" funding scheme.

This paper outlines the key concept behind the project EXPERT, its objectives and current activities, encompassing both capacity building and experimental research. With regard to the latter, the paper describes the research activities and the test site in Romania addressing the agricultural use-case of the project.

2. METHODS

2.1 The EXPERT project

EXPERT aims to improve the excellence, capacity and resources of ROSA in the area of HS remote sensing through knowledge and best practices transfer by ASI and DLR. Started in June 2024, EXPERT achieves such ambitious goal through international cooperation between the two space agencies – ASI and DLR – which are European leaders in HS sensor technologies, data analysis, applications and downstream services, and the national organization – ROSA – which

has the institutional mandate and profile for playing the above said technological innovator hub and accelerator in Romania. Centered around the HS area of research and innovation, the EXPERT project targets an increased science and innovation capacity for the organization based in the widening country, consequently generating a greater involvement of local actors in the research and innovation process, both at national and European levels, through the specific actions designed for the wider communities around ROSA. Additionally, ROSA will develop a research profile and technical competence in order to fully exploit the R&D opportunities of such emerging field given the upcoming, HS satellite technologies and missions in Europe and beyond, under the guidance of both ASI and DLR, Agencies at the forefront of HS remote sensing science and applications at global level.

The concept behind EXPERT is underpinned by three fundamental pillars (Figure 1):

- A research component represented by HS remote sensing;
- Coordination and support measures for stimulating scientific excellence and innovation capacity;
- The enhancement of research management and administration skills;

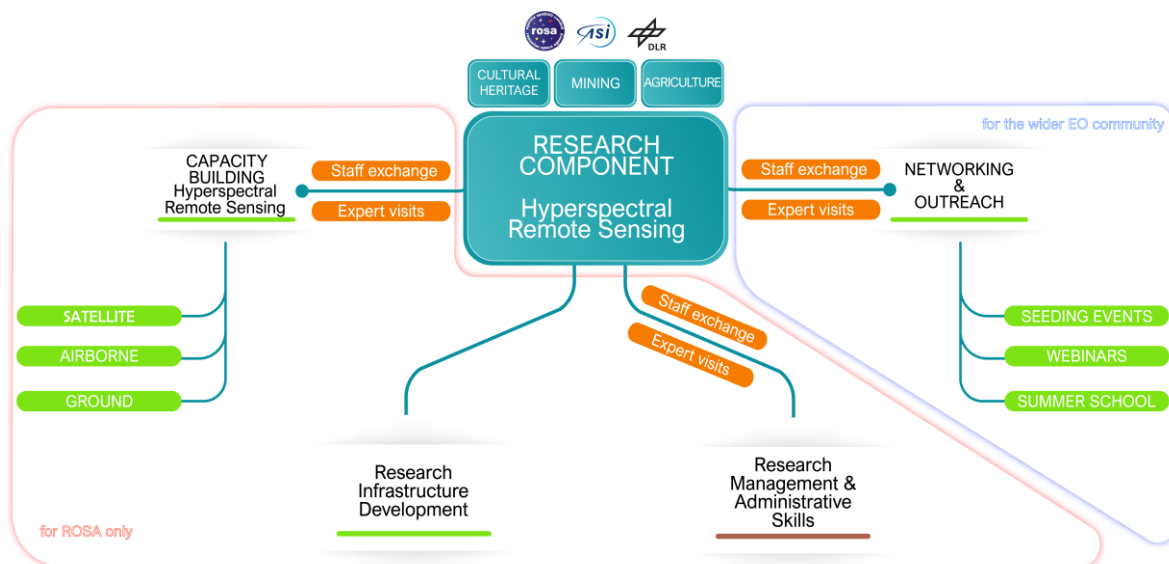


Figure 1. The EXPERT concept, with the research component being at the core of the project and the three research-uses addressed, among which the one focused on agriculture.

