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Transfarm4.0

CASE STUDY 2 REMOTE AND PROXIMAL SENSING

D.T2.2.5 - 2.2.6 - 2.2.7 - 2.2.8 - 2.3.1 Version 1

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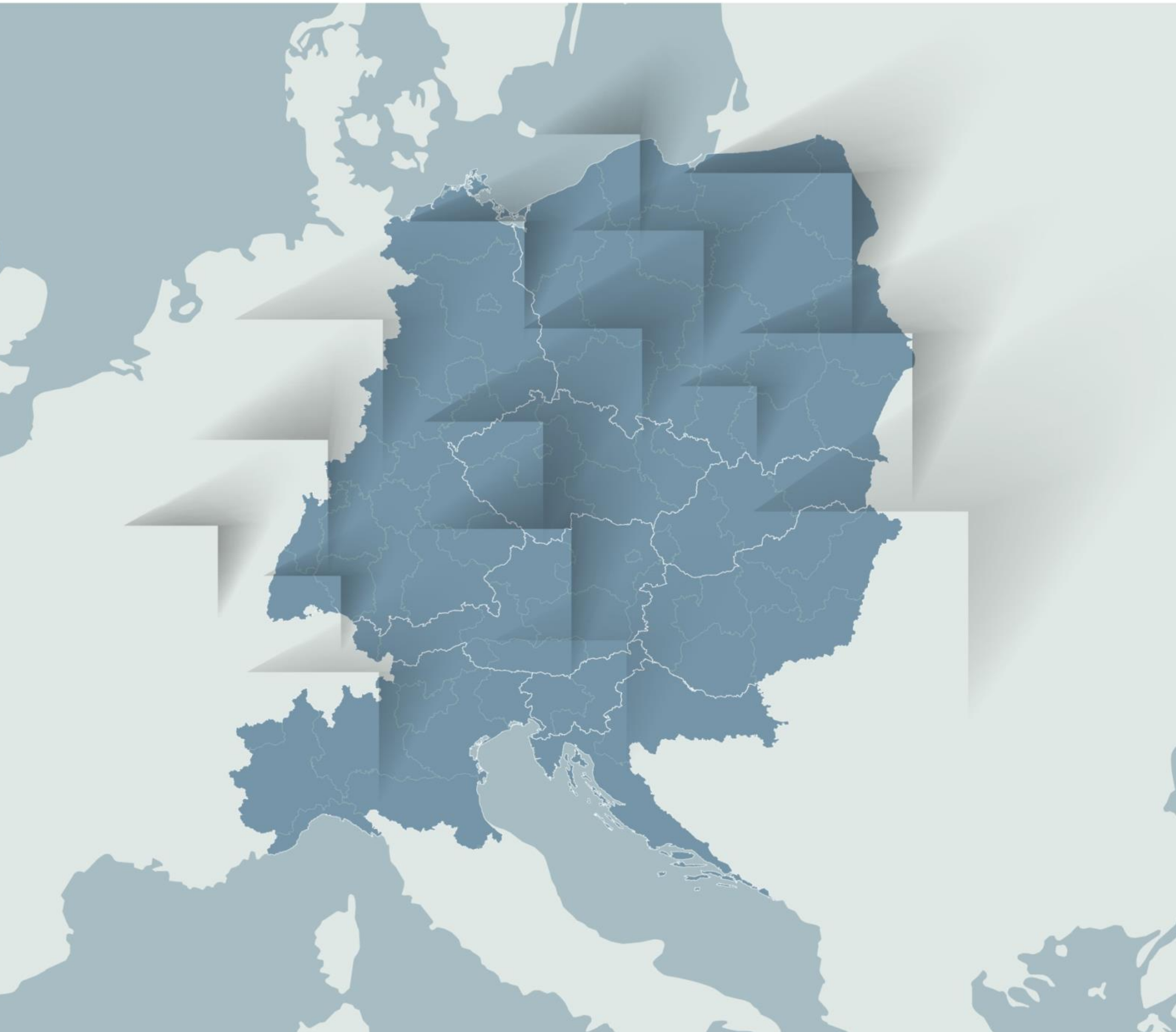

Contents

A. D.T2.2.5 One joint industrial undertaking in remote and proximal sensing (co-design of case study 2)

Pilot action 2 Remote and Proximal Sensing is led by LP Crea in close collaboration with the University of Maribor and the AE-ROBO cluster.

The partners scouted the market by following the D.T1.4.4 business plan which identified specific technological optimisation to be implemented in the A.T2.2 Pilot action in order to accelerate PF technological uptake in a trans-collaborative environment. As a result, they involved Maschio Gaspardo, an Italian multinational company that produces agricultural implements, to install the technology of proximal sensing on a machine that is already available on the market to update and widen precision farming solutions tailored to the farmers' needs.

The company provided the project with a Turbo Teuton P Polipo mist blower, specifically designed for small and medium farms specialising in fruit production, e.g., vineyards and orchards. The machine was prepared for the pilot action by including specially mounted Pulse with Modulation (PWM) solenoid valves that made it possible to precisely open/close the nozzles and adjust the flow rate according to the canopy characteristics measured by a LiDAR sensor. In addition, the system included a second LiDAR sensor to precisely determine the system's location and control the valves at the suitable locations, which is possible by a specially integrated SLAM (Simultaneous Localisation and Mapping) algorithm developed by the members of the UM and AE-ROBO cluster.

This innovation aims to respond to the farmers' need and EU guidelines (that require a reduction of chemicals in the following years) to have a ready-to-use and economic, environmentally sound mist blower that performs higher distribution accuracy.

Nowadays, highly technological mist blowers are equipped with a recovery system to catch the drifting spray to avoid treatment losses and guarantee the coverage of the treated canopy alone. However, these machines have some limitations: they are expensive, meaning that only large farms or subcontractors can afford them, and their employment is limited to flatlands or gentle hills due to their size and weight, which does not allow them to proceed on steep or terraced slopes.

