WeLASER

Eco-innovative weeding with laser

Sustainable Weed Management in Agriculture with Laser-Based Autonomous Tools

D1.3 – Multi-actor involvement plan and activities (III)

Funded by the Horizon 2020 programme of the European Union

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EXECUTIVE SUMMARY

Deliverable "D1.3 - Multi-actor involvement plan and activities (III)" is the third document intended as a report of the annual activities regarding the involvement and management of the Multi actors in the WeLASER project updating the deliverable D1.2. It covers three periods of the project duration:

- First period October 2020 - September 2021
- Second period October 2021 - September 2022
- Third period October 2022 – December 2023.

The report provides an overview of the activities carried out in work package 1, including the following tasks:

- Identification, involvement, coordination and knowledge exchange with stakeholders and other entities
- Scientific and technical continuous assessment – value chain follow-up
- Economic assessment and risk management in farms
- Health and environmental issues
- Social aspects concerning the adoption of novel techniques

In the first reported period, the stakeholders were identified and involved in project activities. They represent various interest groups, including farmers, NGOs, policymakers, research and industry. This activity was continued and intensified in the second reported period. Five WeLASER Stakeholders' events were organised in the course of the project (four events as online meetings due to the COVID-19 pandemic). The aim of the first event was to stimulate involvement and include stakeholders in the decision loop regarding the definition of the WeLASER system characteristics. The second event was dedicated to safety issues, legal aspects and infrastructural requirements for efficient and safe operations of the system. The third event was focused on environmental issues, including environmental performance, key benefits and potential impacts related to the WeLASER application in practice. In the third period, further actions were focused on engaging the stakeholders in the evaluation of WeLASER development. Two events were organised. The fourth event was a new opportunity to involve stakeholders in the project activities. It was focused on the results of the WeLASER machine integration, its testing, its key features, functionalities and efficiency, as well as key factors and strategies for its successful implementation. The fifth event focused on demonstrating WeLASER functionalities and capabilities and its market implementation. Beside Stakeholder's events, four Focus Group Interview workshops were organised. The results of the events provided information on barriers, bridges, opportunities and threats of WeLASER implementation.

All events brought valuable opinions regarding the sustainability of the invention from a practical perspective and an input for its designing, testing and future introduction to the market. The scientific-technical progress of the project is satisfactory and gives positive prospects for the market introduction of the final design of the system. It is also positively evaluated by the stakeholders. Stakeholders' interaction was accompanied by communication of project activities by issuing Practice Abstracts, demonstration activities carried out in the third period and dissemination activities. The tasks related to the evaluation of the project from scientific-technical, financial-marketing and sustainability perspectives were launched in the first period and continued into the second and third periods.

The economic and sustainability assessments were planned in the first period. Basic information on the WeLASER invention was gathered and evaluated, and methodologies of assessment for socio-economic studies and Environmental and Social Life Cycle Assessments were worked out. In this respect, stakeholder events brought valuable opinions regarding the sustainability of the weeder from a practical perspective. In the second reporting period, the economic and sustainability assessments were further progressed. WeLASER weeder and conditions of its applications were characterised, and relevant data was gathered.

In the third period, the assessments were concluded along with the CATI survey. Economic evaluation of WeLASER implementation potential gives useful information for WeLASER commercialisation. It shows profitability for producers and reasonable financial conditions for farmers. It is concluded that WeLASER is a suitable alternative for conventional farmers in the future. WeLASER was also positively assessed in S-LCA and E-LCA studies, although certain aspects have to be addressed in further development to secure its sustainability. The key aspect is the energy, in terms of its demand as well as the type, reliability of the technology and its economics. WeLASER is perceived as a promising technology by interviewed experts, stakeholders and farmers surveyed by the CATI method. There is expressed high interest and expectations of the laser-based weeding solution, but it is also observed that the invention still requires further testing and optimisation of key performance parameters. To complement S-LCA and E-LCA studies, Life Cycle Costing was performed, providing valuable information regarding costs. The achieved results were presented in practice abstracts and promoted in dissemination activities and publications, and, most important, used in discussions with stakeholders.

During the project, all partners interacted intensively within their already established networks or with new parties and organisations expressing interest in WeLASER. Actions were undertaken to use project results as a basis for further development of the invention as a commercial product to be applied in practice in various sectors.

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LIST OF ACRONYMS AND ABBREVIATIONS

AGC:	Agreenculture
AHP	Analytical Hierarchy Process
AGRI:	Agricultural (manager)
CATI	Computer Assisted Telephone Interviewing
CBA	Cost benefit analysis
COAG:	Coordinator of Farmer Organizations and Livestock Rural Initiative of Spain
CSIC:	Spanish National Research Council
DoA:	Description of the Action (A part of the Grant Agreement)
FGI	Focus group interviews
FUT:	Futonics
IETU:	Institute for Ecology of Industrial Areas
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
LZH:	Laser Zentrum Hannover
M1 – M36:	Month within the period of project development
PESTEL	Political (P), Economic (E), Social (S), Technological (T), Environmental (E), and Legal (L).
S-LCA	Social Life Cycle Assessment
UCPH:	University of Copenhagen
UGENT:	Ghent University
UNIBO:	University of Bologna
VDBP:	Van den Borne Projecten
WP:	Work Package

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1. Purpose of the document

Deliverable D1.3 is the third document intended as a report of the annual activities regarding the involvement and management of the Multi actors in the WeLASER project. There were planned three deliverables D1.1, D1.2, D1.3 – Multi-actor involvement plan and activities (I), (II), and (III) delivered in months 12, 24 and 39 of the project duration. The delivery of the D1.3 was extended to month 39 (December 2023) along with the project duration. The reports have to contain the identification, involvement, coordination and knowledge exchange with stakeholders and other entities and the assessment of the scientific, technical, social, economic, health and environmental issues. D1.2 updated D1.1 and D1.3 updates D1.2.