In practice, EXPERT involves:

- Capacity building through training delivered by ASI and DLR to ROSA scientific and technical staff members, in order to build specialist competence and hands-on technical skills in collection, processing, post-processing and analysis of HS data collected from ground-based, airborne and spaceborne sensors;
- Joint development of research use-cases focusing on the main applications that ROSA has identified as priorities to support the growth of the national satellite-based downstream and applications sector, i.e. mining, agriculture and cultural heritage;
- Outreach, networking and capacity building towards the user community, with the main focus on the Romanian academic, scientific and commercial sectors and, secondarily, neighboring countries in the Eastern Europe. Specific actions include: outreach webinars for awareness about HS remote sensing and basic and entry-level training; summer school devoted to EO researchers and professionals for an intensive specialist training; networking events to expand the community benefitting from the EXPERT impact and create opportunities for future partnerships and development in HS remote sensing at national level. Networking also encompasses liaising and partnering with other TWINNING project, such as AI4AGRI (<https://www.ai-4-agri.eu/>) coordinated by the R&D Institute of Transilvania University of Brasov in Romania.

It is worth noting that the capacity building, training and research use-cases rely on the joint exploitation of PRISMA and EnMAP. This choice accounts for the fact that PRISMA and EnMAP share several technical properties and are currently paving the way to the future generations of HS missions. Their joint use can dramatically increase the timeliness of critical acquisitions, and the robustness and completeness of hyperspectral image time series on a given area of interest. In September 2022, ASI and DLR signed an implementation agreement to share HS data and the strategies, methods and results, and strengthen the synergies between the two missions (<https://www.asi.it/en/2022/09/orbital-twinning-between-the-italian-prisma-satellite-and-the-german-enmapsatellite/>). Therefore, in the context of this inter-agency twinning initiative, the EXPERT project represents an excellent opportunity to capitalize on this cooperation and widen the benefits from PRISMA and EnMap HS data exploitation and applications development in the framework of the cooperation with ROSA. The longer-term objective is to help ROSA and its surrounding national ecosystem in preparing for HS-based R&D and downstream applications, also towards data exploitation of future missions such as CHIME.

2.2 The EXPERT agricultural research use-case

All the project research use-cases are planned to be developed during Year 2 of the project, i.e. from 1 June 2025 to 31 May 2026.

Table 1 summarizes the main elements of the agricultural research use-case.

More specifically, the agricultural research use-case focuses on the use of multi-temporal hyperspectral satellite data to monitor the evolution of crops over at least one year. The activities include the identification and monitoring of the crop development stages (phenology), the assessment of the canopy water and pigment content, the detection of micronutrients, the quantification of non-photosynthetic vegetation / biomass, vegetation stress, changes in land cover use, and other research interests that are defined by ROSA with the support of DLR and ASI.

The research activities are undertaken by ROSA, ASI and DLR over the Moara Domnească Didactic Farm, situated 15 km northeast of Bucharest (reference coordinates: LAT 44.495200°, LON 26.253000°; Figure 2). The site is operated by the University of Agronomic Sciences and Veterinary Medicine of Bucharest, and has been used as an experimental site for agricultural research for years (see e.g. [7-9]). The site encompasses a variety of cropfields – e.g. corn, wheat and rapeseed – and is equipped with a network of mini weather stations that permanently record air temperature, precipitation, global radiation, relative humidity, and wind direction and speed.

Satellite analysis is based on both PRISMA [10-11] and EnMAP [12] imagery that are tasked for acquisition to be as much temporally co-located as possible with ground-truth data collection. Furthermore, the satellite acquisitions are tasked to document the site in between successive field surveys, and thus create a multi-sensor hyperspectral time series with at least monthly revisit time. If adverse atmospheric conditions or other hindrances prevent the acquisition of hyperspectral satellite data, the comparison with ground-truth data is carried out using Sentinel-2 images. The latter data are anyway exploited to retrieve the trend in crop phenology and history of agricultural practices at the site over the past decade (i.e. 2015-2025).

Ground-based spectroscopic measurements are made by means of the hand-held field spectrometer, model SVC XHR-1024i (Table 2), that was acquired by ROSA during the initial phase of the project. The spectrometer has several additional devices, such as a rugged and waterproof smartphone furnished with the SVC proprietary software which was also provided separately for computer installation. Spectral data can be viewed in real time on the sunlight readable color display. Additionally, a reflectance probe is provided as an accessory of the instrument, allowing for rapid reflectance measurements.

Furthermore, in collaboration with the University of Agronomic Sciences and Veterinary Medicine Bucharest, soil and vegetation samples are taken from selected crops and are analyzed both in the field and laboratory in order to retrieve key parameters – e.g. chlorophyll content, plant height, wet and dry biomass, soil organic carbon, nitrogen content and permeability – to either match or integrate with satellite estimates.

