ROBS4CROPS

D6.2 Report on the evaluation protocol

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Abstract:	This deliverable provides the detailed evaluation protocol for the large-scale pilots. It includes Key Performance Indicators (KPIs) derived from measurable metrics (WP1) and a methodology for the timely and efficient evaluation of each LSP and its associated robotic solutions. Moreover, individual evaluation templates and timeplan are provided, as well as information about the composition and envisioned contributions of the LSP Focus Groups.

Document Revision History			
Date	Version	Author/Contributor/ Reviewer	Summary of main changes
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PP	Restricted to other programme participants (including the EC Services)	No
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1 Introduction to the evaluation protocol

Deliverable D6.2, "Report on the evaluation protocol", defines the protocol that will be followed to evaluate the large-scale pilots. The report describes the methodology for assessing the implementation and the results of the experiments in accordance with the piloting plan (D6.1 Pilot Planning). Deliverable D6.2 is based on the individual piloting plans of the following pilots:

a. LSP 1 – France - Vineyard and vegetable mechanical weeding with CEOL Robot (TERRENA);
b. LSP 2 - Greece – CEOL and retrofitted tractor for spraying operations on table grapes (PEGASUS);
c. LSP 3 – Spain – Apple orchards spraying with retrofitted tractor (SERRATER);
d. LSP 4 – The Netherlands – Mechanical weeding with Robotti (SmartAgriTechnology).

For the definition of evaluation criteria and the creation of the evaluation templates, information from deliverable D1.4, "Measurable Metrics", is used. Deliverable D1.4, submitted in M6, describes the agricultural, technical and non-technical metrics that will be considered in the evaluation of the large-scale pilots, and are included in this evaluation protocol. These metrics, as well as additional information included in this deliverable, showcase information provided directly by pilot leader organisations.

This deliverable is to be validated and, if needed, adapted throughout the implementation of the evaluation activities for the large-scale pilots, and the submission of the reporting documents: deliverable D6.3, "Report on evaluating the performance of the robotic systems in real-environmental conditions", in M24, M36, and M48.

In the next sections of this document, the following items are included: evaluation methodology, individual evaluation criteria for large-scale pilots, evaluation report templates, timeplan, information on safety issues and the large-scape pilot focus groups.

2 Evaluating Large-Scale Pilots

2.1 Evaluation methodology

In order to implement an efficient and timely evaluation of the large-scale pilots, it is essential to initially define a plan on the means used (e.g., templates, meetings) and the timing of the actions to be taken (e.g., timing of pilot progress reporting, timing of meetings etc.). For evaluating the four large-scale pilots, WP6 leader (AUA) will utilise face-to-face online meetings and individual report templates. According to deliverable D6.1, "Pilot Planning", each large-scale pilot has a pre-defined timeline on the activities and measurements to be conducted. Based on cornerstone activities and their timing, large-scale pilots will be invited to report on their activities and achievements reached, as well as problems encountered via online meetings with WP6 and reporting, using report templates, which are described in this deliverable. This work will be done in order to assess performance based on evaluation criteria. Moreover, in the criteria, information is given about the validation of the three minimum viable products (MVBs) of the large-scale pilots throughout the three years of implementation. It is crucial to highlight that pilot leaders will have to follow this evaluation protocol document throughout the whole pilot implementation, study their individual KPIs and be able to report on a monthly and annual basis, as described in the sections that follow in this deliverable.

2.2 Evaluation criteria

The evaluation of the large-scale pilots will be conducted based on:

a. agronomic, technical and other non-technical KPIs derived from D1.4, "Measurable metrics", with an additional KPI about social acceptance of the robotic solutions;
b. the expected timeline presented in D6.1, "Pilot Planning";
c. the measurements defined in D6.1, "Pilot Planning", to take place during pilot activities.

In the tables that follow in sections 2.2.1-2.2.4 (Tables 1,2,3,4), the KPIs are presented, including: (a) their relation to measurable metrics derived from WP1, (b) description/analysis of measurement, (c) timing of measurement and (d) target value/goal.

The KPIs have been grouped in three (3) major categories: agronomic, technical (including: Unmanned Ground Vehicle (UGV), Implements, Farming Controller & FMIS) and non-technical (including: safety, labour, ethics, economics, social). Moreover, KPIs have been sub-grouped in the tables, using colour coding to indicate KPIs that have to be measured: (a) at the development phase of the pilot and (b) specific times during the project, several times during crop season or during every task/field operation.

These KPIs are going to be monitored using the evaluation templates provided in section 2.3. To add to this, during the lifespan of the pilots, the expected timelines regarding pilot activities and measurements (D6.1) will be evaluated and, if needed, adapted to the specific needs of each pilot. For this reason, large-scale pilots will be monitored in order to: (a) ensure accordance with the pre-defined timeline, (b) indicate possible changes/adjustments, (c) justify the adjustments, (d) ensure that, despite the possible adjustments, all KPIs will be measured and evaluated. This reporting will also be implemented using the evaluation templates, as well as regular online meetings, e-mail communications etc. Regarding the timing of KPI reporting and timeline monitoring, more information is included in section 2.4 of this document (Evaluation Timeplan).

2.2.1 LSP 1 – France - KPIs

Below, the KPIs for LSP 1 are presented.

Table 1 KPIs for the evaluation of LSP 1[1]

AGRONOMIC KPIs					
KPI	**KPI title**	**Related measurable metric from WP1 (D1.4)**	**Measurement**	**Description**	**Target**
1	Plant damage/ destruction	MET_AGRO_1	Number of damaged or destroyed plants that are not normally expected to be wounded. <u>**Timing**: at least 2 times/year</u>	Throughout the weeding season, analyse one-hectare equivalent of vine by following the UGV on different rows and record the number of damaged or destroyed plants. If a damaged or destroyed plant is detected, record the origin of the damage: cuttings poorly attached to their stakes, not straight row, implements badly adjust (too strong), robotic guidance or other origin.	<3% damage with a good quality of weeding (tool adjusted, and crop management adapt to robotic guidance law)

[1] based on measurable metrics derived from WP1

2	Agronomic performance of the robot	MET_AGRO_3	Agronomic satisfaction of the robotic system work **Timing**: After each field operation	End user or Ecosystem chair feedback with a 1 to 5 scale (very good, good, ok, bad, very bad).	At least feedback between "Ok" to "very good"
TECHNICAL KPIs					
Unmanned Ground Vehicle (UGV)					
3	Size of robot suitable for different crops	MET_TEC_UGV_05 b	Is the size of the robotic system suitable to the crop? **Timing**: At the development phase	Robot should be suitable to all vegetables (Sugar beets, pumpkin, onions, broccoli, lettuce etc.), vineyards and orchards. Record width between the rows of vine and the height where the robotic system cannot pass.	Common row spacing (1,40 cm to 3 m) Crop height and surrounding (pole, net) should match the UGV height.
4	Hardware present and operational	MET_TEC_UGV_17	Hardware is present and works on robot. Is there hardware for data transmission, for GNSS positioning, for mobile connection to the cloud? **Timing**: At the development phase	UGV is equipped with a connectivity system for data transmission, GNSS positioning, mobile connection to the cloud	Yes. Robot can operate successfully. Comment.
5	Electrical, hydraulic and PTO output to the implement	MET_TEC_UGV_20	Hardware is present and works on robot. **Timing**: At the development phase	The robotic platform should provide electrical, hydraulic and PTO output to the implement. Is there hardware to provide electrical, hydraulic and PTO output to the implement?	Robot can operate successfully with the implement.
6	Robotics platform regroups the data to communicate with the user	MET_TEC_UGV_22	GUI communicating information needed. **Timing**: At the development phase	Record all types of messages the robotic platform communicates. Confirmation that hard/software is available and functional.	The robot operator is able to receive the data s/he needs to make decisions and supervise.
7	3-point hitch	MET_TEC_UGV_07	Is the UGV equipped with an equivalent to a 3-point hitch. Does it have a 3-point hitch (ISO730,	Do the implements and UGVs follow the same Cat or standard for the 3-point hitch dimensions and lifting capacity. Record the UGV 3-point hitch dimensions	Yes

			CAT I, II, or III)? **Timing**: At least once during the project (Before weeding season).	Record the 3-point hitch of the implement	
8	AB lines import from GNSS system	MET_TEC_UGV_24	The AB lines are moved from a shape file to the robot management/ planning software. **Timing**: When creating a new path planning	Are AB lines displayed correctly in the robot management software? Ensure that AB lines from commercial systems in use in 2021 can be imported into the robotic system through FMIS and Farming controller interfaces.	No need for AB line setup should be necessary on the field robot itself.
9	Performing in wet clay soil	MET_TEC_UGV_12	Ability to perform a mission with implements in the limits of the robotic systems. **Timing**: After the weeding season - At least once per year	Use the heavier tool of the Large-Scale Pilot (up to 400 kg) and record the level of easiness of the robot to handle it in a wet clay soil (Very Easy - Easy - Suitable - Hard - Very hard)	At least “Suitable” to “Very Easy” assessment.
10	Performing in terrain slopes	MET_TEC_UGV_13	Performing missions within terrain slope without an implement and with a weeder. **Timing**: After field operation – At least once per year	Record the slope max of the terrain. Record slope where the robot cannot pass. Testing the robot in a terrain slope of maximum 10% with a mechanical weeder and a lifted tool that doesn't exceed the defined weight by the UGV manufacturer.	Up to 10%.
11	Obstacle detection	MET_TEC_UGV_03	Detect obstacle and stop before obstacle. Can the robot detect case of emergency? Does the robot avoid collision?	Place a heavy (+40 kg min) container in the middle of the passageway in place of a man: record if the robot detects the obstacle and slow down. Record if the robot avoid collision. If not record if the collision was violent.	The obstacle is detected. Collisions are avoided.

			Timing: In the off season – At least twice per year		
12	Autonomy of the whole robotic system	MET_TEC_UGV_04	The robot should have an autonomy of minimum 8 -10 hours. **Timing**: During a specific test – once a year	Let the robot run in a loop until it stops, and record time during the operation.	Time > 8hours
13	Use of common implements	MET_TEC_UGV_06	Can the robotic system use one type of each current common mechanical weeding implement? Are they simple to attach? **Timing**: Once a year after all field operation	Work with current common mechanical weeding tools for vineyards (vineyards ploughshares and knives, disk harrow, Kress Fingers, rotatory tool mower, ripper) and vegetables (hoeing machine). The UGV can tow vineyards using ploughshares – knives ploughshares – disk harrows – Kress Fingers – rotatory tool mower – ripper. End user and technical chair feedback with a 1 to 5 scale (very good, good, ok, bad, very bad) concerning the easiness to attach those implements	All implements usable. At least feedback between "Ok" to "very good".
14	Teach in	MET_TEC_UGV_25	Precision of teach in and efficiency **Timing**: Once a year after all field operation	Teach in: Driving routes can be taught, including patterns of AB lines and connecting headland turns. Deviation of the teach in. End user feedback with a 1 to 4 scale (Very efficient, Efficient, Not efficient, Unusable)	Deviation < 5cm Feedback at least Efficient
15	Human intervention in robotic work	MET_TEC_UGV_01	Cases where the robotic system cannot work without human assistance **Timing**: During field operations	Record a description of the intervention and the time allocated to it. Record the total time used by the end user for the whole weeding operation. Determine the % of intervention time in relation to total time.	<10% intervention time
16	Farmer competences for using the robot	MET_TEC_UGV_01	Competences required for farm workers, using robotic systems for repetitive work	Record the number of operations consider as harder than driving a tractor and the competences required to achieve them. Record the number of operations consider as easier	>10% easier operations

			Timing: At the end of each weeding season	than driving a tractor and the competences required to achieve them.	
17	Deviation of the trajectory of the towing system.	MET_TEC_UGV_02	Deviation of the trajectory of the towing system. **Timing**: After each operation	Record the time of entry and the time of exit of 3 straight rows of the UGV. Record the speed of the UGV in those rows. Retrieve log of the UGV.	Percentage of deviation from the planned trajectory between 50 and 100 mm: <10%. Percentage of deviation from the planned trajectory above 100 mm: <2%.
18	Capacity of robot and tractor to work under different conditions	MET_TEC_UGV_05	Condition where a robot couldn't work and where a tractor could. **Timing**: After field operation – when it happens	In practice, mechanical weeding or spraying can only be done under certain conditions (weather, state of the soil (e.g., moisture level), and growth stages of both the crop and the weeds), the robot must be able to work at least in those conditions where a tractor could pass. Record all situations where a robot couldn't work and where a tractor could. Define the expected work. Record all operation of the field. Determine the % of operations carried out by a robot.	50% of tractor-based operations are carried out autonomously .
19	Blockage detection and rectification	MET_TEC_UGV_08	Detection of blockage of mechanical tools and the ability to overcome. **Timing**: During field operations - At least twice per weeding season	Intentionally cause a blockage of the tool (with a branch or stuff on field) record if after 1 minute of blockage, the robotic system has done nothing to rectify it. Otherwise, record if it had worked. Record all unintentionally caused blockages. Determine: % of blockages detected % of blockages rectified	> 95% blockages detected > 90% rectified
20	Equipment breakdown. Reliability of the UGV.	MET_TEC_UGV_09	Number and Importance of the breakdown. Ability to repair. **Timing**: All along the process –	Record all breakdown (hardware or software) and record the time needed to repair and if help from the constructor was needed. Record if the issue is documented. Determine: Number and % of small breakdown: less than 1h of	90% of all mechanical breakdowns are documented or can be repaired by a user equipped for mechanical

			when it happens	repairs and no need of help from constructor. Number and % of medium breakdown: less than 2 hours of repairs or help of the constructors Number and % of serious breakdown: more than 2 hours of repairs.	interventions by season. 2 small breakdown max per month. 2 medium breakdown max per season. 2 serious breakdown max per 10 years.
21	UGV works in low temperatures	MET_TEC_UGV_10	UGV Performing a mission in low temperatures **Timing**: During fields operations – for each operation	Record the temperature min of the environment when the robot was used without issues link to temperature.	Be able to work at low temperatures (-5°C).
22	UGV works in high temperatures	MET_TEC_UGV_11	UGV Performing a mission in high temperatures **Timing**: During fields operations – for each operation	Record the temperature min of the environment when the robot was used without issues link to temperature.	Be able to work in high heat (+40°C).
23	Improvement of guidance and U-turn of the UGV	MET_TEC_UGV_14	Areas for improvement of guidance and U-turn of the UGV **Timing**: During fields operations – when it happens	Record any movement that the robot does not do the way the farmer wants. Rate their importance: End user feedback with an 1 to 3 scale (Efficient, Not efficient, Unusable). Determine the number of "Unusable" comments.	Efficient. If not, optimize the path planning and reduce pass overs and soil compaction.
24	Level of system deterioration due to weather	MET_TEC_UGV_16	Does the weather significantly deteriorate the system? **Timing**: During fields operations – when it happens	The robot should be robust with an IP similar to tractors (IP 65-67). Record breakdown caused by the weather. Determine repetitive breakdowns of one component due to weather.	All robotic components are Robust (IP 65-67) or protected to have a similar robustness.
25	Trajectory optimisation/	MET_TEC_UGV_19	Number of pass overs.	Record the number of pass overs during each operation.	< 2 pass overs

	Reduction of pass overs		**Timing**: During fields operations - At least twice per weeding season		
			Implements		
26	Speed of the UGV	MET_TEC_IMP_01	Speed of the UGV. **Timing**: After each field operation	Tow implements that need a speed between 2km/h to 8 km/h. Record speed use for each implement. Record speed expectation for this tool. Record speed instruction (speed set in the path planning instructions). [speed difference for each tool= speed expectation– speed use]	speed difference <1km/h
27	Precise height stabilisation	MET_TEC_IMP_02	Mechanical weeding tool pass depth. **Timing**: During a field operation - At least twice per weeding season	Mechanical weeding: Stabilize implements to a precise height regardless of the terrain. Pause the robot 3 times on different location of the fields and record the tool pass depth in cm. Re do it 10 meters after each pause. Deviation of all the pass depths. Deviation max of two successive path depths.	<1 cm for both deviations
28	Implement communication with robotic platform / activating supply sources	MET_TEC_IMP_08	Consumption of supply sources. **Timing**: During field operation - At least twice per weeding season	Record situations where the robotic system can optimize its consumption (energy or consumable).	Robotic system can optimize its consumption.
			Farming Controller & FMIS		
29	Presentation of geospatial data	MET_TEC_F-C_15	Virtual map of the plot. **Timing**: At the development phase.	Is there a virtual map of the plot?	Presence of a virtual map of the plot usable during the operation for the end-user.
30	Communication protocols between implements and the machinery established	MET_TEC_F-C_08	Is it possible to link implements and machinery such that they work together?	Establish communication protocols in all levels: Use of ISOBUS or TCP/IP or other protocols to enable communication from the FC up to the implement/UGV. Count incidences where help of dealer / manufacturer is required to make the	No incidences.

