Interreg CENTRAL EUROPE

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AGRI-DIGITAL GROWTH

D2.1.2 Joint Report Resuming the 5 experiences in Living Labs and Relative Results.

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1. Introduction

1.1. Purpose of the Deliverable

This deliverable (D2.1.2) presents a joint report summarizing the experiences and results generated through the implementation of the five Living Labs established within Work Package 2 (WP2) of the Agri Digital Growth project.

The report consolidates the activities carried out by project partners, providing an overview of the technologies tested, the results achieved, and the challenges encountered. It also includes a comparative analysis identifying common lessons learned, future opportunities, and potential applications of the developed approaches.

1.2. Living Lab Approach within WP2

WP2 focuses on strengthening collaboration between project partners and quadruple helix actors in Central Europe to support the digital transformation of agrifood SMEs and improve access to Precision Farming expertise and innovation.

The Living Labs were established as collaborative environments connecting research institutions, SMEs, technology providers, students, advisors, and agricultural stakeholders. They represented a key component of the Precision Farming Knowledge Transfer Ecosystem, addressing complementary thematic areas including agro-robotics, artificial intelligence, smart irrigation, remote and proximal sensing, geospatial data processing, autonomous systems, and decision-support tools.

1.3. Common Methodology and Stakeholder Engagement

The Living Labs followed a practice-oriented approach based on experimentation, testing, validation, and direct interaction with end users in real agricultural environments. Activities included field demonstrations, prototype development, sensor deployment, data acquisition and analysis, and pilot testing under operational conditions.

Stakeholder participation, through workshops, hackathons, study visits, and technical events, supported practical learning, feedback collection, and knowledge exchange. The Labs also promoted cross-sector and cross-country cooperation, strengthening dissemination of innovative agricultural approaches.

1.4. Training, Education, and Knowledge Transfer Activities

Training was integrated throughout the Living Labs, with participants engaging in hands-on activities related to prototype testing, field monitoring, data analysis, AI applications, and decision-support technologies. Particular attention was given to students and young professionals through applied learning and collaborative problem-solving, with events held at both regional and international level.

2. Overview of the Five Living Labs

Living Lab	Lead Partner	Main Focus Area	Main Technologies
Robotics & Automation	UM	Agro-robotics, photonic pest management, smart vineyard infrastructure	Autonomous UGV, UV-C treatment, agrivoltaics, smart irrigation
Decision Support Systems & Drones	MATE / LCM	Precision viticulture monitoring	NDVI, PRI, RGB imaging, GPS-based sensing
Geospatial Data	Plan4all	Geospatial data, AI, and precision farming knowledge transfer	JackDaw GeoAI
Precision Viticulture and Water Use Optimization	CREA	Vineyard water status monitoring and smart irrigation	Stereo cameras, thermal imaging, CWSI, DSS, proximity sensors
Sensors & Computer Vision	JR	AI-assisted sensing and computer vision for agriculture	Machine vision, AI-based image analysis, smart sensors, object detection

3. Living Lab Experiences and Results

3.1. Robotics & Automation (UM)

3.1.1. Main activities and timeline

The Robotics & Automation Living Lab, implemented by the University of Maribor (UM), focused on the development, integration, testing, and demonstration of agro-robotic and digital technologies for sustainable agriculture and precision viticulture. Activities combined robotics, renewable energy systems, precision irrigation, autonomous systems, and sustainable crop protection within a multidisciplinary experimental environment involving researchers, engineers, students, and agricultural stakeholders.

The Living Lab addressed agricultural challenges related to climate change, agrochemical use, water scarcity, labour shortages, and energy efficiency. Three pilot activities were implemented:

Photonic Pest Management Using an Autonomous Unmanned Ground Vehicle (UGV)

Sustainable Vineyard Infrastructure Integrating Agrivoltaics and Smart Water Management

FarmBeast, an extracurricular educational activity focused on agro-robotics and the international Field Robot Event competition.

Phase 1 focused on concept development: autonomous robotic systems, photonic pest management, renewable energy integration, precision irrigation, and climate-resilient vineyard infrastructure. FarmBeast students developed mobility concepts, sensing strategies, and navigation approaches for autonomous field robots.

Phase 2 focused on prototype design and system integration. A Clearpath Husky robotic platform was equipped with UV-C illumination modules for autonomous crop treatment, and adjustable gantry structures and illumination arrays were developed. In parallel, a modular agrivoltaic vineyard infrastructure prototype integrating flexible photovoltaic panels, hollow water-storage pillars, and micro-drip irrigation was constructed and tested.

Phase 3 included field demonstrations covering robotic navigation, UV-C crop treatment, canopy illumination coverage, agrivoltaic shading evaluation, water harvesting, and irrigation system testing. FarmBeast students tested their robotic systems under simulated field conditions, evaluating navigation performance, obstacle detection, and operational reliability.