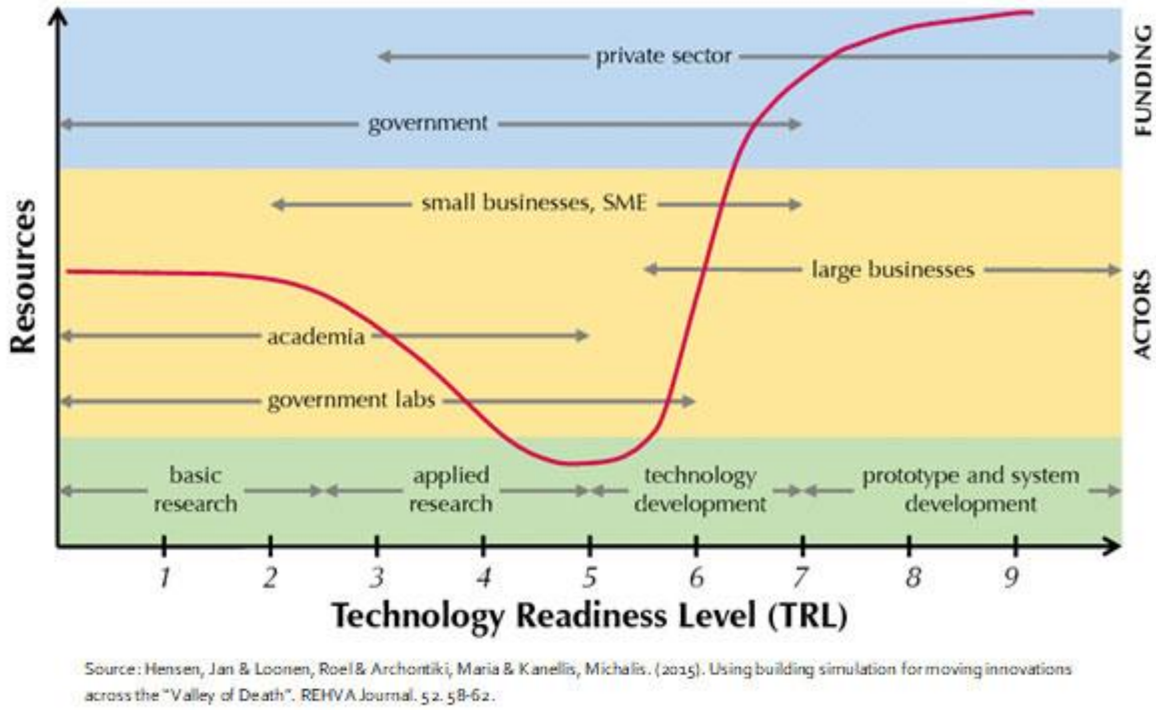

Figure 1: Technology Readiness Level (TRL), source: Hensen, Jan and Loonen, Roel and Archontiki, Maria and Kanellis, Micahalis (2015), Using building simulation for moving innovations across the »Valley of Death«, Rehva Journal, 52, 58-62.

As shown in Fig. 1, the development of technology can be represented on a scale of 9 steps; in the initial phase, the new technology is studied and developed by academics in association with base and applied research and supported by government funds. Once the technology has a medium grade of maturity, TRL 3-5, small-medium enterprises are involved in the prototyping and application. In our case, the technology developed combines with existing machines and can be applied to the mist blowers present on the market.

The machine with its technological application was presented at Vite in Campo, an exhibition specialised in viticulture held in Susegana on July 2021, at Agra(August 2021), the leading agricultural fair in Slovenia, EIMA in Bologna (October 2021), and Fieragricola in Verona (March 2022). The farmers and technicians gave positive initial feedback regarding the technology and its further development. The field trials and public exhibitions are essential steps in developing new technology in an open, innovative environment, as in the case of Transfarm 4.0.

We aim to improve the application of the technology and reach a TRL 7 'System prototype in the operational environment'. The goal is to measure the machine's efficiency in terms of the amount of chemicals saved compared to the current applications, considering the same disease control level achieved with the traditional applications. Field trial also initiates the calibration and fine-tuning of the system to get the best out of the technology.

Remote and proximal sensing systems in future agricultural applications will provide new ways to support the precise practices in the fields. This operation can include accurate field preparation and crop fertilisation, precise seeding plans based on the soil characteristics, specific treatments on plants to support optimal growing conditions, and precise harvesting to support maximal quality and provide means for optimal growing conditions. But the optimisation of plant production does not end here; it can also include steps to support food processing in the subsequent phases of the food industry, such as sorting, transforming, preserving and logistics.

In recent years considerable development in sensors and camera devices has taken place, and this trend is bound to continue in the coming years. Remote and proximal sensors are very similar and can include the same sensor devices. The main difference is that remote sensing includes remotely positioned systems related to the measuring instruments, such as satellites and drones. Usually, they do not belong to the farmers but are owned by external agencies or governments that provide a service to farmers. On the other hand, proximal sensing can be performed by mounting sensors on the agricultural machinery owned by the farmer. It provides a way to assess and act according to the properties of the plants. These two technologies can also be combined: for example, field robots can use satellite or drone-supported multispectral field maps to move to a specific location and adjust their operation on the plants according to the data detected by proximal sensing. In both cases, remote and proximal sensing can be used to support intelligent precision farming applications.

To optimise the labour-intensive operations in the fields, members of UM and AE-ROBO joined forces in the past to build autonomous field and vineyard robots, including small Cornstar and Farmbeast robots and two larger vineyards robots - Rovitis and Rovitis 4.0. These involved the creation of multiple state-of-the-art solutions, including sensor fusion-based localisation, and custom-built FieldSLAM algorithm, among others.

