Interreg
CENTRAL EUROPE

European Union
European Regional Development Fund

Transfarm4.0

Transnational collaborative system to bring precision farming innovative applications closer to the market & address regional specializations in Central Europe

Project Handbook

PROJECT PARTNERS

The Interreg Central Europe project Transfarm 4.0 coordinated by Crea Viticoltura ed Enologia of Conegliano brings together 10 partners from five regions of Europe: the University of Maribor (SL), Hungarian University of Agriculture and Life Sciences (HU), the Linz Mechatronic Center (A), the Francisco Josephinum Institute (A), three Entities specializing in robotics and technology transfer, T2i (IT), AE-ROBO-NET (SI) and Agro ICT Cluster (HU), the National Federation of Agricultural Machinery Manufacturers Federunacoma (IT) and the Regional Development Authority Arssa (PL).

crea
Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria

The Crea Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria is the main Italian research organization dedicated to agrifood sector; it includes expertise ranging from the agricultural, livestock, fish, forestry, agroindustrial, and nutritional sectors to the socioeconomic sphere. Crea Viticoltura Enologia, a historical reality of research in Viticulture with its headquarters in Conegliano, in one of the most important wine districts in the world, has coordinated the Transfarm project and has several projects related to precision agriculture to its credit. The five research centers distributed in Veneto, Friuli, Piedmont, Tuscany, and Apulia focus their activities mainly in 4 macro-areas: applications of precision viticulture; characterization, valorization, and genetic improvement of biological resources; sustainable winery and vineyard management; innovative methods of traceability; and valorization and characterization of table and wine grapes. Crea VE in the year 2020 carried out 97 researches, produced 42 publications and obtained 4 patents.

University of Maribor

Faculty of Agriculture and Life Sciences

The University of Maribor (UM) is the second largest and oldest university in Slovenia. It is an autonomous, scientific, research and educational institution whose purpose is to expand and transmit knowledge through the interconnection of the humanities, social sciences, engineering and economics, medicine, natural sciences, law, education and the arts to the wider social community. The University of Maribor is rapidly developing new areas of activity, testing new methods of study and finding new ways to follow its vision: to become a global innovation ecosystem.

The Faculty of Agriculture and Life Sciences (FALS) is one of the founding members of the University of Maribor. Since its inception, FALS has followed the needs of the economy and the development of society by adapting the content of the programs, the basic objectives of the research work, and the ways of knowledge transfer. FALS, independently and in collaboration with scientific groups from other institutions, has worked on development, applied research and fundamental research. Research activities are carried out through research groups and various independent research projects. Researchers publish the results of their research in leading international scientific journals, at world and European scientific congresses and symposia, and at home. In recent years, this has greatly strengthened FALS' international cooperation with several eminent global and European institutions. The cooperation also includes the exchange of faculty and students through Erasmus programs. The main mission of FALS is to carry out educational, research and innovation processes for the needs of Slovenia's agriculture, food and processing industry and, more generally, for the needs of agriculture-related economic sectors (tourism, renewable energy, waste materials industry, environmental protection, new technologies in agriculture).

The Slovenian cluster **AE-ROBO-NET,** which specializes in robotics and encompasses several companies, played a key role in the development of the Remote and Proximal Sensing prototype. The cluster was founded in 2016 to increase the national and international competitiveness of cooperating organizations. In order to achieve the founders' goals, they worked in the following themes while trying to exploit synergies between them: more efficient use of resources, communication, advocacy, foreign markets and facilitated finance. The network's primary goal is to provide agricultural and environmental robotics systems and services tailored to the needs of farmers, road operators, ecological remediation providers, and underwater construction operators thereby increasing their efficiency, innovation potential, and environmentally friendly operations. The network organization can provide an ever-expanding knowledge base that can build on user-friendly research and development activities that stimulate innovation. The network association is able to contribute to the development of competitive agricultural and environmental robotic systems needed by domestic and international agricultural and environmental suppliers, thereby increasing both sectors' efficiency and profit capacity. Agricultural and environmental technology has become particularly important in the Alps-Adriatic region in recent years.

The T2I Technology Transfer and Innovation cluster is a consortium company owned by the Chambers of Commerce of Treviso and Belluno, Venice and Rovigo, and Verona.
t2i supports companies in making innovation a continuous process as a key lever to regain competitiveness in the markets, accompanying them in the definition and development of innovation paths through its services.
t2i caters to all types of businesses, accompanying both new entrepreneurs in the definition and birth of an innovative enterprise and supporting large companies or multinationals in research projects, internationally.
The services offered are:

- Trademarks, Patents and Technical Standards: services for the protection of the company's intellectual property and information and guidance on UNI and CEI standards;
- Testing and Calibration Laboratories and User centered design: state-of-the-art laboratories to support the qualification and recognition of products in markets, and to test new products in the pipeline
- Innovation, Research and Funding Opportunities: services to support companies in developing innovation and research projects
- Training, organization and skills development: skills development pathways for both companies and individuals seeking new training and employment opportunities;
- Business start-up and Certified Incubator: services to support the birth of new innovative enterprises through accompanying activities and the opportunity for establishment at the Incubator.

t2i became the control room for the construction of a Veneto system of innovation and the first company in Italy of regional dimension participated by multiple chamber entities (Chambers of Commerce of Treviso - Belluno, Verona and Venice Rovigo).

The **Hungarian University of Agriculture and Life Sciences** is one of the leading universities in Hungary. The Institute of Viticulture and Enology consists of two departments and two research centers: the Department of Viticulture and the Department of Enology, both located in Budapest on the Buda campus and research centers in Badacsony and Kecskemét. The center's main research topics are: precision viticulture, terroir assessment, digital image analysis in ampelography, and molecular genetic research. In oenological chemistry MATE analyzes fine compounds, physiologically active compounds and biogenic amines. In the Transfarm4.0 project, together with the Mechatronics Center Linz (A) and Agro ICT (HU), MATE participated in the case study 3 Big and Smart Data Management 'Sensor data capture for precision Viticulture in a fiware data lake pilot action'.

The Linz Center of Mechatronics GmbH (LCM) is a private, non-university research organization that supports its partners and customers along the entire innovation chain, from basic research (university) to solutions, prototypes, and products (customers). The center involves a network of industrial partners of about 300 customers and 50 scientific partners strengthen the network of the Linz Mechatronics Center. LCM has extensive experience in electrical and hydraulic drive design, sensor technologies, wireless communication, and system modeling, simulation, and optimization and is, therefore, able to provide smooth connectivity between various mechatronics fields. In general, LCM conducts high-level mechatronics research in six thematic areas: Process Modeling & Mechatronic Design; Sensors and Signals; Wireless Systems: Model Based Mechanics and Control; Information and Control; and Drives and Actuators. In these fields, LCM provides holistic solutions, from numerical solutions to the development and implementation of mechatronic systems within prototypes and small-scale series. LCM's mission is to develop cutting-edge technologies and distribute these solutions across all fields among existing and new partners.

HBLFA Francisco Josephinum Wieselburg

The **Federal Institute of Education and Research Francisco Josephinum**, located in Wieselburg, Austria, contributed to the project in analyzing the potential of precision agriculture and developing the pilot action 'new ISOBUS applications.' The research center specializes in the development of new methods and applications of innovative technologies for agriculture, particularly digitization, precision agriculture, digital agriculture, sensing, mechatronics and robotics. JR's current research topics are soil and plant sensors using image processing, model development for fertilizer application techniques, and applications of robotics. Josephinum Research is the coordinator and headquarters of the Innovation Farm in Austria.