Phase 4 consolidated all activities through dissemination and stakeholder engagement events, including workshops, field demonstrations open to agricultural stakeholders, and reporting activities.

3.1.2. Key results achieved

Technical outcomes

The robotic UV-C pest management platform successfully integrated UV-C treatment modules onto an autonomous UGV capable of targeted canopy illumination and nighttime operation for non-chemical crop treatment. Adjustable gantry systems enabled adaptation to different crop geometries and vineyard row configurations.

The agrivoltaic vineyard infrastructure prototype demonstrated combined implementation of solar energy harvesting, rainwater collection, localized water storage, precision micro-drip irrigation, and microclimate regulation through controlled shading, with potential for reducing heat stress and improving climate resilience in vineyard production.

Educational and capacity-building outcomes

Students and young researchers gained practical experience across robotics integration, autonomous systems, embedded electronics, agricultural automation, renewable energy, and precision agriculture. The interdisciplinary structure strengthened cooperation between agriculture, engineering, computer science, and renewable energy disciplines.

A major outcome was the participation of the UM FarmBeast team in the 22nd international Field Robot Event competition held near Milan, Italy, involving 16 teams and approximately 150 participants from 10 European countries. The team competed across multiple disciplines, autonomous navigation, plant detection, fruit counting, and bioluminescent object detection, and in the freestyle task presented an AI-assisted robotic asparagus harvesting system. The team achieved:

- 2nd place in plant detection
- 2nd place in bioluminescent fungi detection
- 2nd place in the freestyle innovation task
- 3rd place in the overall competition ranking

Figure 1. *Agrivoltaic vineyard infrastructure prototype developed for solar-energy harvesting, rainwater collection, and precision irrigation applications*

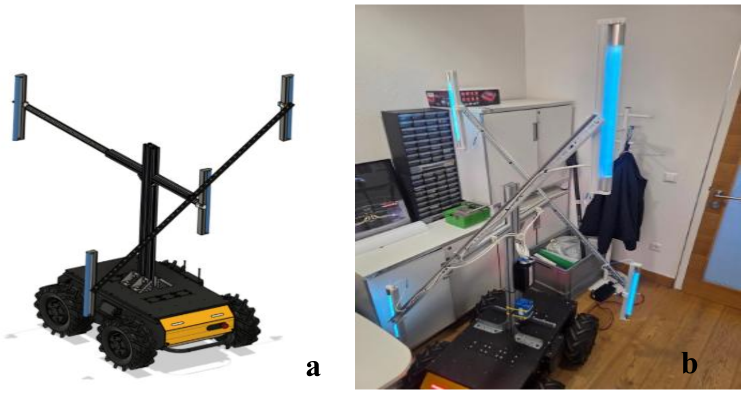

Figure 2. *(a) CAD design and (b) laboratory prototype of the autonomous UV-C robotic platform developed for photonic pest management in vineyards.*

Figure 3. *FarmBeast autonomous agro-robotic platform*

3.1.3. Main challenges encountered

Integration of UV-C illumination systems onto the robotic platform required continuous optimization of electrical power distribution, mechanical positioning, illumination intensity, and user safety protocols. Correct UV-C dosage management was particularly critical to suppress pathogens while avoiding phytotoxic effects on crops. Canopy density, leaf orientation, and shaded areas further limited illumination effectiveness, requiring iterative adjustment of positioning and crop accessibility.

The agrivoltaic infrastructure introduced engineering challenges related to integrating flexible photovoltaic panels into curved support structures and ensuring the water-tightness, controlled flow, and outdoor durability of the hollow water-storage pillar system.

Environmental variability, including fluctuations in sunlight, temperature, humidity, precipitation, and uneven terrain, affected robotic mobility, illumination consistency, and the repeatability of field demonstrations. The interdisciplinary nature of the work required continuous coordination between researchers, engineers, students, and agricultural stakeholders throughout iterative design and testing cycles.

3.1.4. Future perspectives and applications

Future developments will focus on increasing automation, intelligence, and adaptability of agro-robotic systems through advanced sensing, AI-assisted decision-making, autonomous navigation, and environmental monitoring. Additional work may include sensor-based disease detection, adaptive UV-C dosage regulation, automated irrigation optimisation, and digital-twin approaches for vineyard management.

Long-term field validation will address operational efficiency, energy consumption, water savings, disease suppression performance, economic feasibility, and commercial scalability. The technologies also show strong transferability to greenhouse systems, orchards, berry and vegetable cultivation, urban farming, and protected agriculture.

3.2. Decision Support Systems & Drones (MATE/LCM)

3.2.1. Main activities and timeline

The Decision Support Systems & Drones Living Lab, implemented by the Hungarian University of Agriculture and Life Sciences (MATE) and Linz Center of Mechatronics GmbH (LCM), focused on assessing vertical vineyard canopy variability through RGB imaging and spectral vegetation indices, specifically NDVI (Normalized Difference Vegetation Index) and PRI (Photochemical Reflectance Index).