			<u>**Timing**: Once for each implement.</u>	implement and UGV work with the FC.	
31	Data retrieved from operations are properly displayed and understood	MET_TEC_F-C_06	End-users are able to find and understand the way the data is displayed. <u>**Timing**: One time per year with 5 users each time.</u>	Receive data from sensors: perception information from the field (examples: soil and weather conditions, 3D mapping of the field and the crops, GPS data for the position of the tractor, diesel level sensor, heat of engine sensor, remote supervision, camera data, etc.). Ask end-users a description of the information displayed. Ask them to find specific information (speed, position, progress of the mission etc.)	The farmer is able to find and understand the information that is displayed. The farmer is able to make decisions from the information displayed (ex: if the diesel levels are low, then he can refill, etc.).
32	Autonomous response of the robotic system to unforeseen events.	MET_TEC_F-C_09	Autonomy to respond to unforeseen events. <u>**Timing**: During a field operation – At least once a year.</u>	Place a heavy (+40kg min) container in the middle of the passageway, on a headland, make the FC believe that the wind is rising, that it is starting to rain: in all cases, record the reaction of the robotic system. Determine if the reaction of the robotic system is appropriate (it bypasses the obstacle without damaged plants or skipping work it could do; it stops its operation due to weather issues;) Number of not appropriate reaction.	System responses autonomously and successfully.
33	Input information of each UGV and implement in the FMIS.	MET_TEC_F-C_11	Ability to input information of each UGV and implement in the FMIS. <u>**Timing**: Once for each robot and implement.</u>	Store description of all robots and implements on the farm (include weight, size, working width, fuel autonomy, source of fuel, which connectors are available, etc.) Indicate the ability or non-ability. Define data size.	Yes.
34	Performance assessment visualisation.	MET_TEC_F-C_13	Efficiency of the user interface to visualize as-applied information and performance assessment.	End user feedback with a 1 to 4 scale (Nothing wrong, Efficient, Not efficient, Unusable).	At least “Efficient” to “Nothing wrong”

			Timing: Once a year.		
35	User interface inputs task-related parameters	MET_TEC_F-C_14	Efficiency of the user interface to input task-related parameters. **Timing**: Once a year.	End user feedback with a 1 to 4 scale (Nothing wrong, Efficient, Not efficient, Unusable)	At least "Efficient" to "Nothing wrong"
36	Conditions to be met before execution of tasks	MET_TEC_F-C_01	Ability to input the conditions under which a task is performed into the robotic system. **Timing**: Before starting fields operations - At least once per task	Record if it is possible or not.	Yes, it is possible
37	Resources for the execution of tasks	MET_TEC_F-C_02	Ability to input the resources available or not for each task. **Timing**: Before starting fields operations - At least once per task	Record if it is possible or not.	Yes, it is possible
38	Constraints on when and how tasks should be executed	MET_TEC_F-C_03	Ability to input time constrain for each task and to parameter each task. **Timing**: Before starting fields operations - At least once per task	Record if it is possible or not.	Yes, it is possible
39	Robot's battery notification	MET_TEC_F-C_04	Does the farmer get a notification when the level of fuel is low and before it reaches 0?	Leave less fuel than the mission needs in the tank of the UGV. Start the mission and record, if you are notified, whether you have time to stop the robot before it stops by itself.	>90%

			Timing: Timing: Before starting fields operations - At least once per task	[= Number of times the robot is refilled before it runs out of power / Number of tests of this measure]	
40	Precision of the digital twin of the field	MET_TEC_F-C_05	Reality of the copy. **Timing**: Before starting weeding season and after weeding season. At least twice per year	Have a digital copy of the field in a virtual environment alongside with the CAD files of the used resources. This digital copy should be precise. End user feedback with a 1 to 5 scale (Exactly the same, strong likeness, similar, some defect, not a copy)	At least "Similar" to "exactly the same"
41	FMIS provides information about the needs of the crops	MET_TEC_F-C_07	Communication between the FC and the FMIS. **Timing**: Before starting a field operation - At least twice per weeding season.	Change a parameter in the FMIS and record if it was changed in the FC.	Communication between the FC and the FMIS is achieved.
42	Input task information in the FMIS.	MET_TEC_F-C_10	Ability to input information on each task in the FMIS. **Timing**: Once a year - At least twice per weeding season.	Store all field operations with related information (e.g., technical, financial, etc.) Indicate if it is possible or not to do it.	Yes.
43	End-user's ability to intervene	MET_TEC_F-C_16	Can the end-user intervene at any time during an operation if the circumstances so require? **Timing**: All along the process - At least twice per weeding season.	Record case where the end user cannot intervene and what s/he would have done.	No cases occur.
44	Ability to pause and resume tasks.	MET_TEC_F-C_17	Can the operation be paused and resumed?	Record if the robotic system can be paused during its operation. Record if it can be resumed. Record the easiness	Both possible. At least "ok" to "very easy".

			Timing: Before starting the weeding season.	of this process: End user feedback of their control of the robotic system with a 1 to 5 scale (very easy, easy, ok, difficult very difficult).	
NON-TECHNICAL KPIs					
Safety					
45	Data security	MET_N-TEC_saf_03	Ensure that data cannot be improperly accessed or modified). **Timing**: Once a year.	Use an expert, like a data integrity expert, cloud security expert from one of the institutes to perform an integrity test (From the land survey to the robotic mission and data record by the robotic system in the field).	99% uptime guaranteed of the robot.
46	Compliance with Machine directive and the EU legislations	MET_N-TEC_saf_04	Check the list of standards and regulations collected in WP1 are compliant with the robotic system. **Timing**: Once a year.	Send list to robot supplier for verification that the standards are harmonized. Number of standards company is in compliance/not in compliance.	Robotic companies are in compliance with the required standards so the product can be CE marked.
47	Injuries and danger created by the robot	MET_N-TEC_saf_01	Injuries to human or dangerous situation created by the robotic system. **Timing**: All along the process – when it happens.	Record the number of injuries suffer by a human and the number of injured humans. Record the number of dangerous situation (users perspective when/if they have felt that the robot was unsafe or if the robot would hurt them) and their level (Minor= No consequences, Significant = Minor injuries / Minor damages of other equipment / Minor damage of public or private property / Temporary damage to environment, Critical = Temporary disability without death threat / Temporary professional disease / Serious injure / Loss or damaged of the robotic system / Loss or big damage of public or private property / Long term damaged to the environment , Catastrophic = Death / Death threat / Permanent disability / Professional diseases). $Injures = number\ of\ injures \times number\ of\ human\ injured$	Injures ≤2/season Danger ≤ 2

				$Danger = number\ of\ dangerous\ situation \times level\ of\ the\ situation\ (1\ for\ minor - 2\ for\ significant - 3\ for\ Critical - 4\ for\ Catastrophic)$	
48	Compliance with local law and regulation	MET_N-TEC_saf_02	Cases where the robotic system do not comply with the local law and regulation. **Timing**: All along the process – when it happens.	Record case where the robotic system does not comply with the local law and regulation. Number of cases.	Zero cases.
49	Possibility to monitor implement and robot's functions	MET_N-TEC_saf_05	Can the final user monitor parameters that drives the implement and the robot's functioning as a tractor driver can? **Timing**: All along the process - At least twice each year	Determine if the final user can monitor parameters of the robotic system as a tractor driver can. Indicate number of parameters not monitored.	Able to monitor: UGV: Speed, chaining of row, height of the implement etc. Implement: height of the implement, adjustment etc.
			Labour		
50	Ability to keep inventory of farm inputs	MET_N-TEC_lab_06	Is the FMIS well construct to keep the inventory of goods? **Timing**: Once a year	End user feedback with a 1 to 4 scale (Nothing wrong, Efficient, Not efficient, Unusable)	At least "Efficient" to "Nothing wrong"
51	Capacity of the end-user to manage the robotic system	MET_N-TEC_lab_01	Capacity of an end-user to control the robotic system with only a user's manual and a training. **Timing**: At least once per season.	End user feedback of their control of the robotic system with a 1 to 5 scale (very easy, easy, ok, difficult very difficult) and assessment by an experienced user of this control (with the same 1 to 5 scale).	End user feedback at least "ok" to "very easy" Experienced user assessment at least "ok" to "very easy"
52	Open road transport of the robotic system	MET_N-TEC_lab_03	Can the robotic system (UGV + Tools) be load	Record if no. If yes, evaluate the maneuverability of your route (Easy - Ok - Hard).	All Yes. Easy to Ok assessment

			on a trailer or within a van? **Timing**: At least once per season		
53	Use of conventional tools	MET_N-TEC_lab_04	The hardware can be maintained with conventional tools that the farmer uses. **Timing**: All along the process – At each maintenance	Indicate the tool needed to maintain the robot or the implement	No unconventional tool is needed.
54	Feasibility of the workplan	MET_N-TEC_lab_05	Measure the feasibility of the workplan. **Timing**: At least once per season	End user feedback with a 1 to 5 scale (Perfect, Feasible easily, not that simple but feasible, Need few changes, Impossible)	At least "not that simple but feasible" to "Perfect".
Ethics					
55	Additional health risk and/or need for additional insurance for the farmer	MET_N-TEC_Eth_03	• Is there is a need for an additional insurance? • Risk to user's health and difficulty of work. • Time invested in discussions with insurance companies. **Timing**: Before starting the field operations – when discussing with insurance companies. After each season.	The system should not invalidate the health insurance of the people using it (high-risk sports such as sky diving require additional insurance - we don't want this for the R4C robotic system). • Is an additional insurance necessary? • Record time invested in discussions with insurance companies. • Record for each conventional and autonomous system: - Amounts and type of pesticides and herbicides used. - Number of operations that may cause human exposure to pesticides - Number of operations that have a lower health risk - Number of operations that have a higher health risk - Time of exposure: • To pesticides • To tractor vibration (with a conventional system) - Hours of physical work (with both conventional and autonomous system)	The use of the robot doesn't recommend a supplementary health insurance.

56	Liability insurance of the testing property	MET_N-TEC_Eth_04	Presence of a health insurance of the operator Time invested from the end user to convince the insurance company. <u>**Timing**: Before starting the field operations - when discussing with insurance companies.</u>	The system should not invalidate the liability insurance of the property on which the R4C robotic system is used. Indicate presence/absence of health insurance.	The use of the robot doesn't recommend a supplementary health insurance.
57	Farmer's understanding	MET_N-TEC_Eth_01	Possibility to follow the FC decision. <u>**Timing**: Before starting a field operation - At least twice per season</u>	Farmer should be able to understand the decisions made by the system. Record if it is possible and understandable or not.	Yes, the farmer is able.
58	Farmer's ability to intervene in the decision making	MET_N-TEC_Eth_02	Ability to manually modified each decision of the FC. <u>**Timing**: Before starting a field operation - At least twice per season</u>	Farmer should be able to intervene in the decisions made by the system when needed. Record if it is possible or not.	Yes, the farmer is able.
Economics					
59	Cost-effectiveness of the robotic system	MET_N-TEC_eco_01	User time to prepare the robotic system and all economic aspects. <u>**Timing**:</u> • Regional data: Year 2. • All other metrics: Once each year - <u>Validation of the minimum viable product</u>.	<u>**For both conventional and autonomous system**</u>: • Time between starting the motor and the implement coupling to the robot. • Time between attaching the implements to the robot and the robot is attached on the transport • Time from the moment the transport arrived at the field to the moment when the transport leaves with the robot • Cost of the Land Survey	Be cost effective.

				• How many field operations are necessary to have a clean plot? • Fuel consumption per hectare • Quantity of pesticide and herbicides used • Type of pesticide and herbicides used • Yield • Cost of: - Herbicide – Fertilizer - Plant protection products - Fuel – Harvest • Fixed costs • Investments • Lifetime of investments • Current interest rate • Number of operations • Total spending per hectare with robotic system • Total spending per hectare with conventional system • Number of hectares that the robotic system can handle • Number of hectares of the farm **Data about the region**: • Total Area (ha) • Geographical relevance and boundaries (e.g., Covered by cooperatives, local region, catchment) • Number of farms within the area, type of farmland (soil type), crops produced, farm sizes and structure, employees • Number of citizens • Data of ~100 Farmer: education, age, farm size and type of farm and crops produced, questions about farmers perception of various autonomous systems, needs, barriers, technical problems, speed, risk, skills, convenience • Assess the number of jobs that could be created in relation to Agri-and IT business **Analysis**: • Time of the end user allocated for the task (weeding or spraying) • Cost per hectare of the task	
Social					

60	Social acceptance	-	Measure the social acceptance of the proposed robotic solution. **Timing**: Once at the end of each year - Validation of the minimum viable product.	End-user feedback. The robotic solution is: Not acceptable (no useful outcome, easiness to use, or benefit) – Acceptable (some benefit) - Highly acceptable (end-user identifies high benefit from the use of the robot)	Acceptable or highly acceptable.

2.2.2 LSP 2 - Greece - KPIs

Below, the KPIs for LSP 2 are presented.

Table 2 KPIs for the evaluation of LSP 2

AGRONOMIC KPIs					
KPI	**KPI title**	**Related measurable metric from WP1 (D1.4)**	**Measurement**	**Description**	**Target**
1	Plant damage/ destruction	MET_AGRO_1	Number of damaged or destroyed plants that are not predisposed to be wounded. **Timing**: at least 2 times/year	Throughout the spraying season, analyse one-hectare equivalent of vine by following the UGV on different rows and record the number of damaged plants (broken cane, bunch of grapes damaged or destroyed) or destroyed plants (trunk cleaved or uprooted). If a damaged or destroyed plant is detected, record the origin of the damage: cuttings poorly attached to their stakes, not straight row, implements badly adjust (too strong), robotic guidance or other origin. Crop damage % and crop destruction % related to: -crop management (=cuttings poorly attached to their stakes and not straight row), -UGV guidance law, - Implement adjustment, - Other issues.	<10% in total (robotic system or other reason)
2	Agronomic performance of the robot	MET_AGRO_3	Agronomic satisfaction of the robotic system work **Timing**: After each field operation	End user or Ecosystem chair feedback with a 1 to 5 scale (very good, good, ok, bad, very bad).	At least feedback between "Ok" to "very good"
TECHNICAL KPIs					
Unmanned Ground Vehicle (UGV)					

3	Size of robot suitable for different crops	MET_TEC_UGV_05 b	Is the size of the robotic system suitable to the crop? **Timing**: At the development phase	Robot should be suitable to all vegetables (Sugar beets, pumpkin, onions, broccoli, lettuce etc.), vineyards and orchards. Record width between the rows of vine and the height where the robotic system cannot pass.	Common row spacing (1,40 cm to 3 m) Crop height and surrounding (pole, net) should match the UGV height.
4	Hardware present and operational	MET_TEC_UGV_17	Hardware is present and works on robot. Is there hardware for data transmission, for GNSS positioning, for mobile connection to the cloud? **Timing**: At the development phase	UGV is equipped with a connectivity system for data transmission, GNSS positioning, mobile connection to the cloud	Yes. Robot can operate successfully. Comment.
5	Electrical, hydraulic and PTO output to the implement	MET_TEC_UGV_20	Hardware is present and works on robot. **Timing**: At the development phase	The robotic platform should provide electrical, hydraulic and PTO output to the implement. Is there hardware to provide electrical, hydraulic and PTO output to the implement?	Robot can operate successfully with the implement.
6	Robotics platform regroups the data to communicate with the user	MET_TEC_UGV_22	GUI communicating information needed. **Timing**: At the development phase	Record all types of messages the robotic platform communicates. Confirmation that hard/software is available and functional.	The robot operator is able to receive the data s/he needs to make decisions and supervise.
7	3-point hitch	MET_TEC_UGV_07	Is the UGV equipped with an equivalent to a 3-point hitch. Does it have a 3-point hitch (ISO730, CAT I, II, or III)? **Timing**: At least once during the project (Before treatment season).	Do the implements and UGVs follow the same Cat or standard for the 3-point hitch dimensions and lifting capacity. Record the UGV 3-point hitch dimensions Record the 3-point hitch of the implement	Yes