ARR Agencja Rozwoju Regionalnego S.A. Bielsko-Biała

The **Bielsko-Białą Regional Development Agency** is a non-profit organization aimed at supporting and stimulating regional development. Recently it has been very supportive of all aspects of digitalization and digital transformation of the economy and society, innovative IT technologies of Industry 4.0, social innovations and the so-called Silver Economy. The agency cooperates with international networks such as: the innovative FabLabNet network of 3D innovation labs, the European Digital Innovation Hub (DIH) network. ARSSA is very active in digitization processes, including extracurricular education for future professionals in the fields of automation, mechatronics and IT; it provides start-up capital and capital for Accelerator and Incubator companies.
In 2014 he founded the first FabLab in southern Poland specializing in technologies related to Industry 4.0. Specifically incremental technologies: 3D modeling and scanning, rapid

prototyping, and reverse engineering. ARSSA provides services and offers expertise in digital technologies; it manages and is a member of the Digital Innovation Hub (DIH) in Bielsko-Biała together with academic institutions and research centers.

In 2014, agricultural companies established the Agricultural Information Technology Cluster **(AgroIT Cluster)** with the aim of increasing the domestic and international competitiveness of organizations and strengthening collaboration between the IT, Agriculture and Food sectors. To achieve the goals, the founders sought to exploit synergies among them: more efficient use of resources, communication, advocacy, and foreign markets in the European Union. AgroIT Cluster members are committed to linking research, development and innovation capacities through the creation of the agricultural-based Quadruple Helix in Hungary. In this sense AgroIT Cluster serves as a boundary organization between private companies (Agrárinformatikai Ltd., AgroComplex Ltd., AgroVIR Ltd., eNET, Eurosmart Ltd., Gremon Systems, Moonsyst, Senit, Bikazug Agriculture Nonprofit Ltd, T-Systems , Veresi Paradicsom and Winery Datamanagement - first helix), Hungarian governmental or political organizations (Hungarian Chamber of Agriculture - second helix), universities/research sphere/educational institutions (Budapest University of Technology and Economics, Eötvös Loránd University, Szent University of István, University of Szeged and University of Pannonia - third) and citizens (Infotér and Magyar Női Unió - fourth helix).

The National **Federation of Manufacturers of Agricultural Machinery, FEDERUNACOMA**, established in 2012 as a continuation in federative form of the activities of Unacoma (Unione Nazionale Costruttori Macchine Agricole born in 1945), groups together, representing them in Italy and abroad, the associations of Italian manufacturers of agricultural operating machinery (Assomao), self-propelled agricultural operating machinery (Assomase), tractors (Assotrattori), components for the various sectors represented (Comacomp) and gardening machinery (Comagarden).

The Federation was created with the aim of recognizing the individual product groups that make it up as more efficient and autonomous, favoring aggregation policies that rationalize activities and service systems for businesses, and allowing the aggregation of additional institutional entities, representing sectors related to mechanization and connected to it, with a view to broadening the Federation's front of representation and thus playing a role of increasing weight in political and institutional forums. FederUnacoma is a member of Confindustria in Italy, CEMA, EGMF and Euromot in Europe. FederUnacoma's activities are aimed at boosting mechanization of agricultural, energy and public and private landscaping activities, promoting the development and technological renewal of reference mechanical fleets in Italy and abroad, and providing members with focused support, assistance and innovative services. Within the Transfarm 4.0 project, Federunacoma held the role of communications manager taking care of communications in social channels and project publications.

PROJECT ACTIVITIES

The Interreg Transfarm4.0 project stems from the idea of promoting, in the Central European states involved in the project, the development, dissemination and adoption of practices related to precision agriculture. Precision agriculture is a major revolution that is sweeping the primary sector, and although some technologies have been around for a few years, only a small proportion of farmers adopt these practices on their farms. There are many reasons for this: implementation costs, farm size, on-farm skills, technological maturity and the added value brought by new instrumentation. The techniques that fall under the umbrella of 'Precision Farming' are a great opportunity to improve farming practices but like all changes take time to be adopted by all users. On the other side of the supply chain, manufacturing companies are also wondering how to succeed in responding to this change in the industry and are beginning to gear up to integrate new technologies into traditional implements by equipping them with sensors, new applications and services. With this in mind, the Interreg Transfarm4.0 project has created an international collaborative environment by bringing together supply chain actors with the aim of developing a new model for innovation in agriculture. Precision agriculture embraces different sectors with very specific and distant know-how: agronomy, mechanics, electronics, mechatronics and information technology. The fabric of companies in the area composed mainly of SMEs internationally known for excellence in specialization and diversification of production is showing its limit at this time. The small medium-sized company is not always able to have a research and development area capable of embracing the fields of electronics and information technology, so collaboration becomes an essential element to continue to develop products of excellence and stay ahead of the times. The project has made it possible to bring around a table all the players in the supply chain: research centers, manufacturing companies, policy makers, technicians and farmers with specific skills and knowledge with the aim of promoting the expansion of precision agriculture and fostering the integration of knowledge toward a more precise model of agriculture that can improve the efficiency of farms aiming at sustainable agriculture with low environmental impact.

The project was developed in three macro-phases that will be explored in more detail in the following chapters:

1. Analysis of the potential of precision agriculture: Fact-finding survey of the state of the art of precision agriculture in the regions involved in the project to delve into the needs, limitations and potential of the sector;
2. Prototyping-Development of new applications of strategic technologies: Identification of partners and creation of a collaborative environment aimed at stimulating the development of new technology applications in precision agriculture. Realization of three prototypes capable of meeting needs that emerged in the first phase of the project;
3. Proposals for expanding the precision agriculture sector: Creation and development of a series of initiatives aimed at expanding the precision agriculture sector and adopting new practices through targeted initiatives toward selected key targets that can influence the sector's development in the short and long term: schools, farmers, contractors, manufacturing industries, and technicians.

CHAPTER 1 - Analysis of the potential of precision agriculture

In 2019, the project began by conducting a survey on the state of the art of precision agriculture. This first part of the project, coordinated by Austrian partner Francisco Josephinum, analyzed the needs of the end users of the technologies, particularly farmers to understand what are the limiting factors that prevent large-scale adoption of the available new technologies.
The survey involving the 5 countries was structured in two parts, a first part aimed at knowing the generalities of the respondents and a second part specifically on precision agriculture issues. The survey involved a sample of more than 200 respondents, most of the farmers are male, Italy turns out to be the 'oldest' country where half of the farmers are between 50 and 59 years old, in the other countries (Austria, Slovenia, Poland and Hungary) on the other hand more than 70% of the respondents are under 50 years old. Farm size varies greatly among countries although it is possible to state that for all countries except Austria and Hungary half of the farms are smaller than 49 hectares.