Finally, when possible, further ancillary data are collected, including a drone survey comprising DSM (Digital Surface Model), RGB aerial views, NIR (Near Infrared), and Red Edge imagery.

Table 1. Main elements of the agricultural research use-case of the EXPERT project.

Parameter	Specification
Scope	crop evolution crop condition
Test site	Moara Domnească, Romania
Data	hyperspectral satellite images hyperspectral ground data field and laboratory analysis high resolution Digital Terrain Model
Frequency	multi-temporal acquisitions

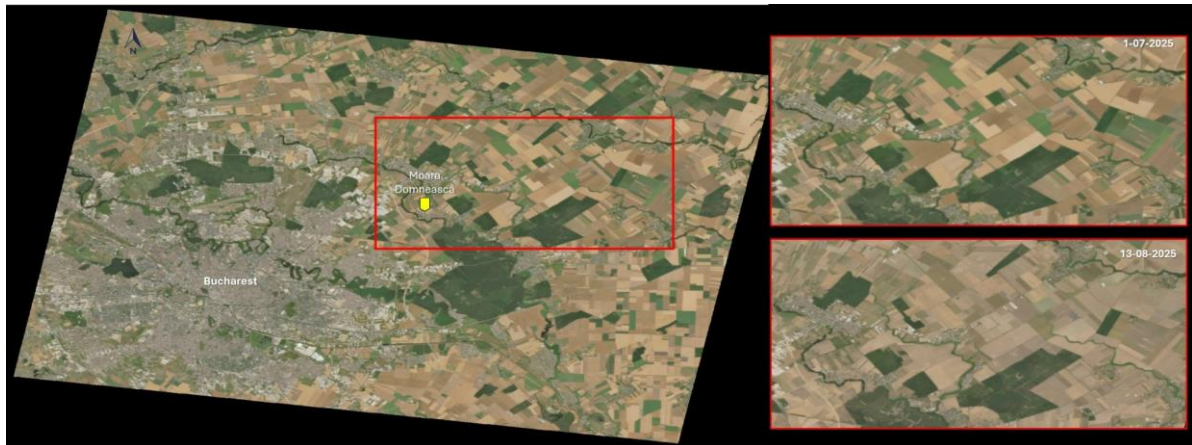


Figure 2. Location of Moara Domnească Didactic Farm, northeast of Bucharest city center, Romania, selected as the test site for the agriculture use-case in the EXPERT project. (left) True color combination of EnMAP image acquired on 01/07/2025. (insert on the right) Zoom over the area including the test site as true color combinations of EnMAP images acquired on the 01/07/2025 (top) and 13/08/2025 (bottom), showing changes in the agricultural fields.

Table 2. Technical specifications of the hand-held field spectrometer, model SVC XHR-1024i, as published by the producer (<https://spectravista.com/instruments/xhr-1024i/>).

Spectral Range	350 nm – 2500 nm
Internal Memory	1000 scans
Channels	1024, 2100 resampled
Linear Array	(1) 512ch Si, 350 – 1000 nm (1) 256ch InGaAs, 1000 – 1890 nm (1) 256ch Extended InGaAs, 1890 – 2500 nm
Spectral Resolution (FWHM)	2.8 nm, 700 nm 8.0 nm, 1500 nm 6.0 nm, 2100 nm
Bandwidth (nominal)	1.5 nm, 350 – 1000 nm 3.8 nm, 1000 – 1890 nm 2.5 nm, 1890 – 2500 nm
Minimum Integration	1 millisecond

FOV	4° standard, 8° or 14° optional 25° optional armored fiber optic
Noise Equivalent Radiance	$\leq 0.8 \times 10^{-9}$ W/cm ² /nm/sr @ 700 nm $\leq 1.2 \times 10^{-9}$ W/cm ² /nm/sr @ 1500 nm $\leq 1.8 \times 10^{-9}$ W/cm ² /nm/sr @ 2100 nm
Stand Alone Measurements (no computer required)	Standard
Calibration Accuracy (NIST Traceable)	±5% @ 400 nm ±4% @ 700 nm ±7% @ 2200 nm
Wavelength Reproducibility	0.1 nm
Dark Current Correction	Automatic
Spectrum Averaging	Automatic/selectable
Internal Digital Camera	Supplied
Internal GPS	Supplied
Head Size	8.75" x 11.5" x 3.0"
Weight	8.5lbs., 3.8kg
Host Communications Interface	Wireless Bluetooth USB RS232
Sealing	Sealed against dirt and dust
Tripod mounting	Standard 1/4-20 camera mounts
Battery Type	7.4 V lithium ion
Battery Life	3 hours approximately
Sighting	Laser diode

3. RESULTS

With regard to capacity building, Year 1 was dedicated to initial capacity building on remote sensing, with the aim to let ROSA technical staff build specialist competence and hands-on technical skills in collection, processing, post-processing and analysis of HS data acquired from ground-based, airborne and spaceborne sensors.