8	AB lines import from GNSS system	MET_TEC_UGV_24	The AB lines are moved from a shape file to the robot management/ planning software. **Timing**: When creating a new path planning	Are AB lines displayed correctly in the robot management software? Ensure that AB lines from commercial systems in use in 2021 can be imported into the robotic system through FMIS and Farming controller interfaces.	No need for AB line setup should be necessary on the field robot itself.
9	Performing in wet clay soil	MET_TEC_UGV_12	Ability to perform a mission with implements in the limits of the robotic systems. **Timing**: After the weeding season - At least once per year	Use the heavier tool of the Large-Scale Pilot (up to 400 kg) and record the level of easiness of the robot to handle it in a wet clay soil (Very Easy - Easy - Suitable - Hard - Very hard)	At least ”Suitable” to ”Very Easy” assessment.
10	Autonomy of the whole robotic system	MET_TEC_UGV_04	The robot should have an autonomy of minimum 8 -10 hours. **Timing**: During a specific test – once a year	Let the robot run in a loop until it stops, and record time during the operation.	Time > 8hours
11	Teach in	MET_TEC_UGV_25	Precision of teach in and efficiency **Timing**: Once a year after all field operation	Teach in: Driving routes can be taught, including patterns of AB lines and connecting headland turns. Deviation of the teach in. End user feedback with a 1 to 4 scale (Very efficient, Efficient, Not efficient, Unusable)	Deviation < 5cm Feedback at least Efficient
12	Human intervention in robotic work	MET_TEC_UGV_01	Cases where the robotic system cannot work without human assistance **Timing**: During field operations	Record a description of the intervention and the time allocated to it. Record the total time used by the end user for the whole weeding operation. Determine the % of intervention time in relation to total time.	<10% intervention time
13	Farmer competences for using the robot	MET_TEC_UGV_01	Competences required for farm workers, using robotic systems for	Record the number of operations consider as harder than driving a tractor and the competences required to achieve them.	>10% easier operations

			repetitive work **Timing**: At the end of each spraying season	Record the number of operations consider as easier than driving a tractor and the competences required to achieve them.	
14	Deviation of the trajectory of the towing system.	MET_TEC_UGV_02	Deviation of the trajectory of the towing system. **Timing**: After each operation	Record the time of entry and the time of exit of 3 straight rows of the UGV. Record the speed of the UGV in those rows. Retrieve log of the UGV.	Percentage of deviation from the planned trajectory between 50 and 100 mm: <10% Percentage of deviation from the planned trajectory above 100 mm: <2%
15	Capacity of robot and tractor to work under different conditions	MET_TEC_UGV_05	Condition where a robot couldn't work and where a tractor could. **Timing**: After field operation – when it happens	In practice, mechanical weeding or spraying can only be done under certain conditions (weather, state of the soil (e.g., moisture level), and growth stages of both the crop and the weeds), the robot must be able to work at least in those conditions where a tractor could pass. Record all situations where a robot couldn't work and where a tractor could. Define the expected work. Record all operation of the field. Determine the % of operations carried out by a robot.	50% of tractor-based operations are carried out autonomously
16	Equipment breakdown. Reliability of the UGV.	MET_TEC_UGV_09	Number and Importance of the breakdown. Ability to repair. **Timing**: All along the process – when it happens	Record all breakdown (hardware or software) and record the time needed to repair and if help from the constructor was needed. Record if the issue is documented. Determine: Number and % of small breakdown: less than 1h of repairs and no need of help from constructor. Number and % of medium breakdown: less than 2 hours of repairs or help of the constructors Number and % of serious breakdown: more than 2 hours of repairs.	90% of all mechanical breakdowns are documented or can be repaired by a user equipped for mechanical interventions by season. 2 small breakdown max per month. 2 medium breakdown max per season.

					2 serious breakdown max per 10 years.
17	UGV works in low temperatures	MET_TEC_UGV_10	UGV Performing a mission in low temperatures **Timing**: During fields operations – for each operation	Record the temperature min of the environment when the robot was used without issues link to temperature.	Be able to work at low temperatures (-5°C).
18	UGV works in high temperatures	MET_TEC_UGV_11	UGV Performing a mission in high temperatures **Timing**: During fields operations – for each operation	Record the temperature min of the environment when the robot was used without issues link to temperature.	Be able to work in high heat (+40°C).
19	Improvement of guidance and U-turn of the UGV	MET_TEC_UGV_14	Areas for improvement of guidance and U-turn of the UGV **Timing**: During fields operations – when it happens	Record any movement that the robot does not do the way the farmer wants. Rate their importance: End user feedback with an 1 to 3 scale (Efficient, Not efficient, Unusable). Determine the number of ”Unusable” comments.	Efficient. If not, optimize the path planning and reduce pass overs and soil compaction.
20	Level of system deterioration due to weather	MET_TEC_UGV_16	Does the weather significantly deteriorate the system? **Timing**: During fields operations – when it happens	The robot should be robust with an IP similar to tractors (IP 65-67). Record breakdown caused by the weather. Determine repetitive breakdowns of one component due to weather.	All robotic components are Robust (IP 65-67) or protected to have a similar robustness.
21	Trajectory optimisation/ Reduction of pass overs	MET_TEC_UGV_19	Number of pass overs. **Timing**: During fields operations - At least twice per spraying season	Record the number of pass overs during each operation.	< 2 pass overs
22	Correct calculation of the tank reserve	MET_TEC_UGV_21	Correct calculation of the tank reserve.	Does the Robotic system detect an empty tank during an operation? Is the tank empty?	Yes

			Timing: During fields operations - At least twice per spraying season		
Implements					
23	Implement's ISOBUS compatibility	MET_TEC_IMP_06	Is the Communication between ECUs (Electronics Control Unit) of vehicle and implement defined? **Timing**: At the development phase	CAN bus/ISOBUS compatibility.	ISOBUS based communication within the implement-vehicle combination operate successfully.
24	Speed of the UGV	MET_TEC_IMP_01	Speed of the UGV. **Timing**: After each field operation	Tow implements that need a speed between 2km/h to 8 km/h. Record speed use for each implement. Record speed expectation for this tool. Record speed instruction (speed set in the path planning instructions). [speed difference for each tool= speed expectation– speed use]	speed difference <1km/h
25	Spraying coverage	MET_TEC_IMP_03	Is spraying homogeneous in all the canopy? **Timing**: Before and After each field operation - At least twice per season	Place papers above 3 leaves, under 3 leaves, 3 in the alley, 3 in a row, 3 just out of the field. Spray with the robot. Check and record which paper are wet which are not. $= Number\ of\ paper\ of\ one\ type\ wet\ /\ Total\ number\ of\ papers$	Above leaves: 100% Under leaves: 80%? In the alley: <5% Out of the field: 0%
26	Detection of nozzle obstruction	MET_TEC_IMP_04	Record of nozzle obstruction. **Timing**: After each field operation – when it happens	Record each nozzle obstruction. Record if the robotic system has detected it or not. Determine the % of not detected nozzle obstruction.	95% of nozzle obstruction detected.
27	Automated cleaning and maintenance	MET_TEC_IMP_05	Is the tank well cleaned? Is the maintenance of the sprayer enough?	End user and technician feedback with a 1 to 5 scale (very good, good, ok, bad, very bad)	≤2

			Timing: After spraying operations - At least twice per season		
28	Implement communication with robotic platform / activating supply sources	MET_TEC_IMP_08	Consumption of supply sources. **Timing**: During field operation - At least twice per season	Record situations where the robotic system can optimize its consumption (energy or consumable).	Robotic system can optimize its consumption.
29	Production of ISOXML files to be sent to the FMIS	MET_TEC_IMP_10	Recording the as-applied information of field application and producing ISOXML file available on the ISOBUS terminal. **Timing**: During each field application	Acquisition of as-applied amount (Sprayer) together with geo-location of applied points.	To represent the behaviour of the implements during field application.
30	Full load tank autonomy	MET_TEC_IMP_11	Full load a tank. Record the time taken for it to empty during autonomous operations. **Timing**: During a spraying operation - At least twice per weeding season	The user can fill the tank of the sprayer during a mission to a full-load tank autonomy of 60 min.	Autonomy of 60 min minimum
Farming Controller & FMIS					
31	Presentation of geospatial data	MET_TEC_F-C_15	Virtual map of the plot. **Timing**: At the development phase.	Is there a virtual map of the plot?	Presence of a virtual map of the plot usable during the operation for the end-user.
32	Communication protocols between implements and the machinery established	MET_TEC_F-C_08	Is it possible to link implements and machinery such that they	Establish communication protocols in all levels: Use of ISOBUS or TCP/IP or other protocols to enable communication from the FC up to the implement/UGV.	No incidences.

			work together? **Timing**: Once for each implement.	Count incidences where help of dealer / manufacturer is required to make the implement and UGV work with the FC.	
33	Data retrieved from operations are properly displayed and understood	MET_TEC_F-C_06	End-users are able to find and understand the way the data is displayed. **Timing**: One time per year with 5 users each time.	Receive data from sensors: perception information from the field (examples: soil and weather conditions, 3D mapping of the field and the crops, GPS data for the position of the tractor, diesel level sensor, heat of engine sensor, remote supervision, camera data, etc.). Ask end-users a description of the information displayed. Ask them to find specific information (speed, position, progress of the mission etc.)	The farmer is able to find and understand the information that is displayed. The farmer is able to make decisions from the information displayed (ex: if the diesel levels are low, then he can refill, etc.).
34	Input information of each UGV and implement in the FMIS.	MET_TEC_F-C_11	Ability to input information of each UGV and implement in the FMIS. **Timing**: Once for each robot and implement.	Store description of all robots and implements on the farm (include weight, size, working width, fuel autonomy, source of fuel, which connectors are available, etc.) Indicate the ability or non-ability. Define data size.	Yes.
35	Prescription map for field operation	MET_TEC_F-C_12	Is the FMIS well construct to create a prescription map for field operation? **Timing**: Once a year.	End user feedback with a 1 to 4 scale (Nothing wrong, Efficient, Not efficient, Unusable)	At least “Efficient” to “Nothing wrong”,
36	Performance assessment visualisation.	MET_TEC_F-C_13	Efficiency of the user interface to visualize as-applied information and performance assessment. **Timing**: Once a year.	End user feedback with a 1 to 4 scale (Nothing wrong, Efficient, Not efficient, Unusable).	At least “Efficient” to “Nothing wrong”
37	User interface inputs task-related parameters	MET_TEC_F-C_14	Efficiency of the user interface to input task-	End user feedback with a 1 to 4 scale (Nothing wrong, Efficient, Not efficient, Unusable)	At least “Efficient” to “Nothing wrong”

			related parameters. **Timing**: Once a year.		
38	Conditions to be met before execution of tasks	MET_TEC_F-C_01	Ability to input the conditions under which a task is performed into the robotic system. **Timing**: Before starting fields operations - At least once per task	Record if it is possible or not.	Yes, it is possible
39	Resources for the execution of tasks	MET_TEC_F-C_02	Ability to input the resources available or not for each task. **Timing**: Before starting fields operations - At least once per task	Record if it is possible or not.	Yes, it is possible
40	Constraints on when and how tasks should be executed	MET_TEC_F-C_03	Ability to input time constrain for each task and to parameter each task. **Timing**: Before starting fields operations - At least once per task	Record if it is possible or not.	Yes, it is possible
41	Robot's battery notification	MET_TEC_F-C_04	Does the farmer get a notification when the level of fuel is low and before it reaches 0? **Timing**: During a field operation - At least twice per weeding season	Leave less fuel than the mission needs in the tank of the UGV. Start the mission and record, if you are notified, whether you have time to stop the robot before it stops by itself. [= Number of times the robot is refilled before it runs out of power / Number of tests of this measure]	>90%

42	Precision of the digital twin of the field	MET_TEC_F-C_05	Reality of the copy. **Timing**: Before starting and after spraying season. At least twice per year	Have a digital copy of the field in a virtual environment alongside with the CAD files of the used resources. This digital copy should be precise. End user feedback with a 1 to 5 scale (Exactly the same, strong likeness, similar, some defect, not a copy)	At least "Similar" to "exactly the same"
43	FMIS provides information about the needs of the crops	MET_TEC_F-C_07	Communication between the FC and the FMIS. **Timing**: Before starting a field operation - At least twice per season.	Change a parameter in the FMIS and record if it was changed in the FC.	Communication between the FC and the FMIS is achieved.
44	Input task information in the FMIS.	MET_TEC_F-C_10	Ability to input information on each task in the FMIS. **Timing**: Once a year - At least twice per season.	Store all field operations with related information (e.g., technical, financial, etc.) Indicate if it is possible or not to do it.	Yes.
45	End-user's ability to intervene	MET_TEC_F-C_16	Can the end-user intervene at any time during an operation if the circumstances so require? **Timing**: All along the process - At least twice per season.	Record case where the end user cannot intervene and what s/he would have done.	No cases occur.
46	Ability to pause and resume tasks.	MET_TEC_F-C_17	Can the operation be paused and resumed? **Timing**: Before starting the season.	Record if the robotic system can be paused during its operation. Record if it can be resumed. Record the easiness of this process: End user feedback of their control of the robotic system with a 1 to 5 scale (very easy, easy, ok, difficult very difficult).	Both possible. At least "ok" to "very easy".
NON-TECHNICAL KPIs					
Safety					
47	Data security	MET_N-TEC_saf_03	Ensure that data cannot be improperly	Use an expert, like a data integrity expert, cloud security expert from one of the institutes to perform an	99% uptime guaranteed of the robot.

			accessed or modified). **Timing**: Once a year.	integrity test (From the land survey to the robotic mission and data record by the robotic system in the field).	
48	Compliance with Machine directive and the EU legislations	MET_N-TEC_saf_04	Check the list of standards and regulations collected in WP1 are compliant with the robotic system. **Timing**: Once a year.	Send list to robot supplier for verification that the standards are harmonized. Number of standards company is in compliance/not in compliance.	Robotic companies are in compliance with the required standards so the product can be CE marked.
49	Injuries and danger created by the robot	MET_N-TEC_saf_01	Injuries to human or dangerous situation created by the robotic system. **Timing**: All along the process – when it happens.	Record the number of injuries suffer by a human and the number of injured humans. Record the number of dangerous situation (users perspective when/if they have felt that the robot was unsafe or if the robot would hurt them) and their level (Minor= No consequences, Significant = Minor injuries / Minor damages of other equipment / Minor damage of public or private property / Temporary damage to environment, Critical = Temporary disability without death threat / Temporary professional disease / Serious injure / Loss or damaged of the robotic system / Loss or big damage of public or private property / Long term damaged to the environment , Catastrophic = Death / Death threat / Permanent disability / Professional diseases). $Injures = number\ of\ injures \times number\ of\ human\ injured$ $Danger = number\ of\ dangerous\ situation \times level\ of\ the\ situation\ (1\ for\ minor - 2\ for\ significant - 3\ for\ Critical - 4\ for\ Catastrophic)$	Injures ≤2/season Danger ≤ 2
50	Compliance with local law and regulation	MET_N-TEC_saf_02	Cases where the robotic system do not comply with the local law	Record case where the robotic system does not comply with the local law and regulation. Number of cases.	Zero cases.

			and regulation. **Timing**: All along the process – when it happens.		
Labour					
51	Ability to keep inventory of farm inputs	MET_N-TEC_lab_06	Is the FMIS well construct to keep the inventory of goods? **Timing**: Once a year	End user feedback with a 1 to 4 scale (Nothing wrong, Efficient, Not efficient, Unusable)	At least "Efficient" to "Nothing wrong"
52	Capacity of the end-user to manage the robotic system	MET_N-TEC_lab_01	Capacity of an end-user to control the robotic system with only a user's manual and a training. **Timing**: At least once per season.	End user feedback of their control of the robotic system with a 1 to 5 scale (very easy, easy, ok, difficult very difficult) and assessment by an experienced user of this control (with the same 1 to 5 scale).	End user feedback at least "ok" to "very easy" Experienced user assessment at least "ok" to "very easy"
53	Launching a mission in field	MET_N-TEC_lab_02	Time needed to launch a mission in field. **Timing**: Before starting a field operation – when it happens At least once per season.	Operational treatment: the robot and the spraying system should be quick to install and start spraying in cases of emergency spraying and in the available opportunity windows. • Record time between starting the motor and the implement coupling to the robot. • Record time between attaching the implements to the robot and the robot is attached on the transport. • Record time from the moment the transport arrived at the field to the moment the robot starts its mission. Sum of each time.	<31minutes
54	Open road transport of the robotic system	MET_N-TEC_lab_03	Can the robotic system (UGV + Tools) be load on a trailer or within a van? **Timing**: At least once per season	Record if no. If yes, evaluate the maneuverability of your route (Easy - Ok - Hard).	All Yes. Easy to Ok assessment
55	Use of conventional tools	MET_N-TEC_lab_04	The hardware can be maintained	Indicate the tool needed to maintain the robot or the implement	No unconvention

			with conventional tools that the farmer uses. **Timing**: All along the process – At each maintenance		al tool is needed.
56	Feasibility of the workplan	MET_N-TEC_lab_05	Measure the feasibility of the workplan. **Timing**: At least once per season	End user feedback with a 1 to 5 scale (Perfect, Feasible easily, not that simple but feasible, Need few changes, Impossible)	At least "not that simple but feasible" to "Perfect".
Ethics					
57	Additional health risk and/or need for additional insurance for the farmer	MET_N-TEC_Eth_03	• Is there is a need for an additional insurance? • Risk to user's health and difficulty of work. • Time invested in discussions with insurance companies. **Timing**: Before starting the field operations – when discussing with insurance companies. After each season.	The system should not invalidate the health insurance of the people using it (high-risk sports such as sky diving require additional insurance - we don't want this for the R4C robotic system). • Is an additional insurance necessary? • Record time invested in discussions with insurance companies. • Record for each conventional and autonomous system: - Amounts and type of pesticides and herbicides used. - Number of operations that may cause human exposure to pesticides - Number of operations that have a lower health risk - Number of operations that have a higher health risk - Time of exposure: • To pesticides • To tractor vibration (with a conventional system) - Hours of physical work (with both conventional and autonomous system)	The use of the robot doesn't recommend a supplementary health insurance.
58	Liability insurance of the testing property	MET_N-TEC_Eth_04	Presence of a health insurance of the operator Time invested from the end user to convince the	The system should not invalidate the liability insurance of the property on which the R4C robotic system is used. Indicate presence/absence of health insurance.	The use of the robot doesn't recommend a supplementary health insurance.