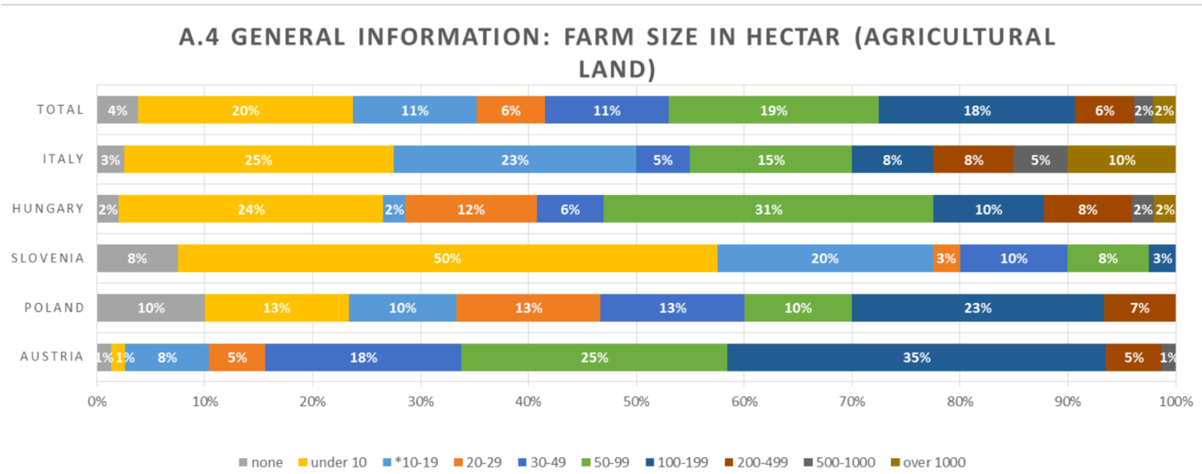

Figure 1 Farm size

To better understand the surveyed audience, the production orientation of the farms was analyzed; in Italy and Hungary the farms specialize in viticulture and fruit growing while in Austria there is more specialization in field crops. The sample interviewed in Poland and Slovenia does not have a predominant specialization.

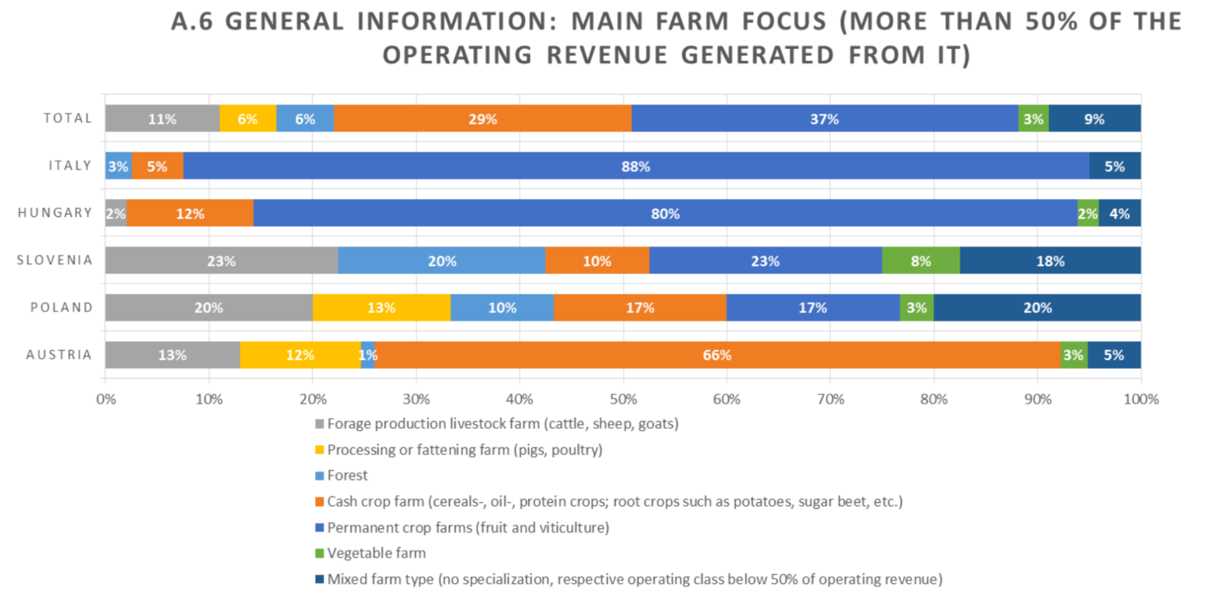

Figure 2 Farm main focus

In the second part of the questionnaire, the propensity for precision agriculture was analyzed, the sample as a whole showed that they do not yet use equipment related to precision agriculture but are interested in the topic (40%), 34% of respondents have purchased one or more equipment related to precision agriculture and started to use it on the farm. Thus, we can highlight that more than 70% of the sample has interest in the topic and there is a lot of room for growth in the field. Proceeding with the questionnaire, it was asked what are the weaknesses of the sector 66 percent of the sample considers the equipment too expensive, 44 percent would like more user friendly equipment, and 37 percent would prefer more training on precision agriculture issues.

To better understand farmers' needs, they were asked what data are most important to monitor on the farm, with the majority considering plant monitoring as important data to collect, as well as data related to weather and product quality and quantity.

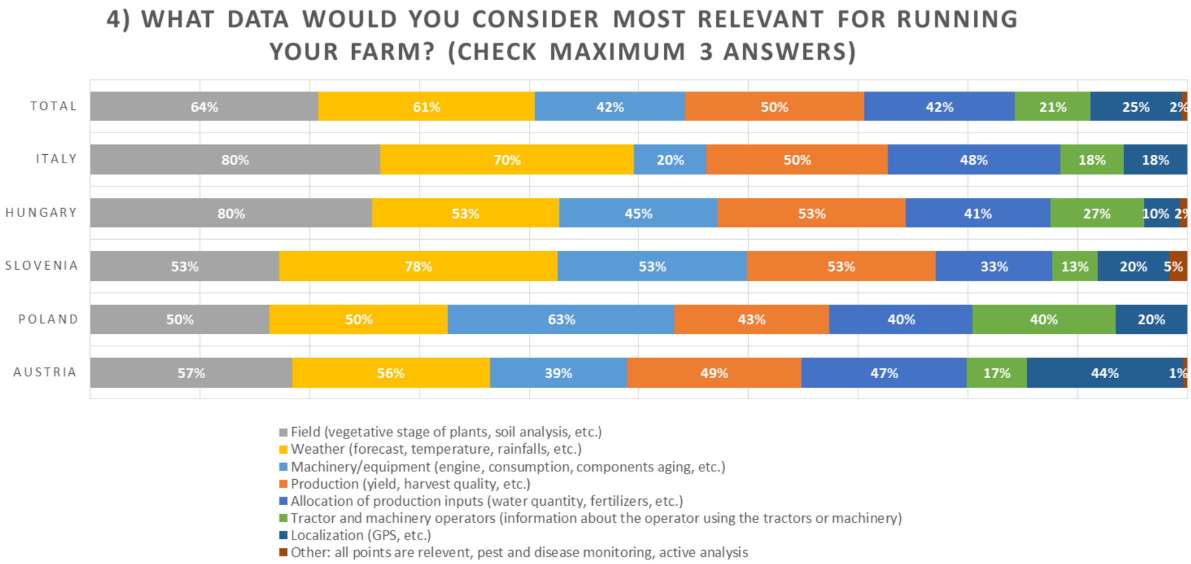

Figure 3 PF most important technologiesi

Based on the type of business, the sample was interested in the main technologies in the market (Decision Support Systems combined with weather stations, Apps that can offer general services and connect supply and demand, specific Apps for soil and plant management, GPS, sensor technology for plant monitoring and management). In contrast, the sample showed less interest in Apps for animal monitoring and augmented reality. Along with the survey, a SWOT analysis was carried out to analyze the sector, below we offer the results that emerged from the survey conducted in Italy:

STRENGTHS	WEAKNESSES
■ several agricultural equipment manufacturers and dealers are present ■ latest technologies are available to the farms ■ high occurrence of stakeholders could generate a good competition in favour to the development and spread of new technologies ■ largest farmers generally are interested in new technologies due to their high affinity towards innovations to increase their farm's sustainability and improve its management (e.g. simplifying bureaucracy, lowering pesticide use, etc.) ■ educational system teaching PF practices ■ reduction of environmental footprint ■ rising of start-up companies dealing with PF services ■ agricultural fairs, exhibitions and workshops on precision farming	■ overall size of farms is generally small ■ high average age of farmers ■ cost of PF technologies is too high for small-medium enterprises, not favouring the spread of PF ■ limited availability of PF sensors' data for the farmers ■ high GPRS prices ■ in hilly zones, with high hand labour demand, mechanization is limited ■ restricted availability and high price of satellite and GIS data, maps for farmers ■ farmers are linked to their traditional methods ■ low salaries, weak education level and missing skilled manpower ■ missing competence in response to EU calls

OPPORTUNITIES	THREATS
■ increase of young farmers with higher education level ■ rising of start-up companies dealing with PF ■ research projects conducted by universities and research centres ■ reduction of environmental footprint ■ mitigation of negative agronomic effects of climate change ■ lower use of input materials ■ less work consuming processes ■ demand from the consumers of more safety food with a certain origin ■ support of free availability of satellite and GIS data, maps for farmers ■ marketing advances of higher food safety (inland and abroad) ■ water saving irrigation technologies ■ developments and innovation in IT ■ rising of start-up companies dealing with PF services	■ resistance to PF innovation ■ uncontrolled failure of field sensors ■ critical security level of field equipment (sensors, data loggers, solar panels, cables, etc.) ■ low GPRS performance, communication failures ■ unexpected data losses ■ internet attacks ■ enhancement and extremes of climate change ■ uncertainty of the market ■ unwanted spread of sensible data linked to the farmers ■ crucial changes in policy ■ missing competence in response to EU calls ■ cutback in EU sources and diminution of project calls

Figure 4 SWOT Analysisi

In conclusion, the precision agriculture sector has shown great potential thanks to a fabric of specialized SMEs capable of building equipment for all types of crops, the target market is expanding greatly, and young farmers can make a difference in modernizing the farm equipment fleet. Despite these excellent premises, we are confronted with a traditional sector that slowly welcomes innovations and needs new skills to make the most of new equipment and overcome the challenges the sector faces at the moment.
The full reports produced as part of the Transfarm4.0 project are available at https://www.interreg-central.eu/Content.Node/Transfarm4.0.html
The same link can be reached through the following QR Code:

CHAPTER 2 - Prototyping - Development of new technological applications

The second phase of the project developed three innovative applications in three key areas of precision agriculture: new ISOBUS applications, Remote and Proximal Sensing, and Big and Smart Data Management. The project partners created a collaborative environment by involving different stakeholders in the supply chain (industries, research groups, industry experts) where expertise could be pooled to create, optimize and field test three new technology applications.

The partnership was divided into three working groups:

Pilot Action 1, New Isobus applications: Francisco Josephinum (Austria), ARSSA (Poland);

Pilot Action 2, Remote and Proximal Sensing: Crea Viticoltura Enologia (Italy), University of Maribor (Slovenia), AE-ROBO-NET (Slovenia);

Pilot Action 3, Big and Smart Data Management: Linz Mechatronic Centre (Austria), Hungarian University of Agriculture and Life Sciences, and AgroIT (Hungary).

Although the project in its central phase was heavily slowed down by the pandemic, the three teams were able to transform the results of their research into 3 prototypes.

According to the European Commission, it is possible to define 9 stages of technological maturity, as highlighted in the following table.

https://en.wikipedia.org/wiki/Technology_readiness_level

TRL	Current NASA usage[14]	European Union[15]
1	Basic principles observed and reported	Basic principles observed
2	Technology concept and/or application formulated	Technology concept formulated
3	Analytical and experimental critical function and/or characteristic proof-of concept	Experimental proof of concept
4	Component and/or breadboard validation in laboratory environment	Technology validated in lab
5	Component and/or breadboard validation in relevant environment	Technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
6	System/subsystem model or prototype demonstration in a relevant environment (ground or space)	Technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
7	System prototype demonstration in a space environment	System prototype demonstration in operational environment
8	Actual system completed and "flight qualified" through test and demonstration (ground or space)	System complete and qualified
9	Actual system "flight proven" through successful mission operations	Actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

The main objective in this phase of the project was to build a collaborative environment to mature three technology applications to a TRL 7 allowing evaluation of the three prototypes in an operational environment.

According to Hensen, Jan and Loonen, Roel and Archontiki, Maria and Kanellis, Micahalis (2015), in their article Using building simulation for moving innovations across the "Valley of Death," Rehva Journal, 52, 58-62, new technologies often stop around TRL 4-5 where research centers have concluded experiments however the technology is still at an embryonic stage to be adopted by companies. Thanks to the collaborative environment, it was possible to overcome the 'Valley of Death' of the technology, bringing the three innovations to an advanced stage of development and offering several field trials and demonstrations at major European trade shows.

Case Study 1 - New ISOBUS application

An important factor in the optimal development of herbaceous crops is seedbed preparation. The size of the clods of soil being prepared is an essential factor in achieving even germination and controlling soil erosion. The control system based on an ISOBUS Class III application can control the tractor according to the soil clod size measured in real time with the aim of preparing the soil optimally by managing the power output in a timely manner optimizing the use of required resources and reducing fuel consumption. The pilot action focused on testing the system, identifying weaknesses and areas for improvement; defining integration into the process flow at planting time. The pilot action was carried out between HBLFA Francisco Josephinum in Austria and Poland by project partner ARRSA and the University of Krakow.