The objective was to develop and test a mobile sensor network integrating NDVI and PRI sensors, an RGB camera, and a GPS module for high-resolution vineyard canopy monitoring.

The initial phase covered literature review and problem definition related to remote and proximal sensing in precision viticulture, with particular attention to vertical stratification of grapevine canopies linked to leaf age and canopy structure.

The technical phase evaluated NDVI and PRI sensors previously developed within the Transfarm4.0 Interreg Central Europe project. Preliminary assessments identified limitations in the stationary configuration's temporal and spatial resolution, leading LCM to develop a mobile acquisition system based on the DisDAQ (Distributed Data Acquisition and Algorithms Quiver) architecture.

The DisDAQ-agri system integrated sensor interfaces, power supply units, data acquisition modules connected to a RaspberryPi computer, wireless communication via WLAN, GPS tracking, and RGB imaging. All datasets were stored in an InfluxDB database.

A portable sensor-carrying frame was tested at the MATE Research Station in Kecskemét, Hungary (Kunság wine region), with upward-looking reference sensors and three pairs of canopy-monitoring NDVI/PRI sensors for vertical and horizontal reflectance monitoring.

Field trials were conducted in June 2025 in two experimental vineyards (M1 and M2), each including four monitored rows (L1–L4). GPS, NDVI, and PRI datasets were filtered and analysed through variance analysis, PCA, Shannon entropy analysis, and correlation analysis.

Dissemination activities included practical field courses for high-school students, training for BSc, MSc, and PhD students at MATE, and presentations at the Lippay-Ormos-Vas Scientific Meeting, the 6th Annual Conference of Viticulture and Oenology, the PREGA

Precision Farming Conference, and the 35th Plant Protection Forum. The Living Lab was also presented at EU-CAP network seminars in the Netherlands, Italy, and Spain (2025–2026). A scientific publication, "DisDAQ-agri: A Mobile Data Acquisition System for Vineyard Canopy Monitoring", is being prepared for submission to MDPI AgriEngineering.

3.2.2. Key results achieved

The Living Lab produced a portable on-the-go sensor system capable of acquiring plant-specific georeferenced RGB, NDVI, and PRI datasets for vineyard canopy monitoring and variability assessment. Compared to the earlier stationary configuration, the mobile system significantly improved temporal and spatial resolution of data acquisition.

NDVI measurements provided information on chlorophyll content and physiological plant status through red and near-infrared reflectance. PRI measurements, calculated as $(R531-R570)/(R531+R570)$, supported evaluation of photosynthetic efficiency through changes in the xanthophyll cycle. Both indices demonstrated potential for monitoring biotic and abiotic stress conditions relevant to precision viticulture.
RGB imaging created opportunities for future calculation of combined vegetation indices integrating RGB, NDVI, and PRI reflectance. Dissemination activities also showed that the system's portability and operational simplicity facilitated understanding among users with limited precision agriculture experience.

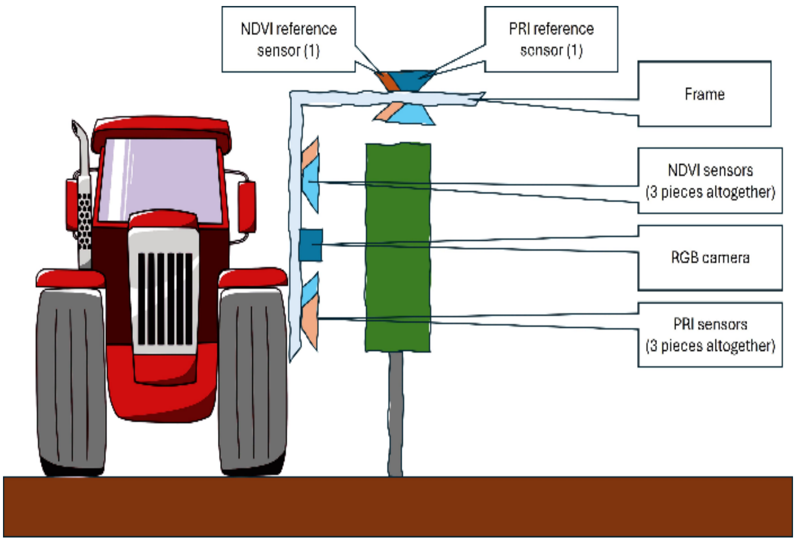

Figure 4. *NDVI, PRI and RGB sensor network designed for the vertical and horizontal reflectance monitoring*

Figure 5. *Test runs in the Research Station of the Hungarian University of Agriculture and Life Sciences, in Kecskemét, Hungary*

3.2.3. Main challenges encountered

The primary technical challenge was the limited temporal and spatial resolution of the original stationary sensor configuration, which drove the development of the mobile acquisition architecture.