			insurance company. **Timing**: Before starting the field operations - when discussing with insurance companies.		
59	Farmer's understanding	MET_N-TEC_Eth_01	Possibility to follow the FC decision. **Timing**: Before starting a field operation - At least twice per season	Farmer should be able to understand the decisions made by the system. Record if it is possible and understandable or not.	Yes, the farmer is able.
60	Farmer's ability to intervene in the decision making	MET_N-TEC_Eth_02	Ability to manually modified each decision of the FC. **Timing**: Before starting a field operation - At least twice per season	Farmer should be able to intervene in the decisions made by the system when needed. Record if it is possible or not.	Yes, the farmer is able.
Economics					
61	Cost-effectiveness of the robotic system	MET_N-TEC_eco_01	User time to prepare the robotic system and all economic aspects. **Timing**: • Regional data: Year 2. • All other metrics: Once each year - Validation of the minimum viable product.	**For both conventional and autonomous system**: • Time between starting the motor and the implement coupling to the robot. • Time between attaching the implements to the robot and the robot is attached on the transport • Time from the moment the transport arrived at the field to the moment when the transport leaves with the robot • Cost of the Land Survey • How many field operations are necessary to have a clean plot? • Fuel consumption per hectare • Quantity of pesticide and herbicides used • Type of pesticide and herbicides used • Yield	Be cost effective.

				• Cost of: - Herbicide – Fertilizer - Plant protection products - Fuel – Harvest • Fixed costs • Investments • Lifetime of investments • Current interest rate • Number of operations • Total spending per hectare with robotic system • Total spending per hectare with conventional system • Number of hectares that the robotic system can handle • Number of hectares of the farm **Data about the region**: • Total Area (ha) • Geographical relevance and boundaries (e.g., Covered by cooperatives, local region, catchment) • Number of farms within the area, type of farmland (soil type), crops produced, farm sizes and structure, employees • Number of citizens • Data of ~100 Farmer: education, age, farm size and type of farm and crops produced, questions about farmers perception of various autonomous systems, needs, barriers, technical problems, speed, risk, skills, convenience • Assess the number of jobs that could be created in relation to Agri-and IT business **Analysis**: • Time of the end user allocated for the task (weeding or spraying) • Cost per hectare of the task	
Social					
62	Social acceptance	-	Measure the social acceptance of the proposed robotic solution. **Timing**: Once at the end of each year - Validation of	End-user feedback. The robotic solution is: Not acceptable (no useful outcome, easiness to use, or benefit) – Acceptable (some benefit) - Highly acceptable (end-user identifies high benefit from the use of the robot)	Acceptable or highly acceptable.

			the minimum viable product.		

2.2.3 LSP 3 – Spain - KPIs

Below, the KPIs for LSP 3 are presented.

Table 3 KPIs for the evaluation of LSP 1

AGRONOMIC KPIs					
KPI	**KPI title**	**Related measurable metric from WP1 (D1.4)**	**Measurement**	**Description**	**Target**
1	Plant damage/ destruction	MET_AGRO_1	Number of damaged or destroyed plants that are not predisposed to be wounded. **Timing**: at least 2 times/year	Throughout the spraying season, analyse one-hectare equivalent of trees by following the UGV on different rows and record the number of damaged trees (broken branch, apple damaged or destroyed) or destroyed tree (trunk damaged). If a damaged or destroyed tree is detected, record the origin of the damage: implements badly adjusted (too strong), robotic guidance or other origin. Crop damage % and crop destruction % related to: -crop management (=cuttings poorly attached to their stakes and not straight row), -UGV guidance law, - Implement adjustment, - Other issues.	<10% in total (robotic system or other reason)
2	Agronomic performance of the robot	MET_AGRO_3	Agronomic satisfaction of the robotic system work **Timing**: After each field operation	End user or Ecosystem chair feedback with a 1 to 5 scale (very good, good, ok, bad, very bad).	At least feedback between "Ok" to "very good"
TECHNICAL KPIs					
Unmanned Ground Vehicle (UGV)					
3	Size of robot suitable for different crops	MET_TEC_UGV_05 b	Is the size of the robotic system suitable to the crop? **Timing**: At the development phase	Robot should be suitable to all vegetables (Sugar beets, pumpkin, onions, broccoli, lettuce etc.), vineyards and orchards. Comparing the dimensions of the tractors that LSP3 uses in 2021 with UGV dimensions.	Same size as currently used tractor or smaller.
4	Hardware present and operational	MET_TEC_UGV_17	Hardware is present and works on robot.	UGV is equipped with a connectivity system for data transmission, GNSS positioning, mobile connection to the cloud	Yes. Robot can operate

			Is there hardware for data transmission, for GNSS positioning, for mobile connection to the cloud? **Timing**: At the development phase		successfully. Comment.
5	Electrical, hydraulic and PTO output to the implement	MET_TEC_UGV_20	Hardware is present and works on robot. **Timing**: At the development phase	The robotic platform should provide electrical, hydraulic and PTO output to the implement. Is there hardware to provide electrical, hydraulic and PTO output to the implement?	Robot can operate successfully with the implement.
6	Robotics platform regroups the data to communicate with the user	MET_TEC_UGV_22	GUI communicating information needed. **Timing**: At the development phase	Record all types of messages the robotic platform communicates. Confirmation that hard/software is available and functional.	The robot operator is able to receive the data s/he needs to make decisions and supervise.
7	3-point hitch	MET_TEC_UGV_07	Is the UGV equipped with an equivalent to a 3-point hitch. Does it have a 3-point hitch (ISO730, CAT I, II, or III)? **Timing**: At least once during the project (Before treatment season).	Do the implements and UGVs follow the same Cat or standard for the 3-point hitch dimensions and lifting capacity. Record the UGV 3-point hitch dimensions Record the 3-point hitch of the implement	Yes
8	AB lines import from GNSS system	MET_TEC_UGV_24	The AB lines are moved from a shape file to the robot management/ planning software. **Timing**: When creating a new path planning	Are AB lines displayed correctly in the robot management software? Ensure that AB lines from commercial systems in use in 2021 can be imported into the robotic system through FMIS and Farming controller interfaces.	No need for AB line setup should be necessary on the field robot itself.
9	Performing in wet clay soil	MET_TEC_UGV_12	Ability to perform a mission with	Use the heavier tool of the Large-Scale Pilot (up to 400 kg) and record the level of easiness	At least "Suitable" to

			implements in the limits of the robotic systems. **Timing**: After the weeding season - At least once per year	of the robot to handle it in a wet clay soil (Very Easy - Easy - Suitable - Hard - Very hard)	“Very Easy” assessment.
10	Autonomy of the whole robotic system	MET_TEC_UGV_04	The robot should have an autonomy of minimum 8 -10 hours. **Timing**: During a specific test – once a year	Let the robot run in a loop until it stops, and record time during the operation.	Time > 8hours
11	Teach in	MET_TEC_UGV_25	Precision of teach in and efficiency **Timing**: Once a year after all field operation	Teach in: Driving routes can be taught, including patterns of AB lines and connecting headland turns. Deviation of the teach in. End user feedback with a 1 to 4 scale (Very efficient, Efficient, Not efficient, Unusable)	Deviation < 5cm Feedback at least Efficient
12	Human intervention in robotic work	MET_TEC_UGV_01	Cases where the robotic system cannot work without human assistance **Timing**: During field operations	Record a description of the intervention and the time allocated to it. Record the total time used by the end user for the whole weeding operation. Determine the % of intervention time in relation to total time.	<10% intervention time
13	Farmer competences for using the robot	MET_TEC_UGV_01	Competences required for farm workers, using robotic systems for repetitive work **Timing**: At the end of each spraying season	Record the number of operations consider as harder than driving a tractor and the competences required to achieve them. Record the number of operations consider as easier than driving a tractor and the competences required to achieve them.	>10% easier operations
14	Deviation of the trajectory of the towing system.	MET_TEC_UGV_02	Deviation of the trajectory of the towing system. **Timing**: After each operation	Record the time of entry and the time of exit of 3 straight rows of the UGV. Record the speed of the UGV in those rows. Retrieve log of the UGV.	Percentage of deviation from the planned trajectory between 50 and 100 mm: <10% Percentage of deviation from

					the planned trajectory above 100 mm: <2%
15	Obstacle detection and avoidance	MET_TEC_UGV_03	Can the robot detect case of emergency? Does the robot avoid collision? <u>**Timing**: In the off season – At least twice per year</u>	Place a heavy (+40 kg min) container in the middle of the passageway in place of a man: record if the robot detects the obstacle and slow down. Record if the robot avoid collision. If not record if the collision was violent.	The obstacle is detected. Collisions are avoided.
16	Capacity of robot and tractor to work under different conditions	MET_TEC_UGV_05	Condition where a robot couldn't work and where a tractor could. <u>**Timing**: After field operation – when it happens</u>	In practice, mechanical weeding or spraying can only be done under certain conditions (weather, state of the soil (e.g., moisture level), and growth stages of both the crop and the weeds), the robot must be able to work at least in those conditions where a tractor could pass. Record all situations where a robot couldn't work and where a tractor could. Define the expected work. Record all operation of the field. Determine the % of operations carried out by a robot.	50% of tractor-based operations are carried out autonomously
17	Equipment breakdown. Reliability of the UGV.	MET_TEC_UGV_09	Number and Importance of the breakdown. Ability to repair. <u>**Timing**: All along the process – when it happens</u>	Record all breakdown (hardware or software) and record the time needed to repair and if help from the constructor was needed. Record if the issue is documented. Determine: Number and % of small breakdown: less than 1h of repairs and no need of help from constructor. Number and % of medium breakdown: less than 2 hours of repairs or help of the constructors Number and % of serious breakdown: more than 2 hours of repairs.	90% of all mechanical breakdowns are documented or can be repaired by a user equipped for mechanical interventions by season. 2 small breakdown max per month. 2 medium breakdown max per season. 2 serious breakdown max per 10 years.

18	UGV works in low temperatures	MET_TEC_UGV_10	UGV Performing a mission in low temperatures **Timing**: During fields operations – for each operation	Record the temperature min of the environment when the robot was used without issues link to temperature.	Be able to work at low temperatures (-5°C).
19	UGV works in high temperatures	MET_TEC_UGV_11	UGV Performing a mission in high temperatures **Timing**: During fields operations – for each operation	Record the temperature min of the environment when the robot was used without issues link to temperature.	Be able to work in high heat (+40°C).
20	Improvement of guidance and U-turn of the UGV	MET_TEC_UGV_14	Areas for improvement of guidance and U-turn of the UGV **Timing**: During fields operations – when it happens	Record any movement that the robot does not do the way the farmer wants. Rate their importance: End user feedback with an 1 to 3 scale (Efficient, Not efficient, Unusable). Determine the number of "Unusable" comments.	Efficient. If not, optimize the path planning and reduce pass overs and soil compaction.
21	Level of system deterioration due to weather	MET_TEC_UGV_16	Does the weather significantly deteriorate the system? **Timing**: During fields operations – when it happens	The robot should be robust with an IP similar to tractors (IP 65-67). Record breakdown caused by the weather. Determine repetitive breakdowns of one component due to weather.	All robotic components are Robust (IP 65-67) or protected to have a similar robustness.
22	Trajectory optimisation/ Reduction of pass overs	MET_TEC_UGV_19	Number of pass overs. **Timing**: During fields operations - At least twice per spraying season	Record the number of pass overs during each operation.	< 2 pass overs
23	Correct calculation of the tank reserve	MET_TEC_UGV_21	Correct calculation of the tank reserve. **Timing**: During fields operations - At least twice	Does the Robotic system detect an empty tank during an operation? Is the tank empty?	Yes

			per spraying season		
			Implements		
24	Implement's ISOBUS compatibility	MET_TEC_IMP_06	Is the Communication between ECUs (Electronics Control Unit) of vehicle and implement defined? **Timing**: At the development phase	CAN bus/ISOBUS compatibility.	ISOBUS based communication within the implement-vehicle combination operate successfully.
25	Speed of the UGV	MET_TEC_IMP_01	Speed of the UGV. **Timing**: After each field operation	Tow implements that need a speed between 2km/h to 8 km/h. Record speed use for each implement. Record speed expectation for this tool. Record speed instruction (speed set in the path planning instructions). [speed difference for each tool= speed expectation– speed use]	speed difference <1km/h
26	Spraying coverage	MET_TEC_IMP_03	Is spraying homogeneous in all the canopy? **Timing**: Before and After each field operation - At least twice per season	Place papers above 3 leaves, under 3 leaves, 3 in the alley, 3 in a row, 3 just out of the field. Spray with the robot. Check and record which paper are wet which are not. $= Number\ of\ paper\ of\ one\ type\ wet\ /\ Total\ number\ of\ papers$	Above leaves: 100% Under leaves: 80%? In the alley: <5% Out of the field: 0%
27	Detection of nozzle obstruction	MET_TEC_IMP_04	Record of nozzle obstruction. **Timing**: After each field operation – when it happens	Record each nozzle obstruction. Record if the robotic system has detected it or not. Determine the % of not detected nozzle obstruction.	95% of nozzle obstruction detected.
28	Automated cleaning and maintenance	MET_TEC_IMP_05	Is the tank well cleaned? Is the maintenance of the sprayer enough? **Timing**: After spraying operations -	End user and technician feedback with a 1 to 5 scale (very good, good, ok, bad, very bad)	≤2

			At least twice per season		
29	Implement communication with robotic platform / activating supply sources	MET_TEC_IMP_08	Consumption of supply sources. **Timing**: During field operation - At least twice per season	Record situations where the robotic system can optimize its consumption (energy or consumable).	Robotic system can optimize its consumption.
30	Production of ISOXML files to be sent to the FMIS	MET_TEC_IMP_10	Recording the as-applied information of field application and producing ISOXML file available on the ISOBUS terminal. **Timing**: During each field application	Acquisition of as-applied amount (Sprayer) together with geo-location of applied points.	To represent the behaviour of the implements during field application.
31	Full load tank autonomy	MET_TEC_IMP_11	Full load a tank. Record the time taken for it to empty during autonomous operations. **Timing**: During a spraying operation - At least twice per weeding season	The user can fill the tank of the sprayer during a mission to a full-load tank autonomy of 60 min.	Autonomy of 60 min minimum
Farming Controller & FMIS					
32	Presentation of geospatial data	MET_TEC_F-C_15	Virtual map of the plot. **Timing**: At the development phase.	Is there a virtual map of the plot?	Presence of a virtual map of the plot usable during the operation for the end-user.
33	Communication protocols between implements and the machinery established	MET_TEC_F-C_08	Is it possible to link implements and machinery such that they work together?	Establish communication protocols in all levels: Use of ISOBUS or TCP/IP or other protocols to enable communication from the FC up to the implement/UGV. Count incidences where help of dealer / manufacturer is required to make the	No incidences.