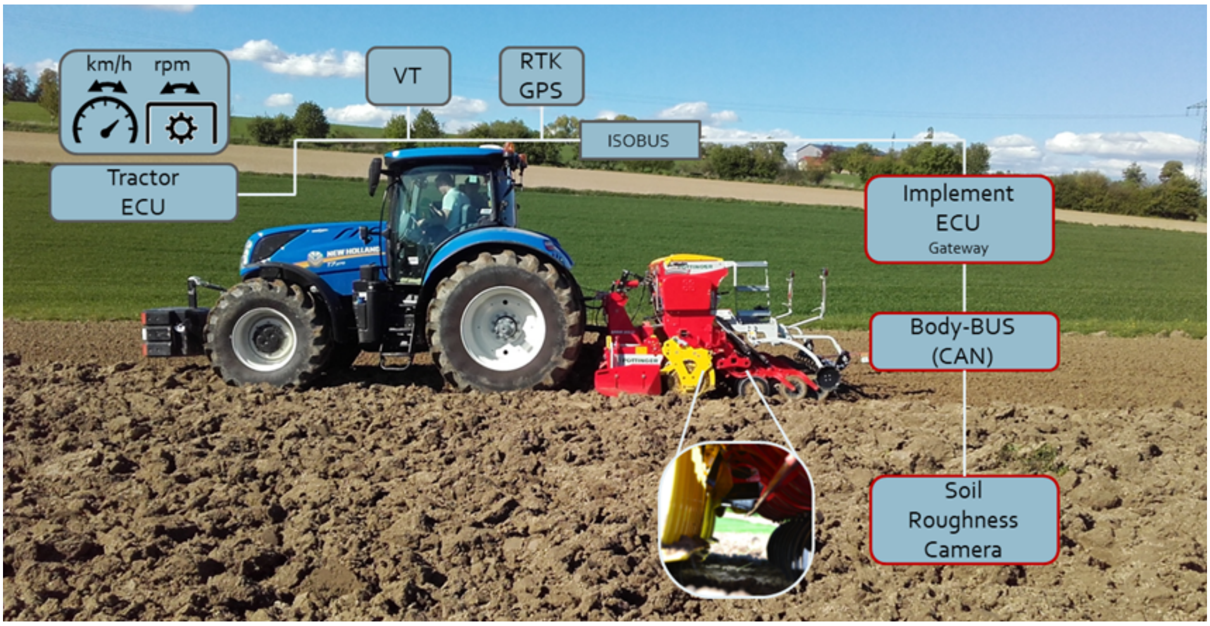

Figure 5 Case study New ISOBUS application

The purpose of the field trials in Austria was to connect a power harrow via TIM - ISOBUS linkage with a tractor. The TIM (tractor implement management system) link is an ISOBUS-based solution for an agricultural technology system that removes barriers between different manufacturers and allows the implement to control certain functions of the tractor. The main concept of TIM is to use the intelligence of the whole combination, i.e., tractor and implement. The solutions developed so far involve the control of the implement by the tractor, with TIM the experts talk about two-way communication, i.e., the ISOBUS link allows the transfer of control in both directions: using the TIM link an implement is able to control certain functions of a tractor, such as forward speed and power distribution. In the pilot action 'new ISOBUS applications' A camera was mounted on a power harrow to assess the suckiness of the soil by providing data for the ECU (electronic control unit). The ECU mounted on the implement once the image is processed, manages the driving speed of the tractor and the speed of rotation of the PTO. In this way, the tractor's power is put to good use by preparing the optimal seedbed, neither too coarse nor too fine. The second part of the field trials took place near Krakow, Poland, on two fields with the measurement of roughness and plant emergence. These data were used to compare them with the results obtained in Austria and to verify the correct operation of the tool. The field research and trials were carried out with the cooperation of Krakow Agricultural University and its innovation center. Krakow University provided access to areas with different soil types. The pilot action coordinated by the Austrian center Francisco Josephinum was carried out on different types of crops and winter cereals, and data collection was carried out in two agricultural years.

Case Study 2 - Remote and Proximal Sensing

Remote sensing and proximal sensing applications in future agriculture will provide new ways to support precise field operations. These new technologies are a useful tool in a variety of agricultural practices, capable of collecting information on the status of crops throughout the season at different phenological stages. This offers a great advantage because data collection can be carried out over very large areas, at low cost, and operations are carried out in a nondestructive manner.
There has been a huge development of sensors and cameras in recent years, and this trend will continue in the coming years.
The remote and proximal sensor are very similar and can include the same types of sensors. The main difference is that remote sensing relies on systems that are far from the objects being measured or observed, such as satellites and drones, and, usually, are not owned by farmers. Usually, they are owned by outside companies or government institutions that provide a service to the farmer. Proximal sensing, however, can be used by mounting sensors on the farmer's machines. On-the-go data collection provides a way to read the status of plants and in case equipment is set up act accurately in the field optimizing resource use.

Spraying Application Control System (SACS).

Thanks to the cooperation of partners from the University of Maribor, SMT/AE-ROBO.NET, AMPS s. p. / Dr. Lepej and Crea, the SAC system was born. The development of the system started from the results of other projects and research with the aim of creating an advanced sensory system for managing precise agricultural operations such as spraying. Our goal is to select, evaluate and try to integrate an advanced sensory system that can take agricultural technologies to new levels. In Transfarm4.0 we aim to create a system for more precise spraying that can inspect and assess the health status of crops. This pilot project aims to build a system that monitors the plant canopy in vineyards and/or orchards and adjusts the use of plant protection products accordingly in "real time." This allows the reduction of plant protection products and at the same time maintains their protective effect. The Spray Application Control System (SACS) integrates advanced sensory systems to perform specific tasks of precision control of pesticide spraying. The SAC system aims to improve and automate the spraying task to be more precise and sustainable. This is possible with the system that detects the presence or absence of plant canopies within orchards or vineyards and allows it to react with precision, spraying only when the target is present and stopping spraying where plants are missing or growth is reduced.

To achieve this goal, the SAC system uses a number of electromechanical components, including:
- Industrial electronics cases and PLA plastic holders for LIDAR.
- SENSORS: 2 x Lidar Sick Tim5xx
- GPS/GNSS USB G-mouse module

- SIGNAL Leds: 12V led lights, 22, industry standard
- Processing unit: Raspberry pi 4B (Rpi)
- PLC microcontroller for implementation: MEGA controller
- ACTUATOR interface valves: standard 13-pin agri connector and plug
- POWER SUPPLY: standard 3-pin AGRI plug + one mounted on the system, for external devices (power splitter)
- USER interface: server on Rpi, parameter configuration, start/stop control

In addition to this, the system takes advantage of the FieldSLAM positioning algorithm, developed in the past by the partners. This gives the system the ability to 'position' the sprayer in the orchard/vineyard, localization is of utmost importance in order to place plant presence readings in space and manage nozzle opening.

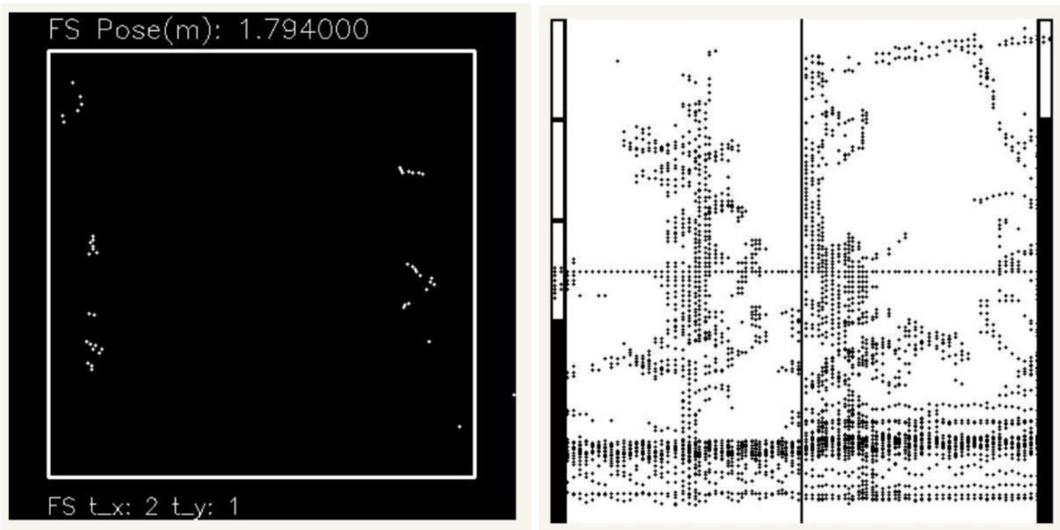

Figure 6
LEFT: FieldSLAM, elaboration immage
RIGHT: recontstruction of tree canopy

SAC, instead of using complicated and expensive systems for positioning, such as GPS RTK, the system uses two LiDAR sensors. The first, in a vertical position, captures the readings needed to determine the presence of plant canopies, while the second, horizontally positioned LiDAR helps position the system.