Long-term availability of NDVI and PRI sensor models also posed a challenge, as manufacturers frequently replace older sensor versions with newer models, creating the need to evaluate alternative sensing solutions. Future work will additionally need to address expansion of the system with additional sensing units across multiple agricultural locations.

3.2.4. Future perspectives and applications

Future developments will focus on integrating additional sensors, expanding multi-location deployment, and developing combined vegetation indices using RGB, NDVI, and PRI datasets. Although initially designed for vineyard canopy analysis, the system shows strong transferability to orchards and vegetable production systems. The adjustable sensor-carrying frame can also be adapted for arable field conditions, supporting broader precision agriculture applications.

3.3. Geospatial Data (Plan4all)

3.3.1. Main activities and timeline

The Geospatial Data Living Lab, coordinated by Plan4all, established a multidisciplinary collaborative environment connecting farmers, SMEs, technology providers, researchers, advisory organisations, and public institutions, including partners WirelessInfo and Lesprojekt-služby, around the practical testing and validation of AI-assisted geospatial tools for precision farming.

Phase 1 focused on establishing the Living Lab structure and onboarding key stakeholders, alongside an initial mapping of training needs and technological gaps in Czech agriculture through consultation with the Small Farmers Association and the Agricultural Union of the Czech Republic. Phase 2 centred on co-creation activities engaging farmers and stakeholders in the identification of practical requirements for digital agriculture tools, broadening the network of actors involved in the Living Lab. Phase 3 included workshops for farmers focused on the practical introduction of digital tools, participation in dissemination events including the Země živitelka 2025 Smart Countryside seminar and the Prague GeoAI week, and continued stakeholder engagement across the Living Lab network. Phase 4 focused on the iterative testing and validation of the JackDaw GeoAI platform with farmers and agricultural stakeholders, collecting end-user feedback to inform tool refinement, and international outreach including the presentation of JackDaw to European institutions and a consultation with Eurostat.

3.3.2. Key results achieved

The central technical output was the continuous development and validation of the JackDaw GeoAI platform, an LLM-powered geospatial assistant enabling natural language interaction with spatial agricultural data. Unlike conventional chatbots that operate without location awareness, JackDaw allows users to select or draw an area of interest on a map, formulate queries in natural language, and receive spatially and temporally contextualised responses. The system automatically identifies relevant spatial and temporal parameters, retrieves data from heterogeneous sources, and generates contextualised outputs.

The platform's GeoAI analytical engine dynamically connects AI reasoning with GIS tools and authoritative datasets, including satellite Earth Observation data, sensor information, geospatial datasets, administrative statistics, and thematic agricultural information, supporting both raster and vector data analysis for contextual interpretation of vegetation indices, environmental conditions, land use, and socio-economic indicators. Its interactive map-based collaboration environment enables annotation of map elements, discussion over spatial layers, and interactive visualisation of territorial data, directly linking analysis to concrete geographic locations. The system architecture incorporates Retrieval-Augmented Generation (RAG), integrating textual knowledge sources such as legislation, methodological guidance, and technical documentation into AI-generated responses, combining data analytics with regulatory and policy context relevant for agricultural advisory. The platform's modular architecture supports scalable integration with additional datasets and AI functionalities, with ongoing improvements in geospatial reasoning, conversational analytics, and AI orchestration. Within the Living Lab, JackDaw was iteratively refined based on end-user feedback, improving contextual interpretation of farm-related data and output visualisation through maps, tables, dashboards, and graphs.