In addition, members of the UM also worked on the precise application of plant protection products (PPP) based on ultrasonic readings as part of the EUREKA project. The idea was to apply plant protection products to target areas precisely and minimise their use. For this, a new kind of ultrasonic sensor was developed. In general, ultrasonic sensors range the distance between the obstacle and the sensor based on the time the ultrasound travels back and forth. Once the sensor records the ultrasound reflection, it stops ranging and calculates the distance. A new approach was studied in the Eureka project: the ultrasound sensor was kept on and continued to take measurements. These kinds of sensors can measure the density of the tree canopy but are still limited to the surfaces parallel to the sensor’s membrane used to generate and record the ultrasound wave. The main limitation of the system was that it worked only with the constant speed of the system and did not include any localisation subsystem. Hence, its possible application was somehow limited.

The know-how acquired in previous projects allowed us to conclude that the FieldSLAM algorithm could provide a good reference for accurate operations where the system's position is of primary importance. In this way, during the first phases of the Transfarm 4.0 project, thanks to the collaboration between different stakeholders of the production chain and research centres (the University of Maribor, CREA, AEROBO and the University of Padua), a new system configuration has been evaluated: by combining the precise canopy and the position readings with LiDAR supported sensing of plant canopies, instead of ultrasonic and based on SLAM support. The evaluated new prototype system is based on two LiDAR sensors; a horizontal one to provide the information to the FieldSLAM used to position the system and a vertical one to create a temporal virtual twin of the scene.

This prototype system was then mounted on a mist blower and assessed. UM and AE-ROBO partnered up with CREA institute, which provided expert knowledge in evaluating the system. Comprehensive research of possible partners was conducted to improve and test the system's TRL (Technology Readiness Level) within an operational environment. Maschio Gaspardo, a multinational company based in Italy, made itself available to share its experience in the sectors of sprayers and collaborate with partners in adapting their mist blower to the partnership's necessities. All partners joined forces to prove the system's usefulness in two possible operational environments, including orchards and vineyards.

B.D.T2.2.6 Small-scale precision farming projects

1.1. Introduction

Orchard and vineyard owners work hard to produce a perfect green wall of plant canopies as possible. However, this is not always achievable, especially when the plants are affected by diseases that prevent their homogeneous development. Unfortunately, the standard spraying machinery is not equipped to deal with this common situation. As a result, a quantity of plant protection products are deposited on non-target organisms rather than on the plants or are drifted away by the wind, causing considerable revenue losses and negatively impacting the environment.
Case study 2 on proximal sensing tried to solve this challenge and included two mini-projects. One was carried out in orchards owned by the University of Maribor, Slovenia. The other mini-project was carried out in a plot of vineyards in Moimacco, Italy. The purpose of the former was to evaluate the effectiveness of the prototype system for spraying apple trees and the latter for grapevine plants.

Figure 2: LiDAR-supported triggering system mounted on a state-of-the-art mist blower.

1.2. Test in orchards

The first set of tests was conducted in the apple orchards owned by the University of Maribor. They are generally in good condition and are employed to evaluate the amount of plant protection products that could be saved when a LiDAR-supported trigger system controls the mist blower.


Figure 3: Example of a well-developed apple orchard (left), where the tests were conducted. The image on the right shows an example of not yet fully developed trees, where the savings of plant protection products could be even higher.

The test included different test runs in which the system recorded each electromagnetic valve's on and off state. By repeating the tests in various orchards featuring different development stages of plants, we concluded that savings ranging from 20% to 30% are already achievable. There is also a margin to improve the system by around 10 % if the system's accuracy is improved.

1.3. Test in vineyards

The second set of tests was carried out in Moimacco, Italy. The actual depositions were measured, along with the consumption of liquid with the help of a flowmeter during the spraying operations. The test field was specific as the plants had been affected by esca disease, and some plants had had to be removed and not repopulated to stop the disease from spreading.

Figure 4: Two examples of the vineyard tests; the image on the right starts with a good distribution of plants but later continues with parts where the plants are missing, as shown.

The two small-scale precision farming tests, controlled by the LiDAR-supported approach, aimed to assess the possibility of employing fewer plant protection products while achieving good PPP distribution to guarantee plant protection as with conventional agricultural machinery and practices. Savings are, of course, site-specific; nevertheless, higher spraying precision is already achievable. This brings us one step closer to one of the goals set by the EU commission, which aims to reduce the use of chemicals by 50% by 2030.

C. D.T2.2.7 Test in environment, tech protocols and operational guidelines for case study 2

1.4. The objectives of the case study 2

Since directive 2009/128/EC, the European Commission has asked the whole agricultural sector to reduce chemical consumption. The request came from the rising need to reduce the environmental impact of food production. Pesticides and fungicides use reduction, healthy production and safe working conditions have been the recent standard agricultural policy (CAP) baseline.
Thanks to the most recent policies, the European Green Deal, Farm to Fork strategy, and sustainable development goals, the European Commission underlined the need to reduce PPP use and other agricultural input waste, promoting sustainable production of produce. However, PPP sales have decreased in the last decade.
Mist blowers are agricultural machines used for the protection of tree crops. Mist blowers come in different sizes but use the same working function; they can be trailed by or installed on a tractor. A tank makes sprayers specialised for orchards with a capacity ranging from 300L to 1500L filled with a mixture of water, PPP and other addictive, a pump, two or multiples of two nozzles booms, and a fan. The nozzle booms are directed towards the tree rows spraying the mixture on fruits and leaves. The airflow produced by the fan carries the mixture droplets into the tree's canopy. The sprayers market offers several models specialised in each crop. However, the amount of mixture reaching the tree canopies usually is less than 50%. This is because most of the sprayed mixture falls to the ground or drifts away from the sprayed field carried by the wind. The number of droplets that do not reach the target is called drift. The spray drift is a source of pollution for surface water and non-target organisms such as wild animals, insects, algae, other vegetal species, and humans. Spray drift is due to human error, wrong machine settings, and unfavourable weather conditions.
The main objective of the present work is focused on reducing the droplet drift produced by sprayers to avoid hitting non-target organisms, thanks to a more accurate and precise vehiculation of chemicals. Drift reduction means reducing chemical waste and pollutant emissions in the tree crops protection operations favouring sustainable practices. The field test intents to achieve three specific objectives:

1. To measure the treatment saved by the precision mist blower;
2. To assess the distribution quality in the "critical spots" at the beginning and the end of the missing plants;
3. To evaluate if the LiDAR sensor correctly detects the gaps in the canopy wall and, at the same time, adjusts the response of the open-close system.