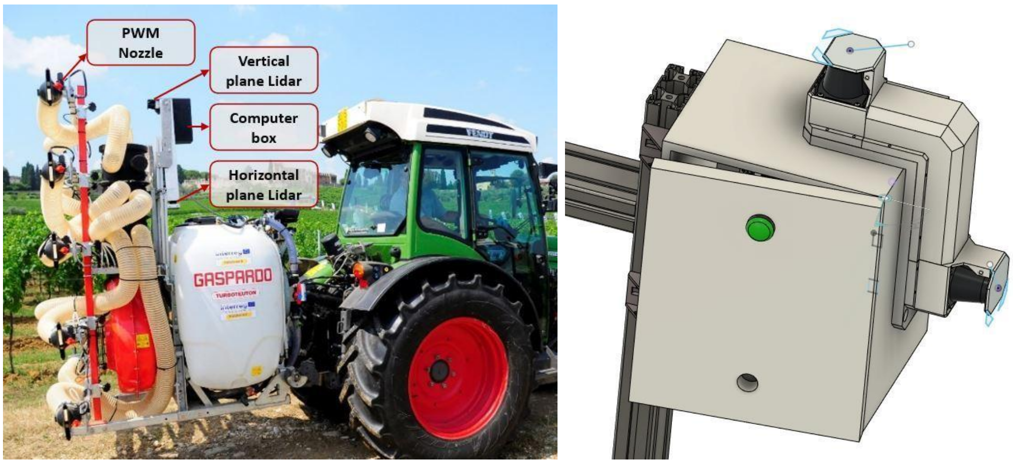

Figure 7 Spraying Application Control System (SACS)

The system was improved and tested through collaboration between the University of Maribor (Slovenia), CREA-VE in Conegliano (TV), and a Slovenian cluster specialized in electronics called AE-ROBO-NET. Testing of the system took place on permanent vineyard crops in Italy and orchard crops in Slovenia. Thanks in part to Maschio Gaspardo's provision of a Turbo Teuton P Polipo model sprayer equipped with solenoid valves in each nozzle holder for flow regulation.

Advanced Sensory System (ASES)

The partners in this pilot project decided to design, build and test an Advanced Sensory System (ASES) for agricultural purposes. Our goal is to integrate an advanced sensory system that can elevate agricultural equipment to new levels. To achieve these goals, we used a variety of commercially available state-of-the-art sensors. The sensors were programmed, run and tested on an integrated computer unit. The integrated computer unit is intended both for recording sensor data and for further processing them. Complex sensor systems were built on the tractor; the IMU was mounted on top of the sensor system to receive the best GPS coverage and optimal data from the inertial motion unit. We installed the GPS receiver of the Micasense Rededge multispectral camera right next to the IMU. The Velodyne 3D Lidar was installed in a tilted orientation to capture as much environmental data as possible. The Micasense RedEdge camera faces forward to acquire relevant environmental data. The lower camera is the Intel Realsense L515 Lidar camera, also facing forward to cover as much environmental data as possible. A platform integrating all the sensors mentioned above was built as part of the pilot project. The system envelope is modular, so it can be upgraded at any time during the testing phase as needed. An on-board computer unit is included to capture all readings needed for later post-processing. The unit is ROS-based and provides the necessary data, supported by an accurate timestamp and readings of various information from the sensors.

Figure 8 sensoric system mounted on the tractor

The data acquired by the system includes one RGB image, captured by a color camera, and six grayscale images captured by the multispectral camera. The data provided by the cameras record the actual color of the environment, and an additional multispectral camera captures images that are in specific wavelengths of light.
The LiDAR sensor provides very dense measured distance readings and provides accurate information under different environmental conditions. With this information, an accurate reconstruction is performed based on the depth information and represented in a 3D point cloud form. Depth information can provide structural density analysis (e.g., tree trunks, pillars, leaves, and canopy density).

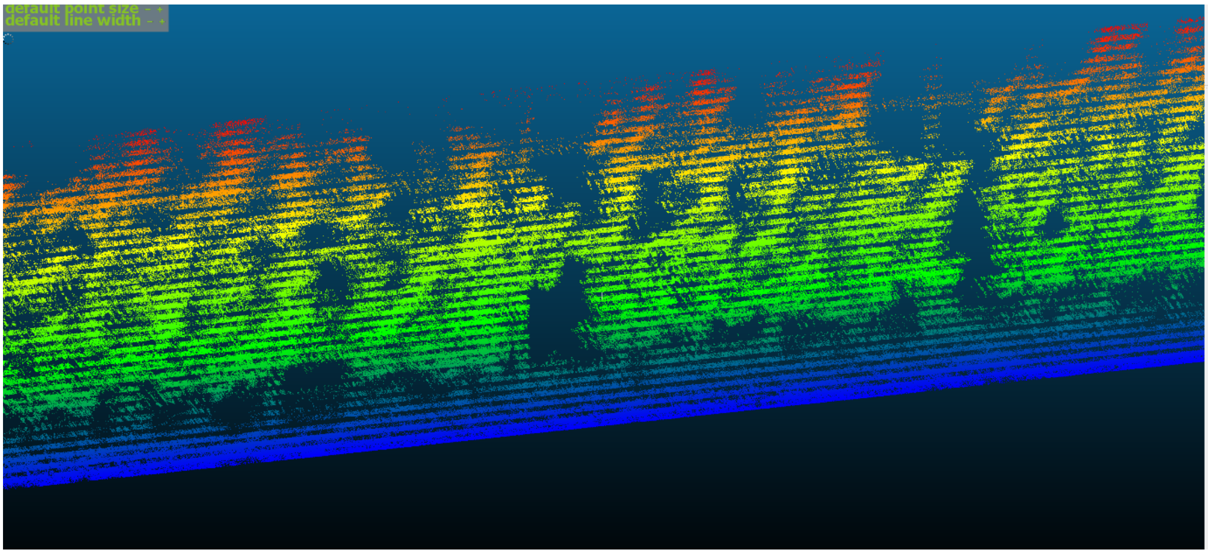

Figure 9 3D image obtained from sensors

The execution of Pilot Project 2 has led to fruitful collaboration between project partners and industry. The maturity of the technologies developed for precision agriculture is at different stages, and consideration is still being given to how to improve their robustness, quality, and how to make them more economical and bring them closer to the market. These activities are a key step in meeting the user needs that emerged in the first phase of the project and will continue after the conclusion of this project.
Thanks to the support of the Transfarm project, it was possible to demonstrate the potential of the technology in the field: during the trials in the demonstration farms, the results were very promising. The rate of savings on Plant protection products (PPP) is between 20 percent and 30 percent in well-formed orchards and over 50 percent in extreme cases such as vineyards infected with the Esca disease. But this is just one example of how precision agriculture technologies could help agriculture in the future. Not only can the use of PPPs be reduced, but thanks to technology, plant management can be optimized by increasing yields and reducing inputs.

Case Study 3 - Big and Smart Data Management

The concept of Terroir in viticulture includes factors that influence yield and quality, e.g., vine cultivar and rootstock, training system and vineyard maintenance practices. Environmental elements also have a significant effect by influencing plant physiology, which is directly related to grape yield and quality. Among the environmental factors, topography, particularly elevation and exposure have direct and indirect effects on microclimatic factors, specifically irradiance, rainfall, temperature, and humidity. The collection of microclimatic data has several purposes, such as evaluating the driving forces of phenological stages and describing the effect of climate change on vines. The life cycle of pests and pathogens is linked to climatic circumstances, which is why decision support system (DSS)-based plant protection relies heavily on environmental observations. Other stages of vineyard management, such as irrigation operation, can also be managed from soil and plant monitoring.