As a first step, a competence mapping and gap analysis was conducted. This exercise was aimed to:

- Delineate ROSA's technical profile in HS imaging, i.e. background knowledge, previous experience, existing capabilities, skills and HD/SW resources available at ROSA in collection, processing, post-processing and analysis of HS data, as well as current gaps;
- Consolidate ROSA's capacity building needs in order to better structure activities of initial (Year 1) and advanced (Year 2) remote sensing training;
- Identify the propaedeutic topics included in the start of the training, the roadmap and the specific measures that ASI and DLR will put in place during capacity building to assist ROSA in developing the needed skills.

Based on this preparatory exercise, training activity included initial online sessions, as well as in-presence practical sessions mocking either desk-based analytical tasks or ground-based measurements collection and tutorials on sample hyperspectral imagery from both satellite and airborne sensors. The ultimate goal was to train ROSA staff on conducting each step of the full chain leading from handling of HS data as they are provided once collected to generation of value-

added products in order to address specific applications, thus gaining autonomy to be able to replicate in future. In particular, one activity encompassed the demonstration of the SVC Spectrometer operation. In specific, the Kautsky effect (i.e. the phenomenon consisting of a typical variation in the behavior of a plant fluorescence when exposed to light) was demonstrated on a living plant. Furthermore, sample spectra were acquired on synthetic materials, liquids, rocks and human skin. Finally, the participants were asked to conduct supervised field measurements by themselves over an open area using the same SVC spectrometer similar to the one that the ROSA staff exploits for the agricultural research use-case (Figure 3).

The corresponding measurements were analysed using conventional data processing tools written in Python programming language.



Figure 3. Training session to practice and familiarise with ground-based spectroscopic measurements by means of an SVC spectrometer of same technical specifications as the one that the ROSA staff exploits for the agricultural research use-case.

With regard to the experimental activities at Moara Domnească test site (Figure 2), the first field survey was undertaken on 30 June and 1 July 2025 and was essentially aimed to characterize the site, by collecting soil and vegetation samples to analyses in the laboratory, alongside SVC measurements. To this purpose, the following two areas were selected (see location in Figure 4):

- The land lot, east of the main entrance, where the Romanian private company TERRASIGNA has installed a Tomographic C-band Synthetic Aperture Radar infrastructure (T-SAR) of its own development and a NIR (Near InfraRed Camera) to carry out measurements focusing on soil moisture and plant health parameters (<https://blogs.esa.int/campaignearth/2025/05/13/t-sar-advancing-earth-observation/>). At the time of the survey, the crops were cultivated with corn, evenly spaced in rows 30 cm apart. The height of the plantation was homogeneous over the study area (mean height 141 cm), with evident spots where the crop growth was reduced, with a height delta of 20 cm circa. Plant phenology observed during the field campaign was related with the vegetative – growth phase (Figure 5). The area was irrigated with evenly spaced dripping pipes, ensuring a water flow sufficient to avoid the manifestation of any drought stress on the plants. Furthermore, the site has been equipped by TERRASIGNA with 8 soil probes acquiring soil temperature and humidity at three different depths.

In this experimental setting, the EXPERT project activities focus on the investigation of vegetation and soil parameters derived from SVC field spectra, correlating such parameters with field probes data and related

spaceborne PRISMA and EnMAP observations. The main scientific goal defined for this case study is the development of a vegetation drought stress indicator, combined with the investigation of soil health.