1.5. Material and Methods

1.5.1. Experimental site

The field trial took place in Moimacco (UD), close to the Slovenian border in the northeast of Italy. Red and white grapevines trained to a Guyot system are cultivated in the vineyard. Vine rows are 500m long and 2.5m wide, while vine spacing is 1m. The load-bearing wire is set at 0.80m, whereas the canopy measured an average of 2m in height. The tests were carried out in October 2021 on hand-harvested grapevines.

Four rows were sprayed with water. Once with the canopy detection system in operation and once not in operation. The same measurements were recorded in each trial. Some artificial “gaps” were made to boost the vine’s canopy variability. For example, some grapevines were pruned entirely to simulate the lack of vine, while others were partially pruned to simulate a low canopy volume. The sprayer mounted a flowmeter to measure water consumption.

1.5.2. Plant protection products Savings

To measure the savings of the treatment, the same vine rows were sprayed with the canopy detection system active and disabled. The flowmeter measured water consumption in the two treatments.

1.5.3. Quality Distribution

To assess the distribution quality in the “critical spot”, water-sensitive papers (WSPs) were used. WSPs are little strips of yellow paper that measure 76mm in length by 26mm in width and are specially coated. They turn dark blue when hit by water droplets. WSPs are usually used to verify the dimensions of the droplets, measure leaf coverage, and detect the spray drift. In the test, WSPs were placed in the canopy at the beginning and end of the gaps, while other WSPs were placed in the continuous hedgerow; hence, allowing to compare the coverage between WSPs in the critical points and WSPs in the continuous hedgerow. Three WSPs were attached to a vertical nylon strip at different heights. At each sampling point, three strips were applied. Putting three strips in sequence allowed us to detect any delay in nozzles turning on-off at the critical moment. Shorter strips with only one or two WSPs were placed on the trimmed vines to assess the distribution quality where nozzles were partially closed. The WSPs were analysed with ImageJ, an image processing software. ImageJ retrieved the fraction of surface coverage by water droplets. Factorial ANOVA and t-student test were used to compare the average coverage level between the sampling point.

1.5.4. Sensor accuracy

To evaluate whether the LiDAR sensor correctly detects the gaps, WSPs were used. First, WSPs were fixed in the row behind the treated one to catch the spray drift passing across the canopy gaps. Next, three strips with three WSP were fixed to the canopy. Finally, two WSPs were put on a panel on the ground under both gaps and trimmed vines to detect the dripping.
An action camera (Crosstour, model CT9000) placed behind one nozzle was useful to detect the exact moment when the nozzle sprayed or not, analysing frame by frame.

1.5.5. Digital Twin

Case study 2 also includes a more advanced sensory system, which we built specifically to create a digital twin of the agricultural environment. Named Advanced Sensory System for Digitalization (ASSD), its primary purpose is to digitalise the traversed environment, map it and create a digital twin. A digital twin is a virtual representation that serves as a real-time digital counterpart of a physical object or process. For example, in the case of row crops with ASSD, we can recreate a volumetric representation of the tree canopies, leaves, wires and pillars.

The main aim of the ASSD case study was to build a digital twin without any global or local positioning system to expand and push forward the usage and implementation of digitalised agriculture environments.

Figure 5: The ASSD system implementation on the tractor, just before the recording session.

For the ASSD, we used different state-of-the-art sensory systems. LiDARS Velodyne, Robosense, Intel Realsense, with whom we were able to recreate volumetrically accurate representations of the environment. An Inertial Motion Unit (IMU) was used to detect small, fast shakes/movements to be compensated during the stage of data postprocessing. We employed a MicaSense multispectral camera, a classical colour camera and other supporting sensors to capture data further. We wanted to evaluate the accuracy of digital twin creation; for this purpose, we used a Leica global positing system for ground accuracy estimation. A built-in computer was used for processing and data capture. A set of electronic components for powering all the sensors was employed, including supporting mechanisms and other small materials, to achieve a fully operational sensory grabbing system. Moreover, over time, the new age of solid-state LiDARS has emerged on the market; these sensors are more suitable for dynamic agriculture environments because they are built for the automotive industry. In addition, they provide more durable operations; we also plan to use new solid-state LiDARS from the producers Cygbot and Ydlidar.

After applying the sensors in different test runs, we can use the recorded data to recreate or build the digital twin offline. With the extensive data set captured, we can now operate and extract different valuable data. The base ground is a volumetric reconstruction of the row crops. For this purpose, we used special algorithms for fast and accurate assembly of given/recorded point clouds using the Simultaneous

Localisation and Mapping (SLAM) technique. After obtaining a 3D presentation of the given environment, we can add other data from the recorded data set. The following figures show a 2D map and a 3D volumetric digital twin recorded in two different seasons.

Figure 6. The 2D map was built from the ASSD sensory data, where the pixels' darkness represents the row's height.