In the case study "Big and Smart Data Management: Sensor data scanning for precision viticulture in a FIWARE data lake," the Hungarian University of Agriculture and Life Sciences (MATE) (Hungary), Linz Center of Mechatronics GmbH (Austria) and AgroIT Cluster (Hungary) set up a sensor network for monitoring plant physiological parameters and microclimate. MATE was responsible for viticulture surveys, definition of monitored parameters and organization and implementation of farm demonstrations. Linz Center of Mechatronics GmbH is a specialist in mechatronics (electronics, sensors, communication, IoT), creating the FIWARE data acquisition system including data delivery and visualization. The AgroIT Cluster was responsible for the territorial dissemination of the technology solutions in an open innovation perspective among the different actors in the sector.

The main objective of this pilot action is to collect, manage and share data on vineyard canopy microclimate and plant physiological data. The model vineyard was located in Tata (Hungary), belonging to the Neszmély wine region. The experiments were conducted in two locations of the Mikóczy and Mikóczy Family Estate. The effect of irrigation on plant physiological parameters is monitored in three plots: control (no irrigation), underground drip irrigation and surface drip irrigation. The effect of climatic conditions on terroir was studied by comparing two plots, one in Tata, Látóhegy (160 meters above sea level), while the other is located in Dunaszentmiklós (250 meters above sea level).

Several data loggers equipped with solar panels from which to collect information were installed in this pilot action

- all-in-one weather stations;
- volumetric sensors of water content, temperature and electrical conductivity;
- two types of multispectral reflectance sensors to monitor photosynthesis and stress-related plant reflectance indices (NDVI and PRI);
- infrared sensors to estimate water relations of grapevine plants with different irrigation systems, from stomatal regulation of leaves

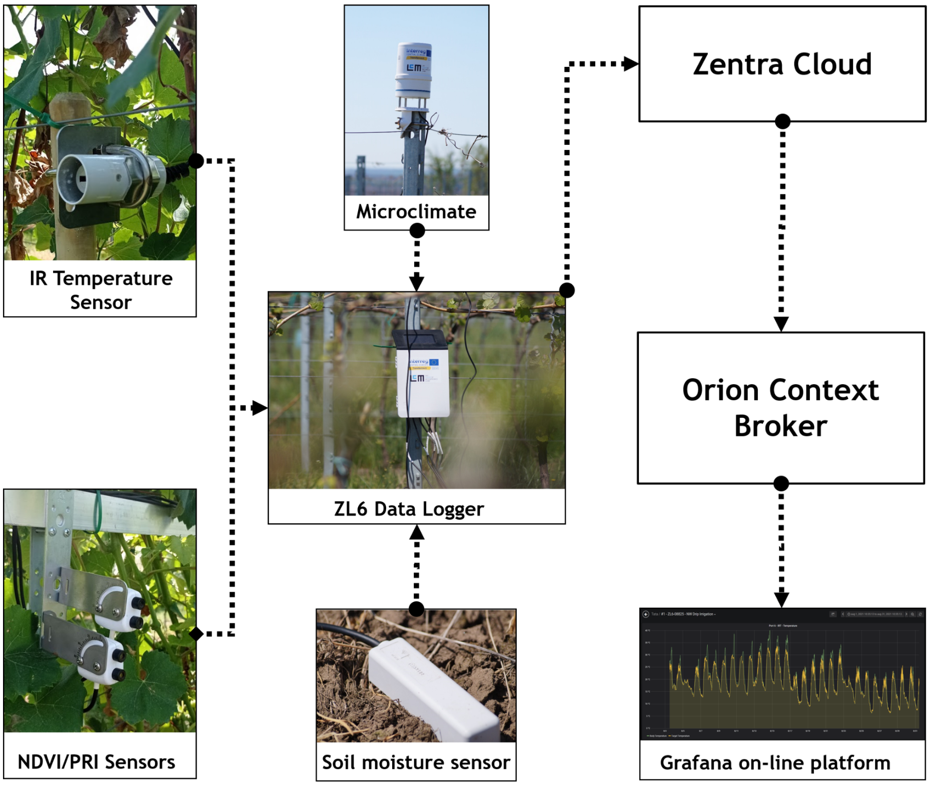

Figure 10 Case study 3 Big and Smart Data Management

From a technical point of view, the realized data acquisition system brings many advantages. The solar cell-powered system minimizes maintenance effort for the farmer. In addition, a data logger was chosen that sends its data to the cloud via the mobile communication network, eliminating the need for the user to establish separate Internet access or have to travel to the sensor site to download the data. Using the open-source FIWARE platform, it is also possible to manage data from different data sources in a common database: this allows, for example, data provided by sensors located in different appreciations and/or belonging to different manufacturers to be combined and displayed together. In addition, additional information such as publicly available weather forecasts or even satellite data could be included in the data analysis. Users of the system access the data through a visualization platform, which was created using a Grafana web server. This platform grants for larger user groups the ability to assign access rights to client-specific data is particularly beneficial for consortia or technicians supporting companies. Another advantage of the data acquisition system is its versatility, since in addition to its application in vineyards, it is also suitable for use in fields with herbaceous crops, forests and orchards.

CHAPTER 3 - Proposals for the development of the precision agriculture sector

During the third phase of the project, a series of activities were carried out to stimulate interest, adoption, dissemination and investment in precision agriculture. The actions carried out in all five regions involved in the project-Italy, Slovenia, Austria, Hungary, and Poland-were designed to go after strategic targets in the supply chain with the aim of creating the greatest possible impact. The objectives of these actions have involved the following stakeholders: companies in the sector in the broad sense, from startups to wineries to equipment manufacturers, trying to go and define the possible directions in which the sector will develop and it will be most appropriate to invest; the needs of users and the constraints they encounter and limit the adoption of new practices and machinery; the skills that the labor market requires of young people and the initiatives that can be taken to update the education system to prepare the workers of the future.
To achieve these goals the partners on the one hand participated in the most important trade fairs in the sector: EIMA, Fieragricola and Vinitaly (Italy), Agra (Slovenia), Agricultural fair in Ried, ALVA Conference and Mechatronic Forum Linz (Austria), PREGA, National Conference of Viticulture and Oenology (Hungary).
At the same time, a series of ad hoc exchange and training events were created for specific targets: researchers, technical decision makers, farmers, contractors, students.
In summary, in this last phase of the project the partners sought to answer questions that touch the sector: how is the primary sector evolving and what will be the main technological developments? What are the needs of farmers and how can industries intercept these needs? How can young people prepare for this new dimension of the primary sector?

Italian Experience:

The precisionfarm.it portal

The Crea Viticoltura Enologia of Conegliano coordinator of the project, together with the other two Italian partners T2I and Federunacoma, has created the portal www.precisionfarm.it by involving key players in the sector to facilitate the exchange of ideas between the parties and stimulate dialogue between them. The portal has the ambitious goal of exploring the boundaries of precision agriculture, identifying its limits and potential in a collaborative and exchange perspective among stakeholders for shared sector development. Precision in agriculture is not a new issue; farmers have always been skillful observers and act according to the variability of land, crops and environmental conditions. What is changing today is how one can act in agriculture. With the use of new technologies, empirical knowledge gained over 10,000 years of experience can be validated and made even more precise and reliable. The sector is facing the challenge/opportunity of a technological transformation unimaginable until a few years ago, the principles of agile, lean manufacturing and Industry 4.0 are being applied to agriculture, making the sector more precise and efficient. The challenge is very big, new technologies are appearing in the fields and new skills are being demanded; the transition is yes technical but also social and value-based. The portal brings together the experience of the partners within the project and is open to discussion with companies and users. Within the portal are uploaded more than a dozen videos with different startups, companies, and key players in the field with whom we have confronted on several occasions to try to give together the answers that the sector asks us at this historical moment.