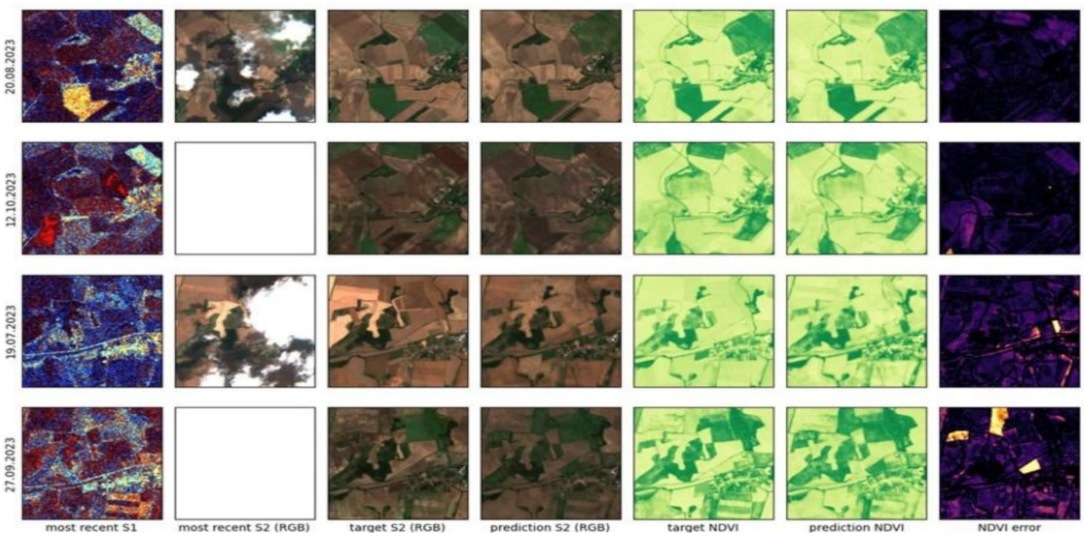

Figure 6. *AI enhanced Earth Observation imagery*

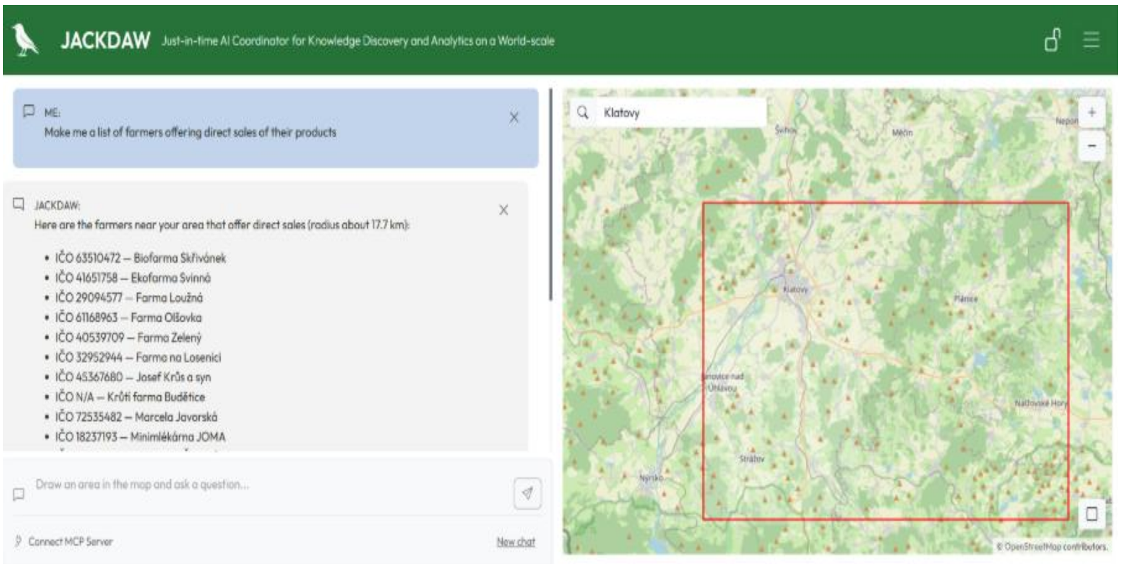

Figure 7. *JackDaw, GeoAI Chat Agent*

3.3.3. Main challenges encountered

Technical challenges centred on the complexity and interoperability of digital agriculture tools and integration of heterogeneous datasets (satellite imagery, sensor data, farm-management information systems). Simplifying interfaces for non-technical users required additional effort.

Organisational challenges included coordinating stakeholders with different levels of digital maturity and aligning training materials with both academic requirements and practical agricultural needs. National certification administrative procedures also added complexity.

User-related challenges included limited digital competences among some farmer groups, resistance to new technologies due to perceived complexity and costs, and the absence of trusted advisory systems. These were addressed iteratively through stakeholder feedback, tool development, and training.

3.3.4. Future perspectives and applications

Future work will focus on expanding certified training programmes toward additional digital agriculture profiles, continued development of the JackDaw GeoAI platform in operational environments, and stronger cooperation with national and European Digital Innovation Hubs.

The developed methodologies also show transferability to environmental monitoring, climate adaptation, water management, regional planning, and land-use management. Long-term sustainability will be supported through integration of outputs into national agricultural advisory systems and continued use of AgriHub.cz for training and knowledge sharing.

3.4. Precision Viticulture and Water Use Optimization (CREA)

3.4.1. Main activities and timeline

The Precision Viticulture and Water Use Optimization Living Lab, implemented by CREA – Research Centre for Viticulture and Oenology in collaboration with CET Electronics, focused on developing an AI-assisted computer vision system for vineyard water-status monitoring based on stereo imaging, thermal sensing, and proximity sensors, aiming to provide a non-invasive, automated methodology for measuring grapevine water needs and supporting irrigation management.

The initial phase (early 2025) analysed the limitations of traditional water-status assessment methods (Scholander pressure chamber, leaf gas-exchange analysis) and defined the experimental framework and sensing approaches through joint technical discussions and literature review.

The developed monitoring system integrated stereo cameras with thermal imaging and AI-based image analysis to estimate canopy parameters including total leaf area, average leaf angle, and canopy geometry variation, with particular attention to leaf angle as a sign of vine water status and leaf firmness.