			Timing: Once for each implement.	implement and UGV work with the FC.	
34	Data retrieved from operations are properly displayed and understood	MET_TEC_F-C_06	End-users are able to find and understand the way the data is displayed. **Timing**: One time per year with 5 users each time.	Receive data from sensors: perception information from the field (examples: soil and weather conditions, 3D mapping of the field and the crops, GPS data for the position of the tractor, diesel level sensor, heat of engine sensor, remote supervision, camera data, etc.). Ask end-users a description of the information displayed. Ask them to find specific information (speed, position, progress of the mission etc.)	The farmer is able to find and understand the information that is displayed. The farmer is able to make decisions from the information displayed (ex: if the diesel levels are low, then he can refill, etc.).
35	Autonomy to respond to unforeseen events	MET_TEC_F-C_09	Robot's respond to unforeseen events in a graceful manner. **Timing**: During a field operation – At least once a year	Place a heavy (+40kg min) container in the middle of the passageway, on a headland, make the FC believe that the wind is rising, that it is starting to rain: in all cases, record the reaction of the robotic system. Determine if the reaction of the robotic system is appropriate (it bypasses the obstacle without damaged plants or skipping work it could do; it stops its operation due to weather issues; …) Number of not appropriate reaction	Successful respond to unforeseen events.
36	Input information of each UGV and implement in the FMIS.	MET_TEC_F-C_11	Ability to input information of each UGV and implement in the FMIS. **Timing**: Once for each robot and implement.	Store description of all robots and implements on the farm (include weight, size, working width, fuel autonomy, source of fuel, which connectors are available, etc.) Indicate the ability or non-ability. Define data size.	Yes.
37	Prescription map for field operation	MET_TEC_F-C_12	Is the FMIS well construct to create a prescription map for field operation? **Timing**: Once a year.	End user feedback with a 1 to 4 scale (Nothing wrong, Efficient, Not efficient, Unusable)	At least "Efficient" to "Nothing wrong",

38	Performance assessment visualisation.	MET_TEC_F-C_13	Efficiency of the user interface to visualize as-applied information and performance assessment. **Timing**: Once a year.	End user feedback with a 1 to 4 scale (Nothing wrong, Efficient, Not efficient, Unusable).	At least "Efficient" to "Nothing wrong"
39	User interface inputs task-related parameters	MET_TEC_F-C_14	Efficiency of the user interface to input task-related parameters. **Timing**: Once a year.	End user feedback with a 1 to 4 scale (Nothing wrong, Efficient, Not efficient, Unusable)	At least "Efficient" to "Nothing wrong"
40	Conditions to be met before execution of tasks	MET_TEC_F-C_01	Ability to input the conditions under which a task is performed into the robotic system. **Timing**: Before starting fields operations - At least once per task	Record if it is possible or not.	Yes, it is possible
41	Resources for the execution of tasks	MET_TEC_F-C_02	Ability to input the resources available or not for each task. **Timing**: Before starting fields operations - At least once per task	Record if it is possible or not.	Yes, it is possible

42	Constraints on when and how tasks should be executed	MET_TEC_F-C_03	Ability to input time constrain for each task and to parameter each task. **Timing**: Before starting fields operations - At least once per task	Record if it is possible or not.	Yes, it is possible
43	Robot's battery notification	MET_TEC_F-C_04	Does the farmer get a notification when the level of fuel is low and before it reaches 0? **Timing**: During a field operation - At least twice per season	Leave less fuel than the mission needs in the tank of the UGV. Start the mission and record, if you are notified, whether you have time to stop the robot before it stops by itself. [= Number of times the robot is refilled before it runs out of power / Number of tests of this measure]	>90%
44	Precision of the digital twin of the field	MET_TEC_F-C_05	Reality of the copy. **Timing**: Before starting and after spraying season. At least twice per year	Have a digital copy of the field in a virtual environment alongside with the CAD files of the used resources. This digital copy should be precise. End user feedback with a 1 to 5 scale (Exactly the same, strong likeness, similar, some defect, not a copy)	At least “Similar” to “exactly the same”
45	FMIS provides information about the needs of the crops	MET_TEC_F-C_07	Communication between the FC and the FMIS. **Timing**: Before starting a field operation - At least twice per season.	Change a parameter in the FMIS and record if it was changed in the FC.	Communication between the FC and the FMIS is achieved.
46	Input task information in the FMIS.	MET_TEC_F-C_10	Ability to input information on each task in the FMIS. **Timing**: Once a year - At least twice per season.	Store all field operations with related information (e.g., technical, financial, etc.) Indicate if it is possible or not to do it.	Yes.
47	End-user's ability to intervene	MET_TEC_F-C_16	Can the end-user intervene at any time during an	Record case where the end user cannot intervene and what s/he would have done.	No cases occur.

			operation if the circumstances so require? **Timing**: All along the process - At least twice per season.		
48	Ability to pause and resume tasks.	MET_TEC_F-C_17	Can the operation be paused and resumed? **Timing**: Before starting the season.	Record if the robotic system can be paused during its operation. Record if it can be resumed. Record the easiness of this process: End user feedback of their control of the robotic system with a 1 to 5 scale (very easy, easy, ok, difficult very difficult).	Both possible. At least "ok" to "very easy".
NON-TECHNICAL KPIs					
Safety					
49	Data security	MET_N-TEC_saf_03	Ensure that data cannot be improperly accessed or modified). **Timing**: Once a year.	Use an expert, like a data integrity expert, cloud security expert from one of the institutes to perform an integrity test (From the land survey to the robotic mission and data record by the robotic system in the field).	99% uptime guaranteed of the robot.
50	Compliance with Machine directive and the EU legislations	MET_N-TEC_saf_04	Check the list of standards and regulations collected in WP1 are compliant with the robotic system. **Timing**: Once a year.	Send list to robot supplier for verification that the standards are harmonized. Number of standards company is in compliance/not in compliance.	Robotic companies are in compliance with the required standards so the product can be CE marked.
51	Injuries and danger created by the robot	MET_N-TEC_saf_01	Injuries to human or dangerous situation created by the robotic system. **Timing**: All along the process – when it happens.	Record the number of injuries suffer by a human and the number of injured humans. Record the number of dangerous situation (users perspective when/if they have felt that the robot was unsafe or if the robot would hurt them) and their level (Minor= No consequences, Significant = Minor injuries / Minor damages of other equipment / Minor damage of public or private property / Temporary damage to environment, Critical = Temporary disability without	Injures ≤2/season Danger ≤ 2

				death threat / Temporary professional disease / Serious injure / Loss or damaged of the robotic system / Loss or big damage of public or private property / Long term damaged to the environment , Catastrophic = Death / Death threat / Permanent disability / Professional diseases). $Injures = number\ of\ injures \times number\ of\ human\ injured$ $Danger = number\ of\ dangerous\ situation \times level\ of\ the\ situation\ (1\ for\ minor - 2\ for\ significant - 3\ for\ Critical - 4\ for\ Catastrophic)$	
52	Compliance with local law and regulation	MET_N-TEC_saf_02	Cases where the robotic system do not comply with the local law and regulation. **Timing**: All along the process – when it happens.	Record case where the robotic system does not comply with the local law and regulation. Number of cases.	Zero cases.
53	Possibility to monitor implement and robot's functions	MET_N-TEC_saf_05	Can the final user monitor parameters that drives the implement and the robot's functioning as a tractor driver can? **Timing**: All along the process - At least twice each year	Determine if the final user can monitor parameters of the robotic system as a tractor driver can. Indicate number of parameters not monitored.	Able to monitor: UGV: Speed, chaining of row, height of the implement etc. Implement: height of the implement, adjustment etc.
Labour					
54	Ability to keep inventory of farm inputs	MET_N-TEC_lab_06	Is the FMIS well construct to keep the inventory of goods? **Timing**: Once a year	End user feedback with a 1 to 4 scale (Nothing wrong, Efficient, Not efficient, Unusable)	At least "Efficient" to "Nothing wrong"
55	Capacity of the end-user	MET_N-TEC_lab_01	Capacity of an end-user to	End user feedback of their control of the robotic system	End user feedback at

	to manage the robotic system		control the robotic system with only a user's manual and a training. **Timing**: At least once per season.	with a 1 to 5 scale (very easy, easy, ok, difficult very difficult) and assessment by an experienced user of this control (with the same 1 to 5 scale).	least "ok" to "very easy" Experienced user assessment at least "ok" to "very easy"
56	Launching a mission in field	MET_N-TEC_lab_02	Time needed to launch a mission in field. **Timing**: Before starting a field operation – when it happens At least once per season.	Operational treatment: the robot and the spraying system should be quick to install and start spraying in cases of emergency spraying and in the available opportunity windows. • Record time between starting the motor and the implement coupling to the robot. • Record time between attaching the implements to the robot and the robot is attached on the transport. • Record time from the moment the transport arrived at the field to the moment the robot starts its mission. Sum of each time.	<31minutes
57	Open road transport of the robotic system	MET_N-TEC_lab_03	Can the robotic system (UGV + Tools) be load on a trailer or within a van? **Timing**: At least once per season	Record if no. If yes, evaluate the maneuverability of your route (Easy - Ok - Hard).	All Yes. Easy to Ok assessment
58	Use of conventional tools	MET_N-TEC_lab_04	The hardware can be maintained with conventional tools that the farmer uses. **Timing**: All along the process – At each maintenance	Indicate the tool needed to maintain the robot or the implement	No unconventional tool is needed.
59	Feasibility of the workplan	MET_N-TEC_lab_05	Measure the feasibility of the workplan. **Timing**: At least once per season	End user feedback with a 1 to 5 scale (Perfect, Feasible easily, not that simple but feasible, Need few changes, Impossible)	At least "not that simple but feasible" to "Perfect".
Ethics					

60	Additional health risk and/or need for additional insurance for the farmer	MET_N-TEC_Eth_03	• Is there is a need for an additional insurance? • Risk to user's health and difficulty of work. • Time invested in discussions with insurance companies. **Timing**: Before starting the field operations – when discussing with insurance companies. After each season.	The system should not invalidate the health insurance of the people using it (high-risk sports such as sky diving require additional insurance - we don't want this for the R4C robotic system). • Is an additional insurance necessary? • Record time invested in discussions with insurance companies. • Record for each conventional and autonomous system: - Amounts and type of pesticides and herbicides used. - Number of operations that may cause human exposure to pesticides - Number of operations that have a lower health risk - Number of operations that have a higher health risk - Time of exposure: • To pesticides • To tractor vibration (with a conventional system) - Hours of physical work (with both conventional and autonomous system)	The use of the robot doesn't recommend a supplementary health insurance.
61	Liability insurance of the testing property	MET_N-TEC_Eth_04	Presence of a health insurance of the operator Time invested from the end user to convince the insurance company. **Timing**: Before starting the field operations - when discussing with insurance companies.	The system should not invalidate the liability insurance of the property on which the R4C robotic system is used. Indicate presence/absence of health insurance.	The use of the robot doesn't recommend a supplementary health insurance.
62	Farmer's understanding	MET_N-TEC_Eth_01	Possibility to follow the FC decision. **Timing**: Before starting a field	Farmer should be able to understand the decisions made by the system. Record if it is possible and understandable or not.	Yes, the farmer is able.

			operation - At least twice per season		
63	Farmer's ability to intervene in the decision making	MET_N-TEC_Eth_02	Ability to manually modified each decision of the FC. **Timing**: Before starting a field operation - At least twice per season	Farmer should be able to intervene in the decisions made by the system when needed. Record if it is possible or not.	Yes, the farmer is able.
Economics					
64	Cost-effectiveness of the robotic system	MET_N-TEC_eco_01	User time to prepare the robotic system and all economic aspects. **Timing**: • Regional data: Year 2. • All other metrics: Once each year - Validation of the minimum viable product.	**For both conventional and autonomous system**: • Time between starting the motor and the implement coupling to the robot. • Time between attaching the implements to the robot and the robot is attached on the transport • Time from the moment the transport arrived at the field to the moment when the transport leaves with the robot • Cost of the Land Survey • How many field operations are necessary to have a clean plot? • Fuel consumption per hectare • Quantity of pesticide and herbicides used • Type of pesticide and herbicides used • Yield • Cost of: - Herbicide – Fertilizer - Plant protection products - Fuel – Harvest • Fixed costs • Investments • Lifetime of investments • Current interest rate • Number of operations • Total spending per hectare with robotic system • Total spending per hectare with conventional system • Number of hectares that the robotic system can handle • Number of hectares of the farm **Data about the region**:	Be cost effective.

				• Total Area (ha) • Geographical relevance and boundaries (e.g., Covered by cooperatives, local region, catchment) • Number of farms within the area, type of farmland (soil type), crops produced, farm sizes and structure, employees • Number of citizens • Data of ~100 Farmer: education, age, farm size and type of farm and crops produced, questions about farmers perception of various autonomous systems, needs, barriers, technical problems, speed, risk, skills, convenience • Assess the number of jobs that could be created in relation to Agri-and IT business **Analysis**: • Time of the end user allocated for the task (weeding or spraying) • Cost per hectare of the task	
Social					
65	Social acceptance	-	Measure the social acceptance of the proposed robotic solution. **Timing**: Once at the end of each year - Validation of the minimum viable product.	End-user feedback. The robotic solution is: Not acceptable (no useful outcome, easiness to use, or benefit) – Acceptable (some benefit) - Highly acceptable (end-user identifies high benefit from the use of the robot)	Acceptable or highly acceptable.

2.2.4 LSP 4 – The Netherlands – KPIs

Below, the KPIs for LSP 4 are presented.

Table 4 KPIs for the evaluation of LSP 4

AGRONOMIC KPIs					
KPI	**KPI title**	**Related measurable metric from WP1 (D1.4)**	**Measurement**	**Description**	**Target**
1	Plant damage/ destruction	MET_AGRO_1	Number of damaged or destroyed plants that are not	With a tractor and with a robot equipped with the 'smart' mechanical weeder and also with a conventional mechanical weeder, for each operation	<2% damage with a good quality of weeding

			predisposed to be wounded. **Timing**: at least 2 times/year	follow the pulling system and record the number of damaged plants. Record the number of plants per number of meters analysed. If a damaged plant is detected, record the origin of the damage: not straight row, implements badly adjust (too strong), robotic guidance or other origin. Crop damage % and crop destruction % related to: -crop management (=cuttings poorly attached to their stakes and not straight row), -UGV guidance law, - Implement adjustment, - Other issues.	
2	Dirty crops	MET_AGRO_2	Plants cover with dirt or sand **Timing**: Before and after weeding operation – At least twice per weeding season	Qualify the condition of the knives (good - worn – broken). Record the number of dirty plants and plants studied. Determine the percentage of dirty plants.	Dirty crops < 20%
3	Agronomic performance of the robot	MET_AGRO_3	Agronomic satisfaction of the robotic system work **Timing**: After each field operation	End user or Ecosystem chair feedback with a 1 to 5 scale (very good, good, ok, bad, very bad).	At least feedback between "Ok" to "very good"
TECHNICAL KPIs					
Unmanned Ground Vehicle (UGV)					
4	Size of robot suitable for different crops	MET_TEC_UGV_05 b	Is the size of the robotic system suitable to the crop? **Timing**: At the development phase	Robot should be suitable to all vegetables (Sugar beets, pumpkin, onions, broccoli, lettuce etc.), vineyards and orchards. Record the track width of the machine, the width of the knives, the height of the machine	Track width of the UGV must match with the row spacing of the crop or with multiple rows of the crop (per crop different, most common spacings are 12,5cm; 25cm; 50cm; 75cm.) Crop size and height should match the knives width

					and machine height
5	Hardware present and operational	MET_TEC_UGV_17	Hardware is present and works on robot. Is there hardware for data transmission, for GNSS positioning, for mobile connection to the cloud? **<u>Timing</u>**<u>: At the development phase</u>	UGV is equipped with a connectivity system for data transmission, GNSS positioning, mobile connection to the cloud	Yes. Robot can operate successfully. Comment.
6	Electrical, hydraulic and PTO output to the implement	MET_TEC_UGV_20	Hardware is present and works on robot. **<u>Timing</u>**<u>: At the development phase</u>	The robotic platform should provide electrical, hydraulic and PTO output to the implement. Is there hardware to provide electrical, hydraulic and PTO output to the implement?	Robot can operate successfully with the implement.
7	Robotics platform regroups the data to communicate with the user	MET_TEC_UGV_22	GUI communicating information needed. **<u>Timing</u>**<u>: At the development phase</u>	Record all types of messages the robotic platform communicates. Confirmation that hard/software is available and functional.	The robot operator is able to receive the data s/he needs to make decisions and supervise.
8	3-point hitch	MET_TEC_UGV_07	Is the UGV equipped with an equivalent to a 3-point hitch. Does it have a 3-point hitch (ISO730, CAT I, II, or III)? **<u>Timing</u>**<u>: At least once during the project (Before weeding season).</u>	Do the implements and UGVs follow the same Cat or standard for the 3-point hitch dimensions and lifting capacity. Record the UGV 3-point hitch dimensions Record the 3-point hitch of the implement	Yes
9	AB lines import from GNSS system	MET_TEC_UGV_24	The AB lines are moved from a shape file to the robot management/ planning software.	Are AB lines displayed correctly in the robot management software? Ensure that AB lines from commercial systems in use in 2021 can be imported into the robotic system through FMIS	AB lines can be imported