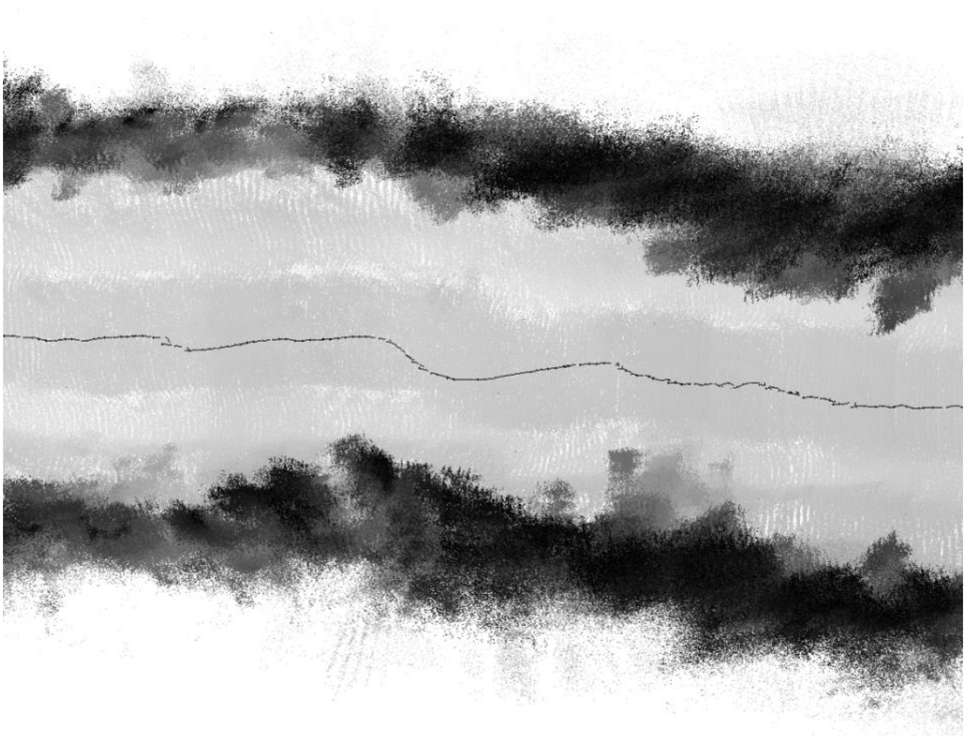

Figure 7: The 2D map built from the ASSD sensory data zoomed in where details of the tractor/ASSD moving in the rows with the trajectory and details on the recreated model can be seen.

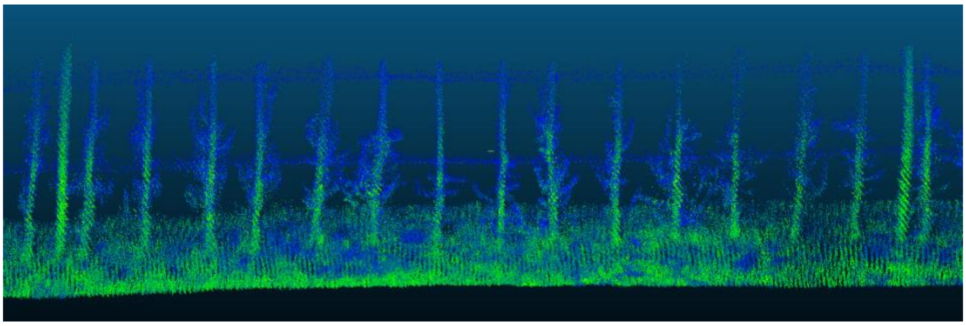

Figure 8: The 3D map or digital twin of the row crop in the winter season clearly can be seen in the pillar's tree trunks and wires.

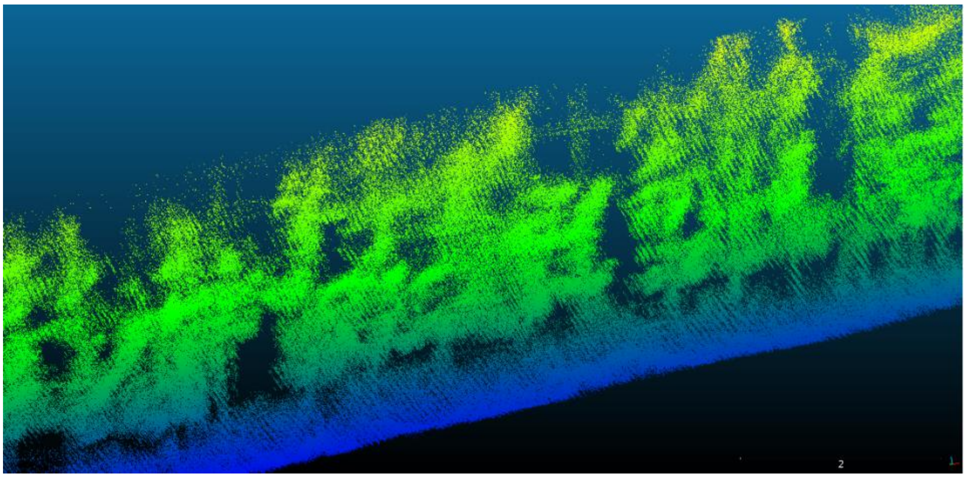

Figure 9: The 3D map or digital twin of the row crop in the vegetation era, where leaves can be seen from the model.

What can we expect from digital twins in agriculture? First, we see this system used as a time capsule for the future estimation of the changing status of agriculture. Additionally, the digital twins have the potential to be recreated during the traversing or real-time digital twin building. Next, the current main purpose is to precisely localise the potential illness of the crop, precision spraying implementations, precision picking operations and generally base for robotics operations in agriculture.

D. D.T2.2.8 Global final report of the case study 2

The European Union (EU) aims to reduce greenhouse gas (GHG) emissions by 45% and increase renewable energy production by 2030, reaching the net-zero balance between the emission and the sequestration of GHG in the atmosphere by 2050. These are the cornerstones of the European Green Deal, a collection of policies and objectives to achieve sustainable growth for the future of all EU countries. Agricultural policies have been strongly considered in this roadmap toward a sustainable future as food production causes 30% of worldwide GHG emissions. Moreover, agriculture plays a dual role as a producer and sequestrator of GHG from the atmosphere. As a consequence of the Green Deal, human health, the preservation of the environment, the adoption of practices against climate change, and the development of rural communities represent the core of the latest Common Agricultural Policy (CAP). Therefore, agriculture must solve the matter of environmental pollution by reducing fuel consumption, fertilisers and plant protection products (PPPs) waste. EU has been asking to reduce the number of PPPs since the introduction of the directive 2009/128/EC. PPPs can be natural or artificial substances with a biocide action against insects, fungal and bacterial diseases and weeds. PPPs are necessary to ensure high crop yield and good quality and preservation of the harvests.