Field trials ran from June to August 2025 included:

- Weekly measurements of vine water stress (ψs) using the Scholander pressure chamber
- Weekly measurements of leaf gas exchange (gs), net photosynthesis (An), and water use efficiency (iWUE) using IRGA instrumentation
- Validation of leaf-angle measurements through a digital angle-measurement app
- Continuous vineyard monitoring through stereo cameras (WCAM) at two-hour intervals
- 3D canopy reconstructions for canopy reconstruction and leaf-angle estimation
- Thermal imaging for Plant Water Stress Index (CWSI) calculation
- Soil water-status monitoring through soil moisture sensors
- Continuous acquisition of local weather data via an in-field weather station

Training activities included a trainee selected through the February 2025 Hackathon, who received technical training in Scholander chamber use, IRGA instrumentation, and digital irrigation planning tool (DSS) concepts for irrigation management.

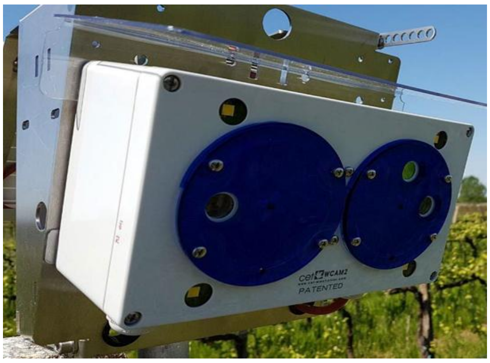

Figure 8*. WCAM stereo-imaging system used for vineyard canopy monitoring.*

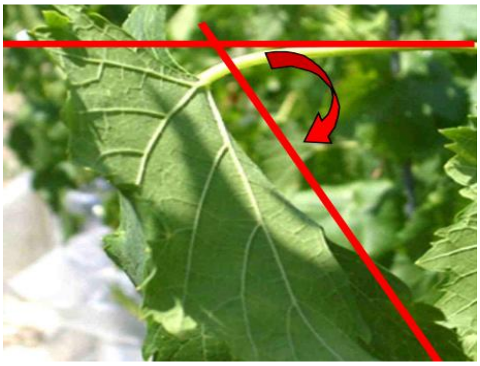

Figure 9*. Measurement of grapevine leaf inclination used for image-based water-status assessment.*

3.4.2. Key results achieved

Leaf-angle measurements from the WCAM stereo camera were differentiated between daytime and nighttime conditions, and the day–night difference values were compared against Scholander chamber readings to generate calibration equations.

Comparisons between camera-estimated water potential (CAM-SWP) and Scholander measurements showed moderate linear correlations, with R^2 values ranging approximately between 0.52 and 0.61, meaning the camera-based approach explained up to 61% of the variation in vine water status under tested conditions.

Thermal-image-derived CWSI values showed broader variability, with correlation coefficients ranging approximately between 0.38 and 0.78. The highest correlation (R^2 = 0.78) highlighted a strong link between canopy temperature, evaporation, and leaf-angle responses associated with plant water status.

The results demonstrated the potential of leaf inclination as a rapid, non-invasive indicator for monitoring vineyard water status in the short term, reducing limitations of traditional, labour-intensive measurement methods. The Lab also initiated development of a digital irrigation planning tool (DSS) to support irrigation scheduling through plant signals and environmental monitoring data.

3.4.3. Main challenges encountered

The 2025 season was characterised by relatively limited drought stress in the experimental vineyards. Even after irrigation suspension, environmental conditions did not generate sufficiently strong water-stress responses to fully differentiate experimental models according to plant water status.

Additional technical challenges arose from irregular image acquisition by the WCAM stereo camera system due to operational interruptions, reducing usable replicates and partially limiting the statistical robustness of the dataset.

3.4.4. Future perspectives and applications

Future work will focus on additional field-validation trials, optimisation of AI-based monitoring algorithms, and expansion of the training dataset to improve model robustness and generalisation under different environmental and vineyard conditions.

The methodology shows potential as a cost-effective alternative to traditional water-status assessment, supporting irrigation management through integration of physiological plant responses, thermal imaging, and local meteorological data. It may also contribute to advanced precision irrigation systems and data-driven DSS tools for sustainable viticulture.

3.5. Sensors & Computer Vision (JR)

3.5.1. Main activities and timeline

The Sensors & Computer Vision Living Lab, implemented by Josephinum Research (JR) in Wieselburg, Austria, focused on the development of a practical demonstration environment for ISOXML-based precision agriculture workflows, machine-data exchange, and digital farm-management applications. The activities addressed interoperability between agricultural machinery, geospatial prescription maps, farm-management information systems (FMIS), and digital decision-support workflows using the IsoCraft software environment.

The initial implementation phase focused on the conceptual design and setup of the Living Lab infrastructure, including thematic stations dedicated to agricultural data acquisition, machine communication, geospatial visualization, and ISOXML task-data management. Interactive visualization systems and digital interfaces were integrated to support practical demonstrations and stakeholder training activities related to precision agriculture technologies.