			Timing: When creating a new path planning	and Farming controller interfaces.	
10	Performing in wet clay soil	MET_TEC_UGV_12	Ability to perform a mission with implements in the limits of the robotic systems. **Timing**: After the weeding season - At least once per year	Use the heavier tool of the Large-Scale Pilot (up to 750 kg with Robotti 150D and 1500 kg with Robotti LR kg) and record the level of easiness of the robot to handle it in a wet clay soil (Very Easy - Easy - Suitable - Hard - Very hard)	At least ”Suitable” to ”Very Easy” assessment.
11	Autonomy of the whole robotic system	MET_TEC_UGV_04	The robot should have an autonomy of minimum 8 -10 hours. **Timing**: During a specific test – once a year	Let the robot run in a loop until it stops, and record time during the operation.	Time > 8hours
12	Use of common implements	MET_TEC_UGV_06	Can the robotic system use one type of each current common mechanical weeding implement? Are they simple to attach? **Timing**: Once a year after all field operation	Work with current common mechanical weeding tools for vineyards (vineyards ploughshares and knives, disk harrow, Kress Fingers, rotatory tool mower, ripper) and vegetables (hoeing machine). The UGV can tow Hoeing machine (a Graford robocrop side-shift guided Steketee weeder with normal V- shaped knives, 75cm row spacing) End user and Technical chair feedback with a 1 to 5 scale (very good, good, ok, bad, very bad) concerning the easiness to attach those implements	All implements usable. At least feedback between “Ok” to “very good”.
13	Teach in	MET_TEC_UGV_25	Precision of teach in and efficiency **Timing**: Once a year after all field operation	Teach in: Driving routes can be taught, including patterns of AB lines and connecting headland turns. Deviation of the teach in. End user feedback with a 1 to 4 scale (Very efficient, Efficient, Not efficient, Unusable)	Deviation < 5cm Feedback at least Efficient
14	Human intervention in robotic work	MET_TEC_UGV_01	Cases where the robotic system cannot work without	Record a description of the intervention and the time allocated to it. Record the total time used by the end user for	<10% intervention time

			human assistance **Timing**: During field operations	the whole weeding operation. Determine the % of intervention time in relation to total time.	
15	Farmer competences for using the robot	MET_TEC_UGV_01	Competences required for farm workers, using robotic systems for repetitive work **Timing**: At the end of each weeding season	Record the number of operations consider as harder than driving a tractor and the competences required to achieve them. Record the number of operations consider as easier than driving a tractor and the competences required to achieve them.	>10% easier operations
16	Deviation of the trajectory of the towing system.	MET_TEC_UGV_02	Deviation of the trajectory of the towing system. **Timing**: After each operation	Record the time of entry and the time of exit of 3 straight rows of the UGV. Record the speed of the UGV in those rows. Retrieve log of the UGV.	Percentage of deviation from the planned trajectory above 25mm: <10%
17	Capacity of robot and tractor to work under different conditions	MET_TEC_UGV_05	Condition where a robot couldn't work and where a tractor could. **Timing**: After field operation – when it happens	In practice, mechanical weeding or spraying can only be done under certain conditions (weather, state of the soil (e.g., moisture level), and growth stages of both the crop and the weeds), the robot must be able to work at least in those conditions where a tractor could pass. Record all situations where a robot couldn't work and where a tractor could. Define the expected work. Record all operation of the field. Determine the % of operations carried out by a robot.	50% of tractor-based operations are carried out autonomously
18	Blockage detection and rectification	MET_TEC_UGV_08	Detection of blockage of mechanical tools and the ability to overcome. **Timing**: During field operations - At least twice per weeding season	Intentionally cause a blockage of the tool (with a branch or stuff on field) record if after 1 minute of blockage, the robotic system has done nothing to rectify it. Otherwise, record if it had worked. Record all unintentionally caused blockages. Determine: % of blockages detected % of blockages rectified	> 95% blockages detected > 90% rectified
19	Equipment breakdown. Reliability of the UGV.	MET_TEC_UGV_09	Number and Importance of the breakdown.	Record all breakdown (hardware or software) and record the time needed to repair and if help from the	90% of all mechanical breakdowns are

			Ability to repair. **Timing**: All along the process – when it happens	constructor was needed. Record if the issue is documented. Determine: Number and % of small breakdown: less than 1h of repairs and no need of help from constructor. Number and % of medium breakdown: less than 2 hours of repairs or help of the constructors Number and % of serious breakdown: more than 2 hours of repairs.	documented or can be repaired by a user equipped for mechanical interventions by season. 2 small breakdown max per month. 2 medium breakdown max per season. 2 serious breakdown max per 10 years.
20	UGV works in low temperatures	MET_TEC_UGV_10	UGV Performing a mission in low temperatures **Timing**: During fields operations – for each operation	Record the temperature min of the environment when the robot was used without issues link to temperature.	Be able to work at low temperatures (-5°C).
21	UGV works in high temperatures	MET_TEC_UGV_11	UGV Performing a mission in high temperatures **Timing**: During fields operations – for each operation	Record the temperature min of the environment when the robot was used without issues link to temperature.	Be able to work in high heat (+40°C).
22	Improvement of guidance and U-turn of the UGV	MET_TEC_UGV_14	Areas for improvement of guidance and U-turn of the UGV **Timing**: During fields operations – when it happens	Record any movement that the robot does not do the way the farmer wants. Rate their importance: End user feedback with an 1 to 3 scale (Efficient, Not efficient, Unusable). Determine the number of "Unusable" comments.	Efficient. If not, optimize the path planning and reduce pass overs and soil compaction.
23	Level of system deterioration due to weather	MET_TEC_UGV_16	Does the weather significantly deteriorate the system? **Timing**: During fields operations –	The robot should be robust with an IP similar to tractors (IP 65-67). Record breakdown caused by the weather. Determine repetitive breakdowns of one component due to weather.	All robotic components are Robust (IP 65-67) or protected to have a similar robustness.

			when it happens		
24	Trajectory optimisation/ Reduction of pass overs	MET_TEC_UGV_19	Number of pass overs. **Timing**: During fields operations - At least twice per weeding season	Record the number of pass overs during each operation.	< 2 pass overs
			Implements		
25	Implement's ISOBUS compatibility	MET_TEC_IMP_06	Is the Communication between ECUs (Electronics Control Unit) of vehicle and implement defined? **Timing**: At the development phase	CAN bus/ISOBUS compatibility.	ISOBUS based communication within the implement-vehicle combination operate successfully.
26	Speed of the UGV	MET_TEC_IMP_01	Speed of the UGV. **Timing**: After each field operation	Tow implements that need a speed between 2km/h to 8 km/h. Record speed use for each implement. Record speed expectation for this tool. Record speed instruction (speed set in the path planning instructions). [speed difference for each tool= speed expectation– speed use]	speed difference <1km/h
27	Precise height stabilisation	MET_TEC_IMP_02	Mechanical weeding tool pass depth. **Timing**: During a field operation - At least twice per weeding season	Mechanical weeding: Stabilize implements to a precise height regardless of the terrain. Pause the robot 3 times on different location of the fields and record the tool pass depth in cm. Re do it 10 meters after each pause. Deviation of all the pass depths. Deviation max of two successive path depths.	<1 cm for both deviations
28	Implement communication with robotic platform / activating supply sources	MET_TEC_IMP_08	Consumption of supply sources. **Timing**: During field operation - At least twice per weeding season	Record situations where the robotic system can optimize its consumption (energy or consumable).	Robotic system can optimize its consumption.

29	Production of ISOXML files to be sent to the FMIS	MET_TEC_IMP_10	Recording the as-applied information of field application and producing ISOXML file available on the ISOBUS terminal. **Timing**: During each field application	Acquisition of as-applied amount (Sprayer) together with geo-location of applied points.	To represent the behaviour of the implements during field application.
30	Full load tank autonomy	MET_TEC_IMP_11	Full load a tank. Record the time taken for it to empty during autonomous operations. **Timing**: During a spraying operation - At least twice per weeding season	The user can fill the tank of the sprayer during a mission to a full-load tank autonomy of 60 min.	Autonomy of 60 min minimum
Farming Controller & FMIS					
31	Presentation of geospatial data	MET_TEC_F-C_15	Virtual map of the plot. **Timing**: At the development phase.	Is there a virtual map of the plot?	Presence of a virtual map of the plot usable during the operation for the end-user.
32	Communication protocols between implements and the machinery established	MET_TEC_F-C_08	Is it possible to link implements and machinery such that they work together? **Timing**: Once for each implement.	Establish communication protocols in all levels: Use of ISOBUS or TCP/IP or other protocols to enable communication from the FC up to the implement/UGV. Count incidences where help of dealer / manufacturer is required to make the implement and UGV work with the FC.	No incidences.
33	Data retrieved from operations are properly displayed and understood	MET_TEC_F-C_06	End-users are able to find and understand the way the data is displayed. **Timing**: One time per year	Receive data from sensors: perception information from the field (examples: soil and weather conditions, 3D mapping of the field and the crops, GPS data for the position of the tractor, diesel level sensor, heat of engine sensor,	The farmer is able to find and understand the information that is displayed. The farmer is able

			with 5 users each time.	remote supervision, camera data, etc.). Ask end-users a description of the information displayed. Ask them to find specific information (speed, position, progress of the mission etc.)	to make decisions from the information displayed (ex: if the diesel levels are low, then he can refill, etc.).
34	Input information of each UGV and implement in the FMIS.	MET_TEC_F-C_11	Ability to input information of each UGV and implement in the FMIS. **Timing**: Once for each robot and implement.	Store description of all robots and implements on the farm (include weight, size, working width, fuel autonomy, source of fuel, which connectors are available, etc.) Indicate the ability or non-ability. Define data size.	Yes.
35	Performance assessment visualisation.	MET_TEC_F-C_13	Efficiency of the user interface to visualize as-applied information and performance assessment. **Timing**: Once a year.	End user feedback with a 1 to 4 scale (Nothing wrong, Efficient, Not efficient, Unusable).	At least “Efficient” to “Nothing wrong”
36	User interface inputs task-related parameters	MET_TEC_F-C_14	Efficiency of the user interface to input task-related parameters. **Timing**: Once a year.	End user feedback with a 1 to 4 scale (Nothing wrong, Efficient, Not efficient, Unusable)	At least “Efficient” to “Nothing wrong”
37	Conditions to be met before execution of tasks	MET_TEC_F-C_01	Ability to input the conditions under which a task is performed into the robotic system. **Timing**: Before starting fields operations - At least once per task	Record if it is possible or not.	Yes, it is possible
38	Resources for the execution of tasks	MET_TEC_F-C_02	Ability to input the resources	Record if it is possible or not.	Yes, it is possible

			available or not for each task. **Timing**: Before starting fields operations - At least once per task		
39	Constraints on when and how tasks should be executed	MET_TEC_F-C_03	Ability to input time constrain for each task and to parameter each task. **Timing**: Before starting fields operations - At least once per task	Record if it is possible or not.	Yes, it is possible
40	Robot's battery notification	MET_TEC_F-C_04	Does the farmer get a notification when the level of fuel is low and before it reaches 0? **Timing**: Timing: Before starting fields operations - At least once per task	Leave less fuel than the mission needs in the tank of the UGV. Start the mission and record, if you are notified, whether you have time to stop the robot before it stops by itself. [= Number of times the robot is refilled before it runs out of power / Number of tests of this measure]	>90%
41	Precision of the digital twin of the field	MET_TEC_F-C_05	Reality of the copy. **Timing**: Before starting weeding season and after weeding season. At least twice per year	Have a digital copy of the field in a virtual environment alongside with the CAD files of the used resources. This digital copy should be precise. End user feedback with a 1 to 5 scale (Exactly the same, strong likeness, similar, some defect, not a copy)	At least "Similar" to "exactly the same"
42	FMIS provides information about the needs of the crops	MET_TEC_F-C_07	Communication between the FC and the FMIS. **Timing**: Before starting a field operation - At least twice per weeding season.	Change a parameter in the FMIS and record if it was changed in the FC.	Communication between the FC and the FMIS is achieved.

43	Input task information in the FMIS.	MET_TEC_F-C_10	Ability to input information on each task in the FMIS. **Timing**: Once a year - At least twice per weeding season.	Store all field operations with related information (e.g., technical, financial, etc.) Indicate if it is possible or not to do it.	Yes.
44	End-user's ability to intervene	MET_TEC_F-C_16	Can the end-user intervene at any time during an operation if the circumstances so require? **Timing**: All along the process - At least twice per weeding season.	Record case where the end user cannot intervene and what s/he would have done.	No cases occur.
45	Ability to pause and resume tasks.	MET_TEC_F-C_17	Can the operation be paused and resumed? **Timing**: Before starting the weeding season.	Record if the robotic system can be paused during its operation. Record if it can be resumed. Record the easiness of this process: End user feedback of their control of the robotic system with a 1 to 5 scale (very easy, easy, ok, difficult very difficult).	Both possible. At least "ok" to "very easy".
NON-TECHNICAL KPIs					
Safety					
46	Data security	MET_N-TEC_saf_03	Ensure that data cannot be improperly accessed or modified). **Timing**: Once a year.	Use an expert, like a data integrity expert, cloud security expert from one of the institutes to perform an integrity test (From the land survey to the robotic mission and data record by the robotic system in the field).	99% uptime guaranteed of the robot.
47	Compliance with Machine directive and the EU legislations	MET_N-TEC_saf_04	Check the list of standards and regulations collected in WP1 are compliant with the robotic system. **Timing**: Once a year.	Send list to robot supplier for verification that the standards are harmonized. Number of standards company is in compliance/not in compliance.	Robotic companies are in compliance with the required standards so the product can be CE marked.

48	Injuries and danger created by the robot	MET_N-TEC_saf_01	Injuries to human or dangerous situation created by the robotic system. **Timing**: All along the process – when it happens.	Record the number of injuries suffer by a human and the number of injured humans. Record the number of dangerous situation (users perspective when/if they have felt that the robot was unsafe or if the robot would hurt them) and their level (Minor= No consequences, Significant = Minor injuries / Minor damages of other equipment / Minor damage of public or private property / Temporary damage to environment, Critical = Temporary disability without death threat / Temporary professional disease / Serious injure / Loss or damaged of the robotic system / Loss or big damage of public or private property / Long term damaged to the environment , Catastrophic = Death / Death threat / Permanent disability / Professional diseases). $Injures = number\ of\ injures \times number\ of\ human\ injured$ $Danger = number\ of\ dangerous\ situation \times level\ of\ the\ situation$ $(1\ for\ minor - 2\ for\ significant - 3\ for\ Critical - 4\ for\ Catastrophic)$	Injures ≤2/season Danger ≤ 2
49	Compliance with local law and regulation	MET_N-TEC_saf_02	Cases where the robotic system do not comply with the local law and regulation. **Timing**: All along the process – when it happens.	Record case where the robotic system does not comply with the local law and regulation. Number of cases.	Zero cases.
50	Possibility to monitor implement and robot's functions	MET_N-TEC_saf_05	Can the final user monitor parameters that drives the implement and the robot's functioning as	Determine if the final user can monitor parameters of the robotic system as a tractor driver can. Indicate number of parameters not monitored.	Able to monitor: UGV: Speed, chaining of row, height of the implement etc. Implement: height of the

			a tractor driver can? **Timing**: All along the process - At least twice each year		implement, adjustment etc.
Labour					
51	Ability to keep inventory of farm inputs	MET_N-TEC_lab_06	Is the FMIS well construct to keep the inventory of goods? **Timing**: Once a year	End user feedback with a 1 to 4 scale (Nothing wrong, Efficient, Not efficient, Unusable)	At least "Efficient" to "Nothing wrong"
52	Capacity of the end-user to manage the robotic system	MET_N-TEC_lab_01	Capacity of an end-user to control the robotic system with only a user's manual and a training. **Timing**: At least once per season.	End user feedback of their control of the robotic system with a 1 to 5 scale (very easy, easy, ok, difficult very difficult) and assessment by an experienced user of this control (with the same 1 to 5 scale).	End user feedback at least "ok" to "very easy" Experienced user assessment at least "ok" to "very easy"
53	Open road transport of the robotic system	MET_N-TEC_lab_03	Can the robotic system (UGV + Tools) be load on a trailer or within a van? **Timing**: At least once per season	Record if no. If yes, evaluate the maneuverability of your route (Easy - Ok - Hard).	All Yes. Easy to Ok assessment
54	Use of conventional tools	MET_N-TEC_lab_04	The hardware can be maintained with conventional tools that the farmer uses. **Timing**: All along the process – At each maintenance	Indicate the tool needed to maintain the robot or the implement	No unconventional tool is needed.
55	Feasibility of the workplan	MET_N-TEC_lab_05	Measure the feasibility of the workplan. **Timing**: At least once per season	End user feedback with a 1 to 5 scale (Perfect, Feasible easily, not that simple but feasible, Need few changes, Impossible)	At least "not that simple but feasible" to "Perfect".
Ethics					
56	Additional health risk	MET_N-TEC_Eth_03	• Is there is a need for an	The system should not invalidate the health insurance	The use of the robot doesn't

	and/or need for additional insurance for the farmer		additional insurance? • Risk to user's health and difficulty of work. • Time invested in discussions with insurance companies. **Timing**: Before starting the field operations – when discussing with insurance companies. After each season.	of the people using it (high-risk sports such as sky diving require additional insurance - we don't want this for the R4C robotic system). • Is an additional insurance necessary? • Record time invested in discussions with insurance companies. • Record for each conventional and autonomous system: - Amounts and type of pesticides and herbicides used. - Number of operations that may cause human exposure to pesticides - Number of operations that have a lower health risk - Number of operations that have a higher health risk - Time of exposure: • To pesticides • To tractor vibration (with a conventional system) - Hours of physical work (with both conventional and autonomous system)	recommend a supplementary health insurance.
57	Liability insurance of the testing property	MET_N-TEC_Eth_04	Presence of a health insurance of the operator Time invested from the end user to convince the insurance company. **Timing**: Before starting the field operations - when discussing with insurance companies.	The system should not invalidate the liability insurance of the property on which the R4C robotic system is used. Indicate presence/absence of health insurance.	The use of the robot doesn't recommend a supplementary health insurance.
58	Farmer's understanding	MET_N-TEC_Eth_01	Possibility to follow the FC decision. **Timing**: Before starting a field operation - At	Farmer should be able to understand the decisions made by the system. Record if it is possible and understandable or not.	Yes, the farmer is able.