On the other hand, PPPs can be dangerous for farmers and represent a risk of environmental pollution. PPPs are sprayed directly on crops in the field. Horizontal booms apply PPPs on cereals and other grass crops, while mist blowers are usually used in tree crops. In the new CAP, the EU again stressed the importance of reducing the use of PPPs and improving their application. A fraction of the sprayed PPPs do not reach the target but deposit on the ground, surface watercourses and other crops or hit wild vegetation and animals, pollinator insects, birds, or even humans as neighbours or passengers. The fraction of PPPs that does not reach the target is defined as “drift”. Avoiding the drift means decreasing the overall quantity of PPPs sprayed in the field and reducing the PPP’s potentially dangerous effects on the environment and humans.

The primary purpose of this study is to implement an affordable precision spraying system (PSS) on a commercial orchard mist blower able to detect the canopy and spray according to its presence. The aim of the PSS precision spraying system, developed within Transfarm 4.0, is to be used for most agricultural perennial crops present in Central Europe. Moreover, it intends to be a solution not only for big farms but aims to satisfy the needs of small and medium farms with limited competencies and budgets for new investments. In this way, the PPS has been tested on a specific mist blower, but with some minor adjustments, it can be installed on most mist blowers already present on the farms regardless of the make. The PSS uses two LiDAR sensors and pulses with modulation (PWM) supported valves. The LiDAR sensors detect the mist blower position and estimate the presence of the tree’s canopy. PWM valves modulate the treatment flow according to the LiDAR sensor’s readings. The system can avoid treatment wasted because it sprays only in the presence of a canopy and closes the nozzles when there is a gap in the vegetation hedge. The system is built as a plug-and-play tool that is easy to use for farmers with low technology skills. It is independent from the sprayer, which means it can be installed on most mist blowers available on the market with minor calibration and fine-tuning.

E. D.T2.3.1 Briefing papers of yield curve due to the introduction of PF practice

1.6. Material and methods

The field trials took place in Moimacco (UD), at Azienda Agricola de Puppi. The farm is located on flatland at 118 m.a.s.l. The vineyard counts a wide range of Vitis vinifera varieties of different ages. Merlot and Sauvignon Blanc were chosen for the trials. Vines were trained as single Guyot in a continuous vertical hedge. Plants were spaced 2.5 m between rows and 1 m between each plant. The first wire was placed at 80 cm from the ground. Two 250 m-long rows were chosen for Merlot and Sauvignon Blanc. Merlot vines were approximately 1.90 m tall, with a compact and homogeneous canopy but less vigorous than Sauvignon Blanc vines. Sauvignon Blanc vines were 2.10 m tall and vigorous with a dense canopy, but there were many dead and missing plants due to Esca disease. Some artificial gaps were created along Merlot rows to enhance the canopy variability. Some vines were completely pruned to simulate a missing plant, and others were trimmed to simulate a delay in vine growth.

The mist blower adopted was provided by the Italian company Maschio Gaspardo, model Turbo Teuton P Polipo. It is a mounted mist blower with a tank of 315 L, spraying from two sides with four nozzles on each side. Each nozzle mounted a solenoid-assisted check valve (SACV) to regulate the treatment flow. Two LiDAR sensors Sick TIM 510, were mounted above the water tank in front of the nozzles (Figure 1). One LiDAR reads following the horizontally and parallel to the ground plane. This sensor detected the position of the mist blower between the two vine rows. The other sensor reads the vertical plane to check the vine's canopy presence and density. Mist blower position and plants' canopy measurements were processed by a python-based script run on a Raspberry Pi 3B computer. The computer's output was open/close signals to the solenoid of the PWM nozzles. The sensor could detect the vine's leaves' presence and position, and the computer chose which nozzle to close to avoid waste of PPPs. Both Merlot and Sauvignon Blanc rows were sprayed with water using the precision spraying system (PSS). In a second passage, all the nozzles were kept open, as an ordinary mist blower working condition (STD). Tractor forward speed was 2,14 km/h, and water pressure was set at 5,5 bar spraying (ca 475 L/ha). The water consumption was recorded by a flow meter mounted just behind the water pump.

Water-sensitive papers (WSPs) helped assess the spray quality and treatment drift. WSPs are little paper strips coated with special yellow paint which turn blue when hit by water drops. Some WSPs were placed in the middle of the next inter-row to assess the water drifting across the gaps. In addition, the quality of the spray was evaluated by placing WSPs among the vegetation and on the border of the gaps. Each paper has been digitalised with a professional scanner. ImageJ was the software employed to determine the coverage on each paper. Coverage means the ratio between the blue area and the whole paper area. A factorial ANOVA tested differences between paper coverage.