The second phase focused on developing demonstration modules for variable-rate fertilisation and seeding applications based on georeferenced prescription maps and site-specific management zones. Prescription maps, field boundaries, machine-operation parameters, and ISOXML task files were visualized, edited, and validated through the IsoCraft platform and connected digital interfaces. Additional demonstration components linked digital workflows with agricultural machinery operations, enabling practical representation of data transfer between FMIS platforms and field equipment.

The final implementation phase focused on testing, stakeholder interaction, and training activities involving farmers, advisors, students, software developers, and agricultural machinery manufacturers. Workshops and practical demonstrations supported understanding of digital agricultural workflows, machine interoperability, and precision farming implementation strategies.

3.5.2. Key results achieved

The Living Lab demonstrated how complex ISOXML-based agricultural workflows and machine-communication standards can be transformed into practical and accessible precision farming applications. The integration of the IsoCraft platform enabled users to visualise, inspect, edit, and validate geospatial prescription maps, field boundaries, management zones, and ISOXML task files within an intuitive digital environment.

The platform additionally supported processing and validation of ISOXML task data, geospatial field information, and machine-operation parameters required for variable-rate agricultural applications and digital farm-management workflows. The implemented demonstration environment improved understanding of site-specific management strategies, agricultural data interoperability, and machine communication systems among participants with different levels of technical expertise.

The Living Lab also strengthened collaboration between farmers, advisors, students, software developers, and agricultural machinery manufacturers through workshops, demonstrations, and practical discussions related to digital agriculture implementation and precision farming standardisation.

From an educational perspective, the Living Lab provided a modern training environment supporting practical learning in agricultural data handling, ISOXML workflows, geospatial processing, and precision farming technologies.

3.5.3. Main challenges encountered

Several technical and organisational challenges were encountered during implementation. One of the principal technical challenges involved interoperability and standardisation of ISOXML task datasets exchanged between FMIS platforms, agricultural machinery terminals, and software environments. Additional testing and adaptation activities were required to ensure compatibility and reliable communication between heterogeneous systems.

Further challenges were associated with simplifying technically complex digital workflows into user-oriented demonstrations suitable for participants with different levels of digital competence while maintaining technical accuracy and operational realism. Stable connectivity and synchronization between hardware devices, software environments, and interactive installations also required continuous optimisation during demonstration activities.

Organisational challenges additionally included procurement, installation, and coordination of multiple hardware and software components necessary for the Living Lab infrastructure. Delays related to equipment delivery and infrastructure adaptation partially affected implementation timelines and increased integration complexity.

3.5.4. Future perspectives and applications

Future developments are expected to focus on expanding the integration of real-time sensor data, agricultural machinery communication systems, and automated decision-support functionalities within the demonstration environment. Additional activities may include development of advanced training workflows related to precision agriculture, digital farm management, and machine-data interoperability.

The developed methodologies and demonstration concepts demonstrate strong transferability to additional agricultural applications including plant protection, irrigation management, autonomous machinery operation, and environmental monitoring systems. The approach may also be adapted for vocational education centres, advisory services, exhibitions, and collaborative innovation environments focused on digital agriculture technologies.

Long-term perspectives additionally include strengthening cooperation between agriculture, software development, education, and agricultural machinery sectors to improve interoperability, usability, accessibility, and adoption of precision farming technologies and ISOXML-based digital workflows.

3.6. FederUnacoma Tech Days for SME-Research Networking (CREA / FederUnacoma)

3.6.1. Main activities and rationale

In addition to the Living Lab on irrigation optimisation in viticulture, further needs emerged from FederUnacoma member companies, particularly concerning difficulties in accessing advanced technological knowledge and establishing structured interactions with research organisations.

To address this gap, a dedicated series of events was designed and implemented as a targeted action within the AgriDigital Growth framework. The initiative aimed to facilitate knowledge transfer, promote technology adoption among SMEs, and foster direct dialogue between industry and leading Italian research institutions active in agricultural engineering, artificial intelligence, and digital technologies.

Three Tech Days were organised between 2025 and 2026, each hosting approximately 60 participating companies, with structured formats combining technical presentations, thematic workshops, and networking sessions. The events were held in Bologna and involved universities, research centres (including CREA, CNR, IIT, FBK), and industry stakeholders.