			least twice per season		
59	Farmer's ability to intervene in the decision making	MET_N-TEC_Eth_02	Ability to manually modified each decision of the FC. **Timing**: Before starting a field operation - At least twice per season	Farmer should be able to intervene in the decisions made by the system when needed. Record if it is possible or not.	Yes, the farmer is able.
Economics					
60	Cost-effectiveness of the robotic system	MET_N-TEC_eco_01	User time to prepare the robotic system and all economic aspects. **Timing**: • Regional data: Year 2. • All other metrics: Once each year - Validation of the minimum viable product.	**For both conventional and autonomous system**: • Time between starting the motor and the implement coupling to the robot. • Time between attaching the implements to the robot and the robot is attached on the transport • Time from the moment the transport arrived at the field to the moment when the transport leaves with the robot • Cost of the Land Survey • How many field operations are necessary to have a clean plot? • Fuel consumption per hectare • Quantity of pesticide and herbicides used • Type of pesticide and herbicides used • Yield • Cost of: - Herbicide – Fertilizer - Plant protection products - Fuel – Harvest • Fixed costs • Investments • Lifetime of investments • Current interest rate • Number of operations • Total spending per hectare with robotic system • Total spending per hectare with conventional system • Number of hectares that the robotic system can handle • Number of hectares of the farm **Data about the region**: • Total Area (ha)	Be cost effective.

				• Geographical relevance and boundaries (e.g., Covered by cooperatives, local region, catchment) • Number of farms within the area, type of farmland (soil type), crops produced, farm sizes and structure, employees • Number of citizens • Data of ~100 Farmer: education, age, farm size and type of farm and crops produced, questions about farmers perception of various autonomous systems, needs, barriers, technical problems, speed, risk, skills, convenience • Assess the number of jobs that could be created in relation to Agri-and IT business **Analysis**: • Time of the end user allocated for the task (weeding or spraying) • Cost per hectare of the task	
			Social		
61	Social acceptance	-	Measure the social acceptance of the proposed robotic solution. **Timing**: Once at the end of each year - Validation of the minimum viable product.	End-user feedback. The robotic solution is: Not acceptable (no useful outcome, easiness to use, or benefit) – Acceptable (some benefit) - Highly acceptable (end-user identifies high benefit from the use of the robot)	Acceptable or highly acceptable.

2.3 Evaluation templates

In the following sections, the individual evaluation templates for the large-scale pilots are presented.

2.3.1 Evaluation template for LSP 1

<table>
<tr><th colspan="5">LSP 1 – FRANCE – VINEYARD AND VEGETABLE MECHANICAL WEEDING WITH CEOL ROBOT</th></tr>
<tr><td colspan="5">Name of the person reporting: Indicate your name
Organisation: Indicate your organisation
Day/Month/Year: Indicate date of reporting
Period of reporting: Indicate the reporting period</td></tr>
<tr><td colspan="5">This evaluation report serves the purpose of monitoring the timeline execution and KPIs of your LSP. Follow the guidelines provided in red "Italic" letters and fill in the whole report template. In case some KPIs or activities have not been measured/executed during the period of reporting, indicate the time you are planning to measure/execute them in the comments section (5th column). This evaluation report corresponds to the 3-year execution of your LPS, thus to the 3 minimum viable products of your robotic solution.</td></tr>
<tr><th colspan="5">TIMELINE MONITORING</th></tr>
<tr><th rowspan="2">Crop</th><th rowspan="2">Expected timeline</th><th>Have you followed the expected timeline?</th><th>Are there any deviations from the expected timeline?</th><th>Comments about the execution of the timeline.</th></tr>
<tr><td>YES/NO</td><td>YES/NO</td><td>Give your comments about the activities conducted. Describe any possible deviations from the expected timeline and give a justification. Explain if these deviations impacted the monitoring of KPIs.</td></tr>
<tr><td rowspan="4">Vineyards</td><td>2021: Receipt and first technical tests</td><td></td><td></td><td></td></tr>
<tr><td>March to July: Six (6) passes with three (3) tools in three (3) fields with 2 to 3 weeks between each pass.</td><td></td><td></td><td></td></tr>
<tr><td>October to December: Preparation of the robotic passages (land survey as example), plus co-design session.</td><td></td><td></td><td></td></tr>
<tr><td>2022: Preparation
Testing the robotic solution with two (2)</td><td></td><td></td><td></td></tr>
</table>

	farmers on their farms, two (2) fields for R&D tests, one (1) co-design session and a few demonstrations of the robotic system.			
	January: Receival of robot. Update of the robots already there.			
	February: One (1) pass with a tool to de-earth (with a tractor if not possible with CEOL)			
	March to July: Six (6) passes with 1/2 weeks between each pass. Measurements and Validation. At the end of each pass a debrief will be done to decide if adaptations are needed / Test of new tools in the R&D fields / Adaptation between each pass during the "free" week. (Co-design session?)			
	July to August: Validations and preparation for the next year.			
	October to December: One (1) pass with disks harrow to earth-up and preparation of the robotic passages for other farmers. Co-design session.			
	2023: "Industrialization" of the procedure: Test the robotic solution with 4 farmers on their farms, plus two (2) fields for R&D test, one (1) co-design session and demonstrations of the robotic system to everybody asking. Same process as 2022			
	2024: Commercialization on Large Scale: Test the robotic solution with			

	ten (10) famers (~100 ha) on their farms, plus two (2) for R&D test, one (1) co-design session and demonstrations of the robotic system to everybody asking. Same process as 2022			
Vegetable	**2022: Receival and first technical tests / test the robotic solution with one (1) farmer on one (1) or two (2) strips vegetable, plus one (1) co-design session.**			
	January-April: Receival of the robotic system. Preparation of the robotic passages (land survey as example).			
	April-May - … ??: Test of the robotic solution. Measurements and Validation. Adaptation between each pass during the "free" week. Co-design-session			
	2023: Preparation of the procedures. Testing of the robotic solution (on a different crop?) with another farmer. Continue to test the robotic solution with one (1) farmer on one (1) or more strips vegetable. Co-design session. Same process as 2022			
	2024: "Industrialization" of the procedure. Testing the robotic solution with a 3rd farmer. Continue to test the robotic solution with the two (2) other farmers on a few hectares. Co-design session. Same process as 2023			

KPI MONITORING				
KPI No.	KPI title	When did you measure?	What did you measure? How did you measure it?	Do you have any comments to add about your measurement?
		Indicate specific time of measurement (day/month/year). Indicate all repeated measurements in case a measurement is conducted multiple times.	*Describe briefly the measurement you conducted.*	*Have you accomplished the measurement as described in the evaluation methodology? What was the outcome? Have you achieved the target?*
AGRONOMIC KPIs				
1	Plant dagame/ destruction			
2	Agronomic performance of the robot			
TECHNICAL KPIs				
Unmanned Ground Vehicle (UGV)				
3	Size of robot suitable for different crops			
4	Hardware present and operational			
5	Electrical, hydraulic and PTO output to the implement			
6	Robotics platform regroups the data to communicate with the user			
7	3-point hitch			
8	AB lines import from GNSS system			
9	Performing in wet clay soil			
10	Performing in terrain slopes			
11	Obstacle detection			
12	Autonomy of the whole robotic system			

13	Use of common implements			
14	Teach in			
15	Human intervention in robotic work			
16	Farmer competences for using the robot			
17	Deviation of the trajectory of the towing system.			
18	Capacity of robot and tractor to work under different conditions			
19	Blockage detection and rectification			
20	Equipment breakdown. Reliability of the UGV.			
21	UGV works in low temperatures			
22	UGV works in high temperatures			
23	Improvement of guidance and U-turn of the UGV			
24	Level of system deterioration due to weather			
25	Trajectory optimisation/ Reduction of pass overs			
Implements				
26	Speed of the UGV			
27	Precise height stabilisation			
28	Implement communication with robotic platform / activating supply sources			

Farming Controller & FMIS				
29	Presentation of geospatial data			
30	Communication protocols between implements and the machinery established			
31	Data retrieved from operations are properly displayed and understood			
32	Autonomous response of the robotic system to unforeseen events.			
33	Input information of each UGV and implement in the FMIS.			
34	Performance assessment visualisation.			
35	User interface inputs task-related parameters			
36	Conditions to be met before execution of tasks			
37	Resources for the execution of tasks			
38	Constraints on when and how tasks should be executed			
39	Robot's battery notification			
40	Precision of the digital twin of the field			
41	FMIS provides information about the needs of the crops			

42	Input task information in the FMIS.			
43	End-user's ability to intervene			
44	Ability to pause and resume tasks.			
NON-TECHNICAL KPIs				
Safety				
45	Data security			
46	Compliance with Machine directive and the EU legislations			
47	Injuries and danger created by the robot			
48	Compliance with local law and regulation			
49	Possibility to monitor implement and robot's functions			
Labour				
50	Ability to keep inventory of farm inputs			
51	Capacity of the end-user to manage the robotic system			
52	Open road transport of the robotic system			
53	Use of conventional tools			
54	Feasibility of the workplan			
Ethics				
55	Additional health risk and/or need for additional insurance for the farmer			
56	Liability insurance of			

	the testing property			
57	Farmer's understanding			
58	Farmer's ability to intervene in the decision making			
Economics				
59	Cost-effectiveness of the robotic system			
	For both conventional and autonomous system			
	Data about the region			
Social				
60	Social acceptance			

MINIMUM VIABLE PRODUCT (MVP)	
	Provide an overall evaluation summary of your MVP, based KPI monitoring. What are the benefits of your solution? Is there room for improvement? Is your solution useful and cost-beneficial? Include photos of your MVP.
MVP 1	
MVP 2	
MVP 3	

SUMMARY ASSESSMENT FROM THE FOCUS GROUP	
	Here, please provide a summary of the FG's assessment of annual activities, as well as the minimum viable product.
MVP 1	
MVP 2	
MVP 3	

2.3.2 Evaluation template for LSP 2

LSP 2 – GREECE – CEOL AND RETROFITTED TRACTOR FOR SPRAYING OPERATIONS ON TABLE GRAPES
Name of the person reporting: *Indicate your name* **Organisation:** *Indicate your organisation* **Day/Month/Year:** *Indicate date of reporting* **Period of reporting:** *Indicate the reporting period*
This evaluation report serves the purpose of monitoring the timeline execution and KPIs of your LSP. Follow the guidelines provided in red "*Italic*" letters and fill in the whole report template. In case some KPIs or activities have not been measured/executed during the period of reporting, indicate the time you are planning to measure/execute them in the comments

section (5th column). This evaluation report corresponds to the 3-year execution of your LPS, thus to the 3 minimum viable products of your robotic solution.				
TIMELINE MONITORING				
Expected timeline	**Expected activities**	**Have you followed the expected timeline?**	**Are there any deviations from the expected timeline?**	**Comments about the execution of the timeline.**
		YES/NO	*YES/NO*	*Give your comments about the activities conducted. Describe any possible deviations from the expected timeline and give a justification. Explain if these deviations impacted the monitoring of KPIs.*
Start to February 2022	Preparations: Measurements, Farm Dimensions, Photos', Purchase of tractor, Robot set up.			
February – September 2022	Robot Implementation and observation of method during cultivation			
October 2022-January 2023	Analyse data and make necessary adjustment, if needed.			
February – September 2023	Robot Implementation and observation of method during cultivation.			
October 2023-January 2024	Analyse data and make necessary adjustment if needed.			
February – September 2024	Robot implementation and observation of method during cultivation.			
October 2024-January 2025	Analyse data and make necessary adjustment if needed. End of project			

Which of the following pests and malnutritions have you treated during the execution of the LSP?		
Period	**Pests and malnutricions (select from below)**	**Comments**
	Indicate one or more pests and malnutricions treated for each period: • *Powdery & downy Mildew* • *Botrytis* • *Grineria* • *Lobesia botrana* • *Thrips* • *Plannoccus* • *Malnutrition Zn, Fe, K*	*Please, provide any additional comments about the treatments.*
Start to February 2022		
February – September 2022		
October 2022- January 2023		
February – September 2023		
October 2023- January 2024		
February – September 2024		
October 2024- January 2025		

KPI MONITORING				
KPI No.	**KPI title**	**When did you measure?**	**What did you measure? How did you measure it?**	**Do you have any comments to add about your measurement?**
		Indicate specific time of measurement (day/month/year). Indicate all repeated measurements in case a measurement is conducted multiple times.	*Describe briefly the measurement you conducted.*	*Have you accomplished the measurement as described in the evaluation methodology? What was the outcome? Have you achieved the target?*
1	Plant damage/ destruction			
2	Agronomic performance of the robot			
TECHNICAL KPIs				
Unmanned Ground Vehicle (UGV)				

3	Size of robot suitable for different crops			
4	Hardware present and operational			
5	Electrical, hydraulic and PTO output to the implement			
6	Robotics platform regroups the data to communicate with the user			
7	3-point hitch			
8	AB lines import from GNSS system			
9	Performing in wet clay soil			
10	Autonomy of the whole robotic system			
11	Teach in			
12	Human intervention in robotic work			
13	Farmer competences for using the robot			
14	Deviation of the trajectory of the towing system.			
15	Capacity of robot and tractor to work under different conditions			
16	Equipment breakdown. Reliability of the UGV.			
17	UGV works in low temperatures			
18	UGV works in high temperatures			
19	Improvement			

	of guidance and U-turn of the UGV			
20	Level of system deterioration due to weather			
21	Trajectory optimisation/ Reduction of pass overs			
22	Correct calculation of the tank reserve			
Implements				
23	Implement's ISOBUS compatibility			
24	Speed of the UGV			
25	Spraying coverage			
26	Detection of nozzle obstruction			
27	Automated cleaning and maintenance			
28	Implement communication with robotic platform / activating supply sources			
29	Production of ISOXML files to be sent to the FMIS			
30	Full load tank autonomy			
Farming Controller & FMIS				
31	Presentation of geospatial data			
32	Communication protocols between implements and the machinery established			
33	Data retrieved from operations are properly			

	displayed and understood			
34	Input information of each UGV and implement in the FMIS.			
35	Prescription map for field operation			
36	Performance assessment visualisation.			
37	User interface inputs task-related parameters			
38	Conditions to be met before execution of tasks			
39	Resources for the execution of tasks			
40	Constraints on when and how tasks should be executed			
41	Robot's battery notification			
42	Precision of the digital twin of the field			
43	FMIS provides information about the needs of the crops			
44	Input task information in the FMIS.			
45	End-user's ability to intervene			
46	Ability to pause and resume tasks.			
NON-TECHNICAL KPIs				
Safety				
47	Data security			
48	Compliance with Machine directive and			

	the EU legislations			
49	Injuries and danger created by the robot			
50	Compliance with local law and regulation			
Labour				
51	Ability to keep inventory of farm inputs			
52	Capacity of the end-user to manage the robotic system			
53	Launching a mission in field			
54	Open road transport of the robotic system			
55	Use of conventional tools			
56	Feasibility of the workplan			
Ethics				
57	Additional health risk and/or need for additional insurance for the farmer			
58	Liability insurance of the testing property			
59	Farmer's understanding			
60	Farmer's ability to intervene in the decision making			
Economics				
61	Cost-effectiveness of the robotic system			
	For both conventional and autonomous system			
	Data about the region			
Social				

62	Social acceptance			

MINIMUM VIABLE PRODUCT (MVP)	
	Provide an overall evaluation summary of your MVP, based KPI monitoring. What are the benefits of your solution? Is there room for improvement? Is your solution useful and cost-beneficial? Include photos of your MVP.
MVP 1	
MVP 2	
MVP 3	

SUMMARY ASSESSMENT FROM THE FOCUS GROUP	
	Here, please provide a summary of the FG's assessment of annual activities, as well as the minimum viable product.
MVP 1	
MVP 2	
MVP 3	

2.3.3 Evaluation template for LSP 3

LSP 3 – SPAIN – APPLE ORCHARDS SPRAYING WITH RETROFITTED TRACTOR

Name of the person reporting: *Indicate your name*

Organisation: *Indicate your organisation*

Day/Month/Year: *Indicate date of reporting*

Period of reporting: *Indicate the reporting period*

This evaluation report serves the purpose of monitoring the timeline execution and KPIs of your LSP. Follow the guidelines provided in red "*Italic*" letters and fill in the whole report template. In case some KPIs or activities have not been measured/executed during the period of reporting, indicate the time you are planning to measure/execute them in the comments section (5th column). This evaluation report corresponds to the 3-year execution of your LPS, thus to the 3 minimum viable products of your robotic solution.