On 1 July 2025, SVC spectra, soil and vegetation sampling was conducted along two transects, the first in proximity of the TERRASIGNA soil probes to maximize the potential relationship with its data; the second perpendicular to the aforementioned transect and following the greatest crop heterogeneity. Figure 6a shows the location and extent of the two transects along which SVC measurements were taken;

- The second investigated plot in the Moara Domnească site, despite being again cultivated with corn, presents peculiar vegetation differences with the aforementioned plot. Geographically, the plot is located west of the farm main entrance (Figure 4), part of a greater corn cropfield (LAT 44.495200°, LON 26.253000°), and irrigated with a center pivot system and with homogeneous fertilization throughout the cultivation. The field sampling was undertaken according to an evidence-based rationale: plant height and greenness homogeneity (expert assessed) served as benchmark, while areas deviating from this mean condition were further investigated. Ancillary investigations were conducted on high-resolution drone derived NDVI (Normalized Difference Index) and DSM datasets. NDVI and DSM analysis highlighted the correspondence between the observed field anomalies – plants less green and tall compared to the homogeneous portions of the cropfield – with lower NDVI index values and local microtopographic depressions. For this reason, the main objective for this plot was the investigation of the phenomena leading to hindered plant growth and its relation with soil and topography. Consequently, according to the field and drone derived evidences, the SVC data collection was conducted along a transect intersecting homogeneous vegetation, partially stressed vegetation and clearly impacted vegetation, therefore maximizing the difference in the elements acquired according to the observed gradient (Figure 6b). In consideration of EXPERT project's capacity building vocation, this second plot in Moara Domnească was used to exemplify the process leading to field data collection, structuring a site tailored rationale, in the end allowing to achieve the desired goals.

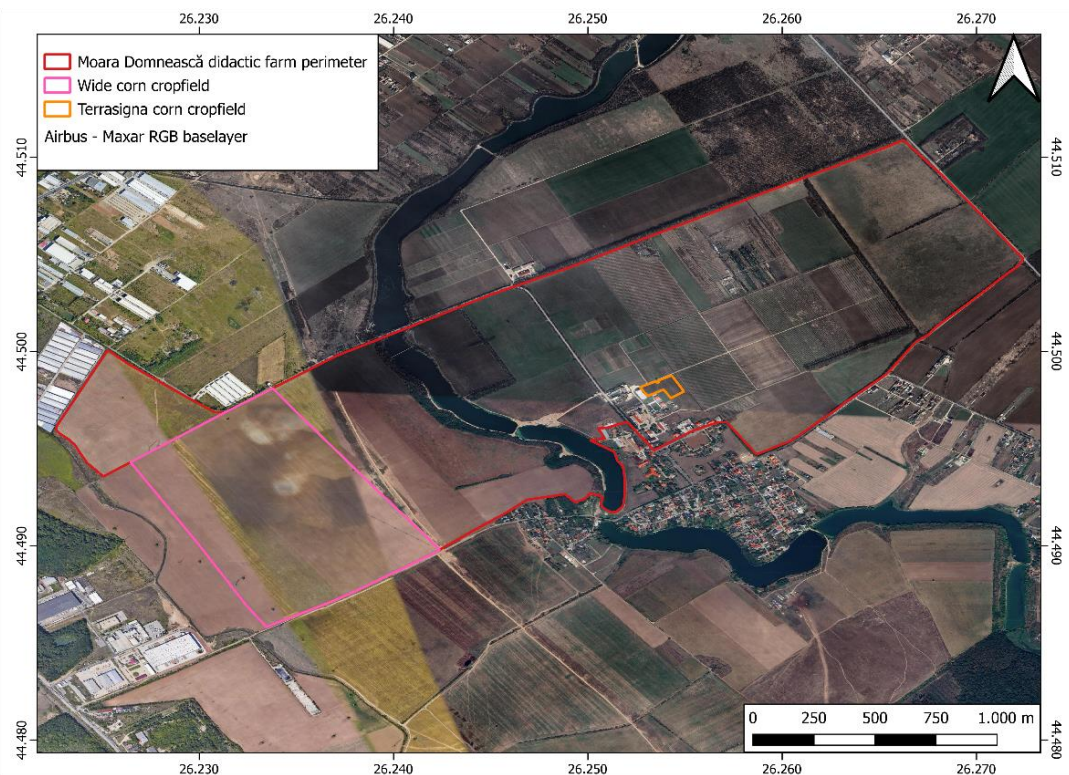


Figure 4. Detailed view of Moara Domnească Didactic Farm with indication of the cropfields where in situ SVC measurements and soil and vegetation samples were collected on 1 July 2025.