Figure 11 the portal www.precisionfarm.it

The new skills required for the sector

Agriculture, a field is itself very broad and diverse involving various fields of knowledge ranging from agronomy, to meteorology involving different branches of science (chemical, biological, physical, mechanical, hydraulic). With the arrival of precision agriculture, it widens further. The latter involves areas of knowledge new to the primary sector: electronics, computer science, robotics, mechatronics. This expansion brings a major change in the skills required to design and use the new tools available to farmers. Consequently, even in the area of training, the challenge/opportunity is proportional to the revolution that agriculture is experiencing. The labor market of industries requires new skilled workers capable of creating new machinery and applications by renovating more classic equipment. On the side of farmers and technicians, there is a need for new skills to choose new equipment to put on farms and make the most of its potential.
From what emerged from the analysis carried out in the project there is a strong demand to advance the skills of the sector across the board: in schools the curricula require adjustment through the inclusion of new subjects of study in line with market demands, in workers there is a need to transfer practical skills to make the best use of the new equipment available. The regions are equipping themselves with ad hoc initiatives: ITS schools (higher technical institutes) offer post-diploma specialization courses that involve teachers from the sector and prepare young people for the corporate world through internships during their training to put into practice what they have learned; for farmers and technicians, some initiatives have been implemented at the point level by individual training centers and companies, but there is still a long way to go to close the skills gap that the precision agriculture revolution has triggered. The survey activity in schools carried out by the partnership in the 5 regions showed very interesting results that give us, however sketchy, an idea of students' propensity regarding precision agriculture. Students are familiar with the topic of precision agriculture although this is often confused with digital agriculture, the main sources of information being school, the internet and exchange with colleagues.

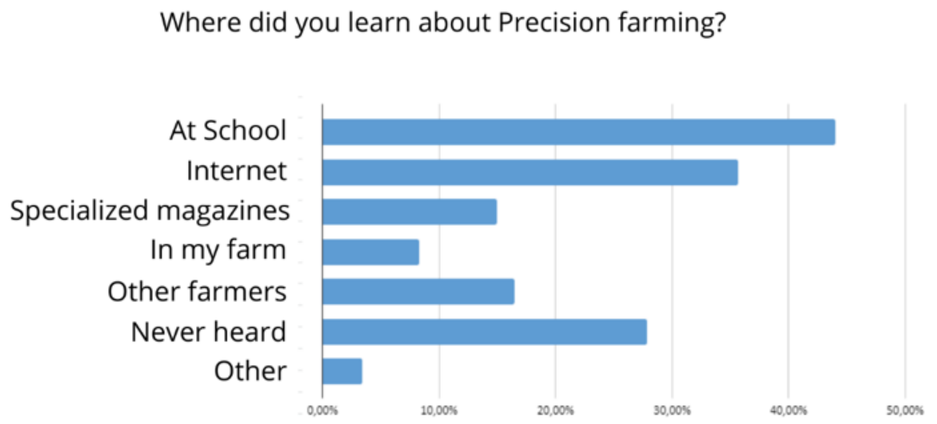

Figure 12 students' interview results

Students are aware that precision agriculture requires new skills; more than half of the students recognize that for the adoption of new practices and technologies there is a need to approach and explore topics related to areas hitherto little covered in agricultural courses such as electronics and computer science.

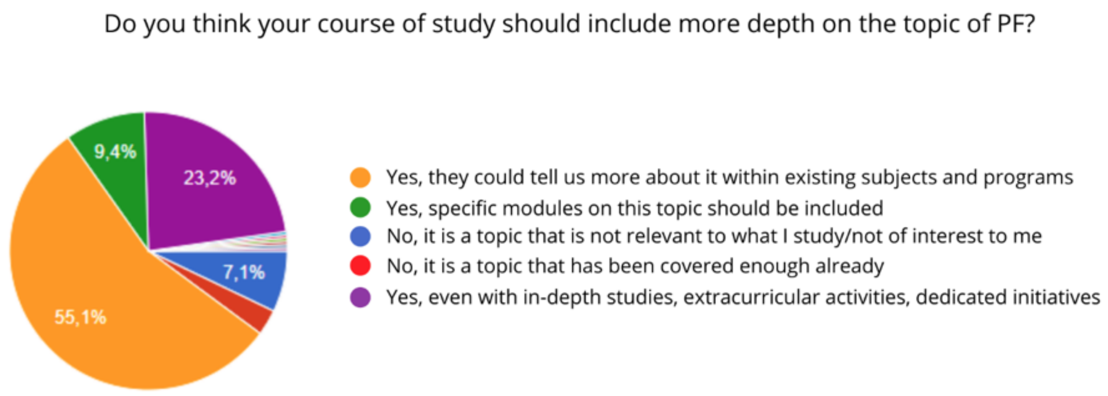

Figure 13 students' interview results

All reports produced within the Transfarm4.0 project are available at https://www.interreg-central.eu/Content.Node/Transfarm4.0.html
The same link can be reached through the following QR Code:

Policy initiatives to support the sector

The project has been in discussion throughout its course with regional agricultural policy makers and RIS3 managers. The project implemented the three prototypes on key technologies whose importance was also stressed by MIPAAF in the guidelines for the development of precision agriculture. The region has endorsed the guidelines by allocating the resources for the innovation of the machinery fleet and the installation of farm platforms capable of linking 'smart' equipment. According to discussions with regional decision makers on the rural development plan (RDP), the region will continue to support the transition to digital agriculture.

Other important initiatives currently in force are the non-repayable contributions agricultural enterprises provided by the Fund for Innovative Investments of Agricultural Enterprises included in the official gazette in October 2021 and made effective by the director's decree of May 2, 2022. the text establishes timeframes and procedures to be followed to obtain non-repayable contributions of up to 20,000 euros for the purchase of new tangible and intangible assets. Another opportunity for companies is the possibility of using the Tax Credit to return investments in new capital goods equipped with 4.0 technology. The financing strand known as Nuova Sabatini has also been refinanced for the period 2022-2027 and for a total amount of €900 million (of which €40 million is earmarked in 2022), the Nuova Sabatini is a measure aimed at supporting companies that apply for bank financing for investments in new capital goods, machinery, plant, factory equipment for production use and digital technologies. The 'Regional Action Plan' resulting from the analysis of active funding lines and from discussions with policy makers shows that there are many opportunities for business improvement, involving both the capital equipment part and the human resources part by offering the possibility of staff training. The full reports produced within the Transfarm4.0 project are available at https://www.interreg-central.eu/Content.Node/Transfarm4.0.html

The same link can be reached through the following QR Code:

CONCLUSIONS

The Transfarm4.0 project, in its three years of development, has been committed to advancing the world of precision agriculture by bringing together supply chain actors in search of the strengths and limitations of the sector to find shared solutions. The partnership aimed to be a tool for enabling innovation in agriculture from an open source perspective that can accelerate technology uptake. The path has not been easy, there have been several hiccups and slowdowns along the way, not all activities have taken place on schedule, nor as we imagined them at the beginning of the project, but we have adapted, rethinking the activities in a different form, adapting them to the new conditions. The working group in these three years of the project has been able to bring three new technological solutions closer to the market, created on the user needs that emerged in the first phase of benchmarking the potential of precision agriculture, create training and information events in all five regions in the presence and at a distance to all possible stakeholders in the supply chain, participate in major European events related to the world of agriculture share the path and compare with realities in the world of precision agriculture in Israel and the Netherlands, offer new insights into the value of precision in agriculture and its potential, to key players in the sector (policy makers, end users, industries) and to young people, the next generation of players who will experience a very different agriculture from the one we have known so far.