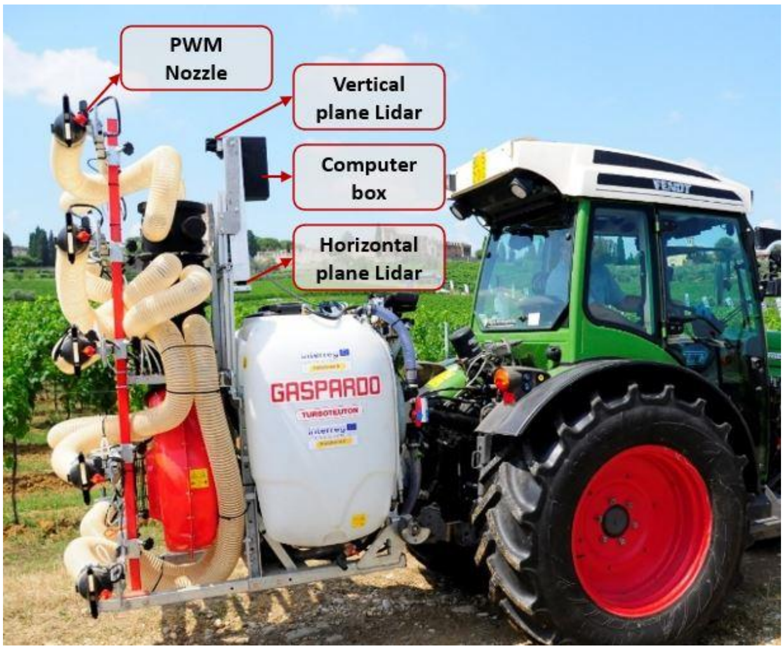

Figure 10: The mist blower used in the field test. The sensor and the computer were placed in front of the nozzles tower.

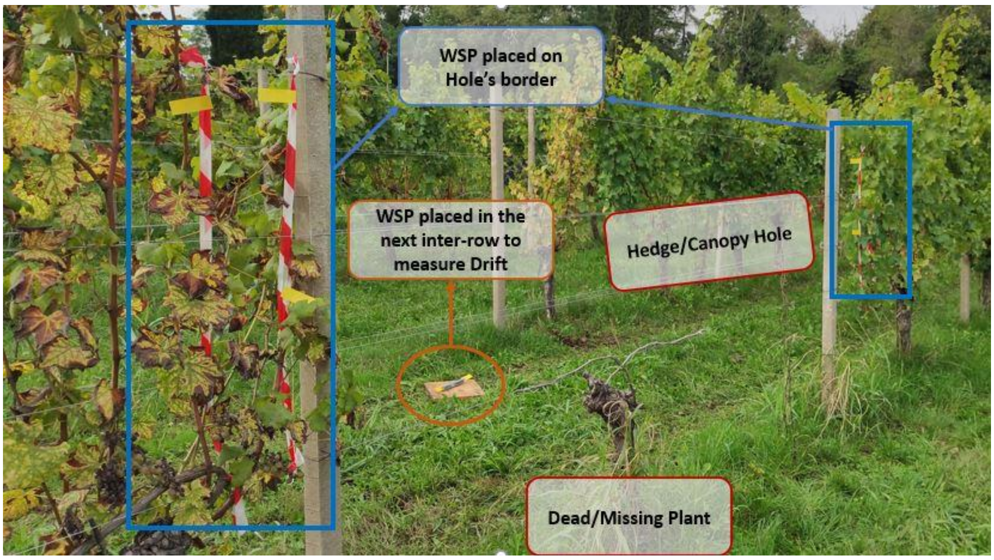

Figure 11: Description of a gap in vine row and WSP position.

1.7. Results

Drift was assessed by comparing the WSPs placed on the next inter-row in the two treatments. In addition, the WSP placed on the border of the gaps was compared with the WSP from the homogeneous canopy. In each trial, Merlot and Sauvignon Blanc were considered two different treatments and analysed separately.
Merlot's WSPs showed higher coverage for STD papers than PSS. The gap is even more substantial in the Sauvignon Blanc's WSP, Figures 1 and 2. It proves that more droplets cross the gaps among the vegetation when spraying with STD rather than the PSS. The ANOVA analysis verified a big difference between the two ways of spraying, both Merlot and Sauvignon Blanc.
The comparison between WSPs placed among the vegetation and WSPs placed on the border of the gaps showed similar coverage values, as illustrated in Figures 3 and 4. According to the ANOVA analysis, there are no differences in the position of the WSPs. It means LiDAR correctly detects the opening and ending points of gaps in the canopy wall.
Thanks to the PSS implementation, 56.51 L of water was saved on Merlot, and 57.73 L of water was saved on Sauvignon Blanc. This means that more than 60% of the volume of water was saved in PSS compared to STD. These results are, of course, connected with the state of the orchard, but, independently from this, the system showed its utility in reducing the PPPs used.

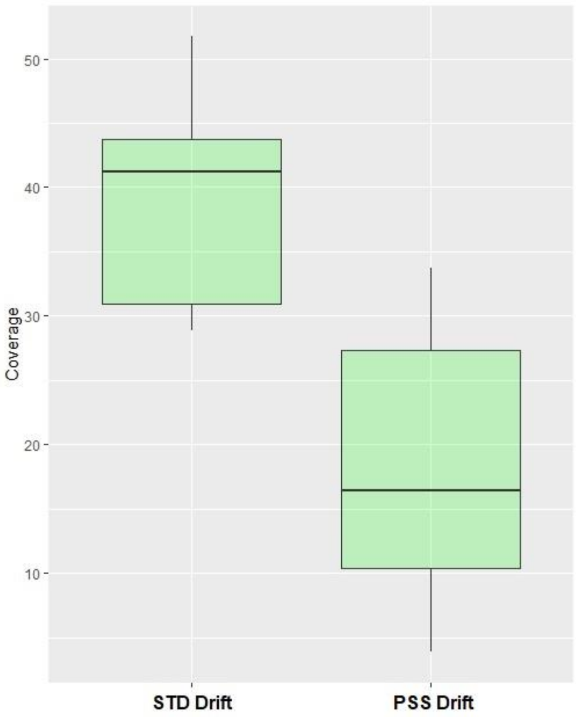

Figure 12: Boxplot of the WSPs coverage used to assess drift on Merlot rows. STD means standard mist blower working set, while PSS means precision spraying system mist blower using lidar sensors.