3.6.2. Topics addressed and technical content

The three events covered complementary themes aligned with the digital transformation of agricultural machinery and processes:

Tech Day 1: Autonomous systems and perception technologies

The first event focused on enabling technologies for automation in agriculture, including:

- Autonomous guidance systems and related engineering and regulatory challenges
- Advanced perception systems (computer vision, sensors) for safety, quality control, and data acquisition

- Integration of sensing technologies into agricultural machinery for operational intelligence

Tech Day 2: Innovative technologies for agricultural machinery

The second event addressed key technological domains relevant to mechanisation:

- Technologies for crop protection machinery
- Soil tillage machinery innovations
- Smart irrigation solutions and digital water management approaches

Tech Day 3: Artificial Intelligence in agricultural engineering

The third event explored advanced AI applications and regulatory aspects, including:

- Data-driven knowledge extraction and decision support systems
- Digital twins and field modelling approaches
- AI on-edge for diagnostic and agronomic evaluations
- AI applications in agricultural robotics and human-machine interaction (including LLM-based interfaces)
- Ergonomic and safety-oriented AI systems
- Impacts of the EU New Legislative Framework on AI-enabled machinery

A roundtable session further examined the regulatory implications of AI in Europe, while an external contribution from industry (Heritable Agriculture) provided insights into AI applications in genomics and crop improvement.

3.6.3. Key results achieved

The Tech Days successfully:

- Engaged a broad base of SMEs (approx. 180 total participants across three events)
- Created a direct interface between companies and high-level research actors, reducing knowledge-transfer barriers
- Identified priority technological needs of the sector, particularly in automation, sensing, and AI integration
- Facilitated interactive discussions on real industrial challenges, supported by workshop-based co-creation formats
- Increased awareness of emerging regulatory frameworks, especially concerning AI-enabled machinery

The initiative complemented the Living Lab activities by extending engagement from experimental validation to sector-wide capacity building and innovation uptake.

3.6.4. Challenges and Future Perspectives

The main challenges encountered were the heterogeneity in the technological maturity of participating SMEs, requiring adaptive communication approaches, and limited prior exposure of companies to advanced AI and digital technologies, necessitating introductory as well as advanced content.

The Tech Days model demonstrated strong potential as a scalable mechanism for innovation dissemination and stakeholder engagement. Future developments may include:

- The establishment of permanent SME-research interaction opportunities
- Integration with Living Lab activities to create *continuous feedback loops between research and application
- Development of training modules and demonstration projects based on identified needs

Overall, the initiative represents a complementary pillar to experimental research activities, supporting the broader adoption of digital and AI-based technologies in the agricultural machinery sector.

4. Comparative Analysis and Lessons Learned

4.1. Key Outcomes of the Living Labs

The five Living Labs demonstrated the potential of collaborative, practice-oriented approaches for supporting the adoption of Precision Farming technologies across different agricultural contexts. Activities addressed complementary domains including agro-robotics, AI-based monitoring, geospatial data processing, remote and proximal sensing, smart irrigation, and decision-support tools.

The implemented activities highlighted the increasing integration of sensing technologies, automation, artificial intelligence, and spatial data analysis within agricultural management practices. Living Labs also contributed to the development and validation of innovative solutions including mobile sensing systems, AI-assisted monitoring approaches, autonomous robotic platforms, geospatial decision-support tools, and digital training environments.

4.2. Knowledge Transfer and Capacity Building

The Labs showed the importance of combining technical experimentation with practical learning and stakeholder participation. They created collaborative environments where researchers, students, SMEs, technology providers, advisors, and agricultural practitioners exchanged technical knowledge and operational experience.

A strong emphasis on interdisciplinary cooperation and hands-on learning, involving young talents and early-career professionals in field testing, prototype development, monitoring, and digital agriculture applications, gave participants practical exposure to robotics, sensing systems, geospatial analysis, AI tools, and precision irrigation. The activities also strengthened connections between research institutions, educational organisations, and agricultural stakeholders.

4.3. Scalability and Future Development Perspectives

The Living Lab activities demonstrated transferability across multiple agricultural sectors and operational contexts. Tested approaches can be further expanded through advanced sensing, AI-assisted systems, automation, and improved data-processing methods, and applied beyond original pilot environments to greenhouse production, orchards, arable systems, environmental monitoring, water management, and climate adaptation.

Future developments will focus on improving interoperability between digital tools, increasing operational scalability, and integrating innovative technologies into practical agricultural workflows and advisory systems. Continued cooperation between research organisations, SMEs, technology providers, and educational institutions will be essential for long-term adoption and sustainability.

5. Conclusions

The Living Labs within WP2 provided a practical framework for testing and demonstrating digital agriculture technologies in real operational contexts, supporting the development and validation of solutions in agro-robotics, smart irrigation, sensing technologies, geospatial data processing, AI-assisted monitoring, and decision-support systems.

Beyond technical results, the Labs strengthened cooperation between project partners, SMEs, research organisations, technology providers, educational institutions, and agricultural stakeholders, and supported the involvement of students, young professionals, and trainees through hands-on learning connected to field testing, data analysis, system development, and practical demonstrations.

The Living Labs contributed to WP2 objectives by supporting knowledge transfer, capacity building, and the practical adoption of Precision Farming technologies. The experiences documented here provide a basis for further development, replication, and integration of digital agriculture solutions across different agricultural sectors and regional contexts.

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