TIMELINE MONITORING				
Expected timeline	**Expected activities**	**Have you followed the expected timeline?**	**Are there any deviations from the expected timeline?**	**Comments about the execution of the timeline.**
		YES/NO	*YES/NO*	*Give your comments about the activities conducted. Describe any possible deviations from the expected timeline and give a justification. Explain if these deviations impacted the monitoring of KPIs.*

Start to February 2022	Preparations: Measurements, Farm Dimensions, Photos', Purchase of tractor, Robot set up.			
February – September 2022	Robot Implementation and observation of method during cultivation			
October 2022-January 2023	Analyse data and make necessary adjustment, if needed.			
February – September 2023	Robot Implementation and observation of method during cultivation.			
October 2023-January 2024	Analyse data and make necessary adjustment if needed.			
February – September 2024	Robot implementation and observation of method during cultivation.			
October 2024-January 2025	Analyse data and make necessary adjustment if needed. End of project			

Which of the following measurements have you conducted during the execution of the LSP?		
Period	**Measurements (select from below)**	**Comments**
	Indicate one or more of the following measurements you conducted during the execution of your LSP: • *product quantity* • *mist-blower efficiency* • *comparation between traditional treatments and automatic treatments*	*Please, provide any additional comments about the activities.*
Start to February 2022		
February – September 2022		
October 2022-January 2023		

February – September 2023		
October 2023-January 2024		
February – September 2024		
October 2024-January 2025		

KPI MONITORING				
KPI No.	KPI title	When did you measure?	What did you measure? How did you measure it?	Do you have any comments to add about your measurement?
		Indicate specific time of measurement (day/month/year). Indicate all repeated measurements in case a measurement is conducted multiple times.	*Describe briefly the measurement you conducted.*	*Have you accomplished the measurement as described in the evaluation methodology? What was the outcome? Have you achieved the target?*
1	Plant damage/ destruction			
2	Agronomic performance of the robot			
TECHNICAL KPIs				
Unmanned Ground Vehicle (UGV)				
3	Size of robot suitable for different crops			
4	Hardware present and operational			
5	Electrical, hydraulic and PTO output to the implement			
6	Robotics platform regroups the data to communicate with the user			
7	3-point hitch			
8	AB lines import from GNSS system			
9	Performing in wet clay soil			

10	Autonomy of the whole robotic system			
11	Teach in			
12	Human intervention in robotic work			
13	Farmer competences for using the robot			
14	Deviation of the trajectory of the towing system.			
15	Obstacle detection and avoidance			
16	Capacity of robot and tractor to work under different conditions			
17	Equipment breakdown. Reliability of the UGV.			
18	UGV works in low temperatures			
19	UGV works in high temperatures			
20	Improvement of guidance and U-turn of the UGV			
21	Level of system deterioration due to weather			
22	Trajectory optimisation/ Reduction of pass overs			
23	Correct calculation of the tank reserve			
Implements				
24	Implement's ISOBUS compatibility			

25	Speed of the UGV			
26	Spraying coverage			
27	Detection of nozzle obstruction			
28	Automated cleaning and maintenance			
29	Implement communication with robotic platform / activating supply sources			
30	Production of ISOXML files to be sent to the FMIS			
31	Full load tank autonomy			
Farming Controller & FMIS				
32	Presentation of geospatial data			
33	Communication protocols between implements and the machinery established			
34	Data retrieved from operations are properly displayed and understood			
35	Autonomy to respond to unforeseen events			
36	Input information of each UGV and implement in the FMIS.			
37	Prescription map for field operation			
38	Performance assessment visualisation.			

39	User interface inputs task-related parameters			
40	Conditions to be met before execution of tasks			
41	Resources for the execution of tasks			
42	Constraints on when and how tasks should be executed			
43	Robot's battery notification			
44	Precision of the digital twin of the field			
45	FMIS provides information about the needs of the crops			
46	Input task information in the FMIS.			
47	End-user's ability to intervene			
48	Ability to pause and resume tasks.			
NON-TECHNICAL KPIs				
Safety				
49	Data security			
50	Compliance with Machine directive and the EU legislations			
51	Injuries and danger created by the robot			
52	Compliance with local law and regulation			
53	Possibility to monitor implement and robot's functions			

Labour				
54	Ability to keep inventory of farm inputs			
55	Capacity of the end-user to manage the robotic system			
56	Launching a mission in field			
57	Open road transport of the robotic system			
58	Use of conventional tools			
59	Feasibility of the workplan			
Ethics				
60	Additional health risk and/or need for additional insurance for the farmer			
61	Liability insurance of the testing property			
62	Farmer's understanding			
63	Farmer's ability to intervene in the decision making			
Economics				
64	Cost-effectiveness of the robotic system			
	For both conventional and autonomous system			
	Data about the region			
Social				
65	Social acceptance			

MINIMUM VIABLE PRODUCT (MVP)	
	Provide an overall evaluation summary of your MVP, based KPI monitoring. What are the benefits of your solution? Is there room for improvement? Is your solution useful and cost-beneficial? Include photos of your MVP.

MVP 1	
MVP 2	
MVP 3	
SUMMARY ASSESSMENT FROM THE FOCUS GROUP	
	Here, please provide a summary of the FG's assessment of annual activities, as well as the minimum viable product.
MVP 1	
MVP 2	
MVP 3	

2.3.4 Evaluation template for LSP 4

LSP 4 – THE NETHERLANDS – MECHANICAL WEEDING WITH ROBOTTI				
Name of the person reporting: *Indicate your name* **Organisation:** *Indicate your organisation* **Day/Month/Year:** *Indicate date of reporting* **Period of reporting:** *Indicate the reporting period*				
This evaluation report serves the purpose of monitoring the timeline execution and KPIs of your LSP. Follow the guidelines provided in red "*Italic*" letters and fill in the whole report template. In case some KPIs or activities have not been measured/executed during the period of reporting, indicate the time you are planning to measure/execute them in the comments section (5th column). This evaluation report corresponds to the 3-year execution of your LPS, thus to the 3 minimum viable products of your robotic solution.				
TIMELINE MONITORING				
Expected timeline	**Expected activities**	**Have you followed the expected timeline?**	**Are there any deviations from the expected timeline?**	**Comments about the execution of the timeline.**
		YES/NO	*YES/NO*	*Give your comments about the activities conducted. Describe any possible deviations from the expected timeline and give a justification. Explain if these deviations impacted the monitoring of KPIs.*
Start to April 2021	Preparation LSP4: Location's check, measurements check, map out our needs.			
May 2021 – October 2021	Fieldwork LSP4: Perform field work, measure			

	variables, adjusting when necessary.			
November 2021 – December 2021	Measurements: processing all data and measurements, analyse data, make conclusion.			
Januari 2022 – March 2022	Preparations LSP4: Searching location, measurements check, map out our needs			
April 2022 – October 2022	Fieldwork LSP4: Perform field work, measure variables, adjust implements.			
November 2022 – December 2022	Measurements: processing all data and measurements, analyse data, make conclusion.			
Januari 2023 – March 2023	Preparations LSP4: Searching location, measurements check, map out our needs.			
April 2023 – October 2023	Fieldwork LSP4: Perform field work, measure variables, adjust implements.			
November 2023 – December 2023	Measurements: processing all data and measurements, analyse data, make conclusion.			
Januari 2024 – March 2024	Preparations LSP4: Searching location, measurements check, map out our needs.			
April 2024 – October 2024	Fieldwork LSP4: Perform field work, measure variables, adjust implements.			
November 2024 – December 2024	Measurements: processing all data and measurements, analyse data, finishing all data we have.			

Which of the following measurements have you conducted during the execution of the LSP?

Period	Measurements (select from below)	Comments
	Indicate one or more of the following measurements you conducted during the execution of your LSP:	*Please, provide any additional comments about the activities.*

	• *Fuel consumption (fuel per hours/hectare)* • *Remote control (time without warning signals)* • *Efficiency (hectares per hours)* • *Depth how many % goes on the right depth)* • *Right spot for seeding mission (how many seeds on the right spot)* • *Square for seeding pumpkin mission (how many % is seeded in square bandage)* • *Hitting Crops for row cleaner mission (how many crops are hit)*	
Start to April 2021		
May 2021 – October 2021		
November 2021 – December 2021		
Januari 2022 – March 2022		
April 2022 – October 2022		
November 2022 – December 2022		
Januari 2023 – March 2023		
April 2023 – October 2023		
November 2023 – December 2023		
Januari 2024 – March 2024		
April 2024 – October 2024		
November 2024 – December 2024		

KPI MONITORING				
KPI No.	KPI title	When did you measure?	What did you measure? How did you measure it?	Do you have any comments to add about your measurement?
		Indicate specific time of measurement (day/month/year). Indicate all repeated measurements in case a	*Describe briefly the measurement you conducted.*	*Have you accomplished the measurement as described in the evaluation methodology? What was the outcome? Have you achieved the target?*

		measurement is conducted multiple times.		
AGRONOMIC KPIs				
1	Plant dagame/ destruction			
2	Dirty crops			
3	Agronomic performance of the robot			
TECHNICAL KPIs				
Unmanned Ground Vehicle (UGV)				
4	Size of robot suitable for different crops			
5	Hardware present and operational			
6	Electrical, hydraulic and PTO output to the implement			
7	Robotics platform regroups the data to communicate with the user			
8	3-point hitch			
9	AB lines import from GNSS system			
10	Performing in wet clay soil			
11	Autonomy of the whole robotic system			
12	Use of common implements			
13	Teach in			
14	Human intervention in robotic work			
15	Farmer competences for using the robot			
16	Deviation of the trajectory of the towing system.			
17	Capacity of robot and tractor to work under different conditions			
18	Blockage detection and rectification			

19	Equipment breakdown. Reliability of the UGV.			
20	UGV works in low temperatures			
21	UGV works in high temperatures			
22	Improvement of guidance and U-turn of the UGV			
23	Level of system deterioration due to weather			
24	Trajectory optimisation/ Reduction of pass overs			
Implements				
25	Implement's ISOBUS compatibility			
26	Speed of the UGV			
27	Precise height stabilisation			
28	Implement communication with robotic platform / activating supply sources			
29	Production of ISOXML files to be sent to the FMIS			
30	Full load tank autonomy			
Farming Controller & FMIS				
31	Presentation of geospatial data			
32	Communication protocols between implements and the machinery established			
33	Data retrieved from operations are properly displayed and understood			
34	Input information of each UGV and implement in the FMIS.			

35	Performance assessment visualisation.			
36	User interface inputs task-related parameters			
37	Conditions to be met before execution of tasks			
38	Resources for the execution of tasks			
39	Constraints on when and how tasks should be executed			
40	Robot's battery notification			
41	Precision of the digital twin of the field			
42	FMIS provides information about the needs of the crops			
43	Input task information in the FMIS.			
44	End-user's ability to intervene			
45	Ability to pause and resume tasks.			
NON-TECHNICAL KPIs				
Safety				
46	Data security			
47	Compliance with Machine directive and the EU legislations			
48	Injuries and danger created by the robot			
49	Compliance with local law and regulation			
50	Possibility to monitor implement and robot's functions			
Labour				
51	Ability to keep inventory of farm inputs			

52	Capacity of the end-user to manage the robotic system			
53	Open road transport of the robotic system			
54	Use of conventional tools			
55	Feasibility of the workplan			
Ethics				
56	Additional health risk and/or need for additional insurance for the farmer			
57	Liability insurance of the testing property			
58	Farmer's understanding			
59	Farmer's ability to intervene in the decision making			
Economics				
60	Cost-effectiveness of the robotic system			
	For both conventional and autonomous system			
	Data about the region			
Social				
61	Social acceptance			

MINIMUM VIABLE PRODUCT (MVP)	
	Provide an overall evaluation summary of your MVP, based KPI monitoring. What are the benefits of your solution? Is there room for improvement? Is your solution useful and cost-beneficial? Include photos of your MVP.
MVP 1	
MVP 2	
MVP 3	
SUMMARY ASSESSMENT FROM THE FOCUS GROUP	
	Here, please provide a summary of the FG's assessment of annual activities, as well as the minimum viable product.
MVP 1	
MVP 2	
MVP 3	

2.4 Evaluation timeplan

As mentioned previously in this document, the evaluation of the large-scale pilots will be implemented using online meetings and evaluation report templates.

2.4.1 Online meetings

Regarding the online meetings, these will take place each month, initiating interaction in January 2022. One monthly meeting will be organised with all LSP leaders in order to:

a. Give updates on the execution of the timeline;
b. Inform about the developments of the LSPs;
c. Inform about possible deviations from the expected timeline and activities;
d. Indicate possible problems encountered during pilot activities and try to find solutions;
e. Make sure that the evaluation protocol is followed throughout the implementation of the LSPs and follow-up on the KPIs that have to be measured during all the stages of pilot implementation.
f. Briefly report on the assessments of the LSP Focus Groups on pilot activities.

2.4.2 Reporting via individual evaluation templates

The official evaluation of the LSPs and their minimum viable products will be implemented using the evaluation templates presented in this deliverable (section 2.3). Although the activities, measurements, timeline and alignment with the KPIs of the LSPs will be monitored on a monthly basis (online meetings), three official reporting periods will take place, one during the end of each experimental year, from August to October (2022, 2023, 2024). These reports will summarise all the activities, KPIs and outcomes of the LSPs, validating the three minimum viable products for each pilot. The outcomes from this reporting will support the work of Task 6.3, "Deployment, feedback collection and performance assessment in real environment", and provide input for deliverable D6.3, "Report on evaluating the performance of the robotic systems in real-environmental conditions", delivered in M24,36,48.

3 Large-Scale Pilot Focus Groups

In the context of WP6, Focus Groups (FGs) for each large-scale are being introduced. FGs consist of technical people, agronomy experts and field technicians. They will contribute in the work of LSPs by continuously evaluate the performance, usefulness, and benefits of the implemented solutions, as compared to their routine operations and decision making. Meetings of LSP leaders and FG members will take place on a regular basis, and feedback from FGs' assessments will be reported in the frame of WP6 (monthly meeting and annual reporting)[2]. In the table below, the FG members for each LSP are presented.

Table 5 LSP Focus Groups

Large-Scale Pilot	Focus Group members
LSP 1 - France – Vineyard and vegetable mechanical weeding with CEOL Robot	• Famers: at least 4, one of them is from the French institute of wine (IFV), 3 others are producers. • Crop advisors: at least 3, from Loire-Vini-Viti-Distribution (LVVD). • field technicians, 1 from AgreenCulture, 2 from Terrena, 1 from LVVD. • 2 agronomists, 1 from Terrena, 1 from LVVD.
LSP 2 - Greece – CEOL and retrofitted tractor for spraying operations on table grapes	• Mark Legas, President • Spiros Karachalios, Agronomist - Grower consultant • Theodore Kokiousis, Project Manager
LSP 3 - Spain - Apple orchards spraying with retrofitted tractor	• Field expert: Raül Sánchez • Agronomist: Oriol Serra • Technician: Josep Vidal
LSP 4 - The Netherlands - Mechanical weeding with Robotti	• Bram Veldhuisen (Technical expert) • Menko Oosterhuis (Farm technician)

[2] See the last section of the individual evaluation templates (sections 2.3.1-2.3.4)