PRISMA and EnMAP images were successfully collected on 30 June and 1 July, respectively. However, the EnMAP image only was sufficiently cloud-free to be used in its entirety for spectra extraction and subsequent analysis (see Figure 2).

A second field survey was undertaken on 12 August 2025 and the activities were mainly focused on SVC measurements in the cornfield cultivated in the land lot that hosts the T-SAR. Measurements targeted both plants and soil, and were performed parallel and perpendicular to the road, combined with GPS point acquisitions. Six plant samples were also collected from this field. At the second plot, located at the Moara Domnească site, only 6 SVC measurements were taken, as the corn had already been harvested.

According to the same approach followed during the first survey, PRISMA and EnMAP images were tasked for collection on the closest data take opportunities (see Figure 2 for the EnMAP image collected on 13 July 2025). The data collected during these two initial surveys are currently being analysed.



Figure 5. Field photos showing the condition of the corn crops during the first survey on 1 July 2025 and the project team collecting in situ measurements.

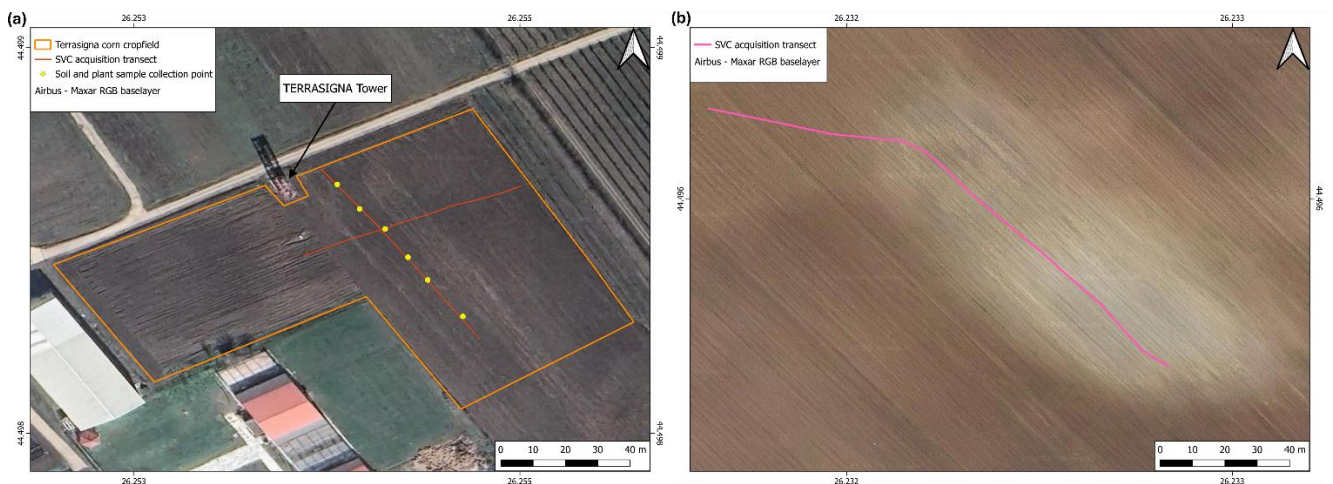


Figure 6. Location of the transects that were measured using the SVC instrument during the field survey undertaken at Moara Domnească Didactic Farm on 1 July 2025 at: a) the land lot cultivated with corn and managed by TERRASIGNA; and b) the wide corn cropfield located west of the farm main entrance (see Figure 4 for the wider location).

4. CONCLUSIONS

After more than one year since its start, the EXPERT project has achieved its first goals. ASI and DLR teams have delivered the initial capacity building activities to provide the ROSA technical staff with the foundational basis of hyperspectral remote sensing, to address the first basic need for a common background. Then, as per the project plan, since 1 June 2025, the research use-cases have been initiated, including the one focused on agriculture. The Moara Domnească test site is advantageous given that it is an experimental and didactic site that is equipped with in situ instrumentations. Furthermore, the site is subject to regular agronomic and remote sensing data collection from the University of Agronomic Sciences and Veterinary Medicine Bucharest and TERRASIGNA. This condition enables the EXPERT project team to network with the national Romanian community and establish collaboration in order to enhance the prospective added value brought by HS EO and field spectroscopy in the agriculture application domain. It is under this perspective that Year 2 of the project will be spent to develop the research use-case and develop prototype products that will showcase how HS EO can support agricultural sciences and applications.

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