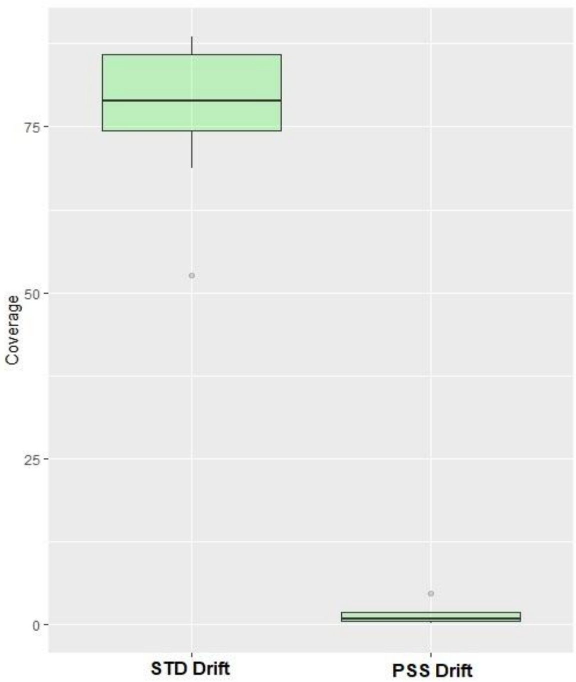

Figure 13: Boxplot of the WSPs coverage used to assess drift on Sauvignon Blanc rows. STD means standard mist blower working set, while PSS means precision spraying system using lidar sensors.

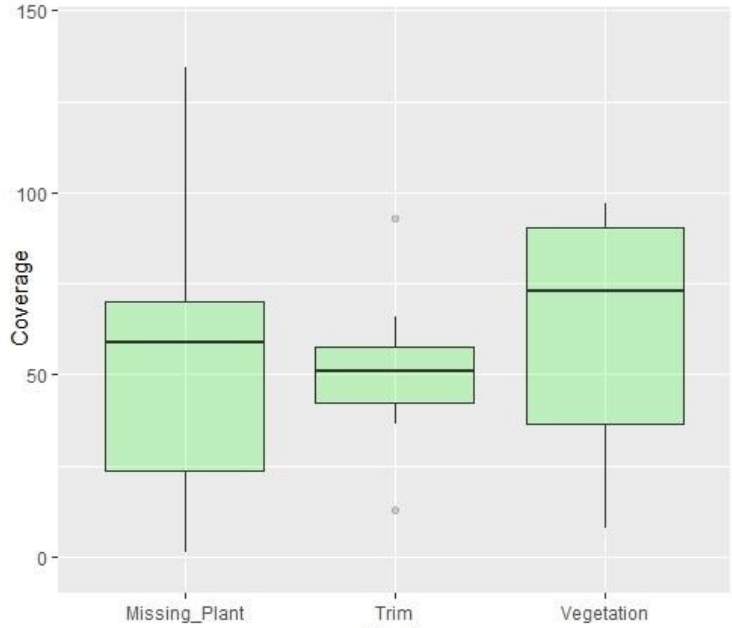

Figure 14: WSPs coverage of Merlot WSPs placed among the vegetation. Missing Plant means paper placed on the border of the gaps; Trim means papers placed in manually trimmed gaps; vegetation means papers placed in continuous canopy hedge.

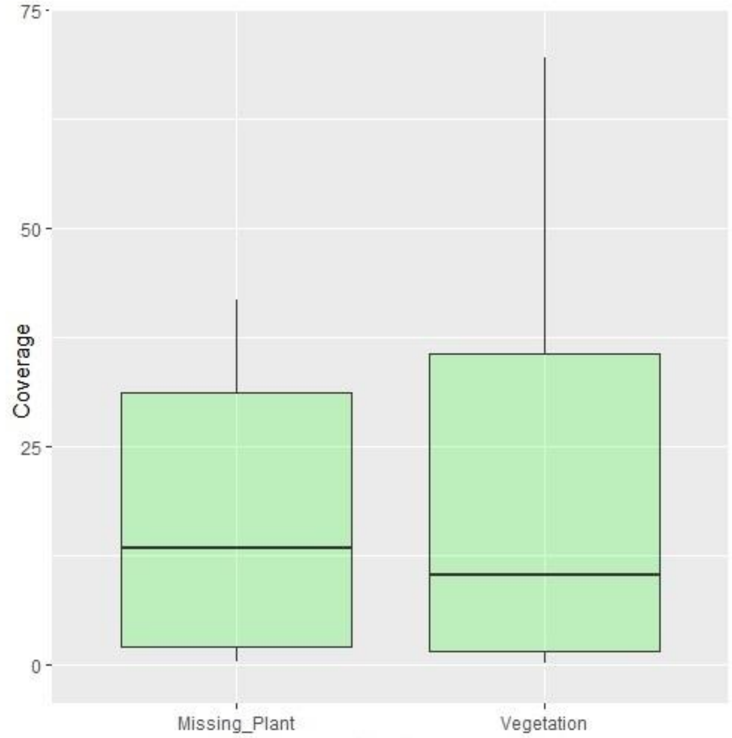

Figure 15: WSP coverage of Sauvignon Blanc WSPs placed among the vegetation. Missing Plant means paper placed on the border of the gap; Vegetation means papers placed in a continuous canopy hedge.

1.8. Conclusion

The precision spraying system (PSS) tested within the project Transfaerm4.0 is an economical, affordable implementation that retrieves interesting results and commercial opportunities. The PSS demonstrated is an accurate tool to detect missing plants and gaps in a continuous vertical hedge such as a vine row or orchard. The main result of the present study is the water volume saved and the creation of a digital twin of the field that supports the improvement of the software without the need to run a test on the field every time.

During the PSS trial, savings reached 60% of water; this means up to 60% of PPPs in each treatment during the growing season could be spared. This reflects an opportunity to reduce the agricultural impact toward a greener Europe. In addition, the innovative spraying system managed to reduce a considerable number of droplets wasted as drift, increasing the treatment efficiency. These two aspects represent important goals aligned with the EU guideline to minimise environmental pollution and agricultural sustainability. Conversely, tractor speed was lower than the standard working speed, but this limitation can be reduced, improving the software and the computing power capacity.