2. Introduction

WeLASER project's Work Package 1 (WP1) – "Open-ended multi-actor networking and activities: from initial specifications to exploitation" executes a multi-level approach to the innovative technology development/assessment. It had to be realised from October 2020 to September 2023 but the task was extended to December 2023 along with the project duration. The task is realised by all partners: IETU, CSIC, FUT, LZH, UCPH, AGC, COAG, UNIBO, UGENT, and VDBP. This is an interdisciplinary and multidimensional approach to deal with multiple effects in different domains, forecasting system behaviour and technology evolution, uncertainties and risks. The approach includes environmental considerations in terms of resources and emissions, risks, economic/financial concerns and socio-cultural considerations. To achieve the objectives, the execution of the following tasks in the WP1 has been planned:

- TASK 1.1 – "Identification, involvement, coordination and knowledge exchange with stakeholders and other entities" led by COAG with involvement of all participants. Period: M1 – M36 (extension to M39). This task focuses on:
  - (i) identifying groups of stakeholders and entities all over Europe,
  - (ii) planning for better understanding how to engage with them and efficiently exchange knowledge,
  - (iii) involving and coordinating them in the development of the weeding system,
  - (iv) attracting potential end-users, and
  - (v) identifying the most appropriate ways and means for the inclusion of hi-tech systems in farms.
- TASK 1.2 – "Scientific and technical continuous assessment – Value chain follow-up" led by CSIC with involvement of all participants in months M5 to M36 (extension to M39). This task is devoted to monitoring all the aspects included in the value chain, not only regarding scientific-technical and evaluation issues, but also monitoring those topics related to financial opportunities to deploy the system in the market as well as related marketing activities

- TASK 1.3 – "Economic assessment and risk management in farms" led by UGENT with participation of all participants in the period: M5 – 36 (extension to M39). For the need of economic assessment, the models for the investment profitability assessment (on the level of individual farmer and entrepreneur) and development of cost benefit analysis (CBA) will be performed. The analysis will include identification and evaluation of investment and operational costs (life cycle perspective) with evaluation of economic benefits to farmers. Opportunities for innovative economic models like machine sharing/leasing/lending will be considered
- TASK 1.4 – "Health and environmental issues" led by IETU with participation of all partners in the period: M5 – M36 (extension to M39). Regarding health and environmental issues, the innovative technology is assessed through the Life Cycle Assessment (LCA) methodology based on the ISO 14040:2009 standard. The main objective is to consider all the aspects, direct and indirect, that could potentially affect the health and environment associated with the new technology.
- TASK 1.5 – "Social aspects concerning the adoption of novel techniques" led by IETU with participation of all partners in the period: M5 – M36 (extension to M39). The Social Life Cycle Assessment (S-LCA) is intended to assess the social and socio-economic aspects of the innovative product and its potential positive and negative impacts along with its life cycle encompassing manufacturing, distribution, use, re-use, maintenance, recycling, and final disposal.

Apart from D1.1, D1.2, D1.3 – "Multi-actor involvement plan and activities", deliverable D5.3 – "Equipment integration, testing, evaluation and impact on crops and soil" reports the consortium's final evaluation of the project.

3. MULTI-ACTOR STRATEGY- WELASER APPROACH

3.1. Description of Multi – Actor strategy plan

WeLASER is a Multi-actor project in which end users and multipliers of research results such as farmers and farmers' groups, advisers, enterprises and others, are closely cooperating throughout the whole research project period.

The identification and involvement of stakeholders in WeLASER are key aspects because (i) the project intends to offer a practical system and the knowledge and recommendations from practitioners are critical for developing useful equipment and (ii) stakeholders can provide understandings of circumstantial factors not covered by the project consortium (societal disputes, gender and cultural local aspects, etc.) that are critical for the exploitation of the equipment. Thus, WeLASER focuses on the identification and involvement of stakeholders as follows:

1. **Identification** – The identification of stakeholders is carried out along the duration of the project with quick identification of key stakeholders done in the first month of the project development with

their participation in the design phase. It was planned that all the WeLASER partners collaborate during the first months in the identification of potential stakeholders comprising the following sectors:

- Governments: Regional and local governments, EU policy-makers.
- Institutions: Research, high education and standard institutions.
- Businesses: Industry (manufacturers, users), investors, etc.
- Civil society: NGOs, general public, etc.

2. Involvement – Stakeholder involvement consists of both **engagement** and **management**:

a) Engagement – This first part of the involvement of stakeholders consists of establishing relationships. Stakeholders are the more valuable if they keep on participating in the project from beginning to end. The engagement plan offers incentives to keep their interest in participating in the project. Those incentives are as follows:

- Access to information: The knowledge generated in WeLASER is accessible to stakeholders
- Personal or institutional interest in being joined to the project.
- Networking: WeLASER offers several opportunities for stakeholders to meet face-to-face with other collaborators and establish new partnerships.

Stakeholders were engaged in through five WeLASER Stakeholders Events held in November 2020, May 2021, November 2021, November 2022 and July 2023. They were also invited and participated in other activities like the Demonstration Field Days in Madrid, Spain (July 2023), Taastrup, Denmark, and Reusel, The Netherlands (August 2023) and Madrid, Spain (September 2023).

b) Management – This second part of the involvement of stakeholders consists of managing the processes of including the stakeholders in the project activities that will be based on (i) Reciprocal communication, (ii) Consensus building and (iii) Co-design.

WeLASER identification and involvement of stakeholders are summarised in the following **Multi-actor involvement procedure**, which is sketched in Fig. 3.1.

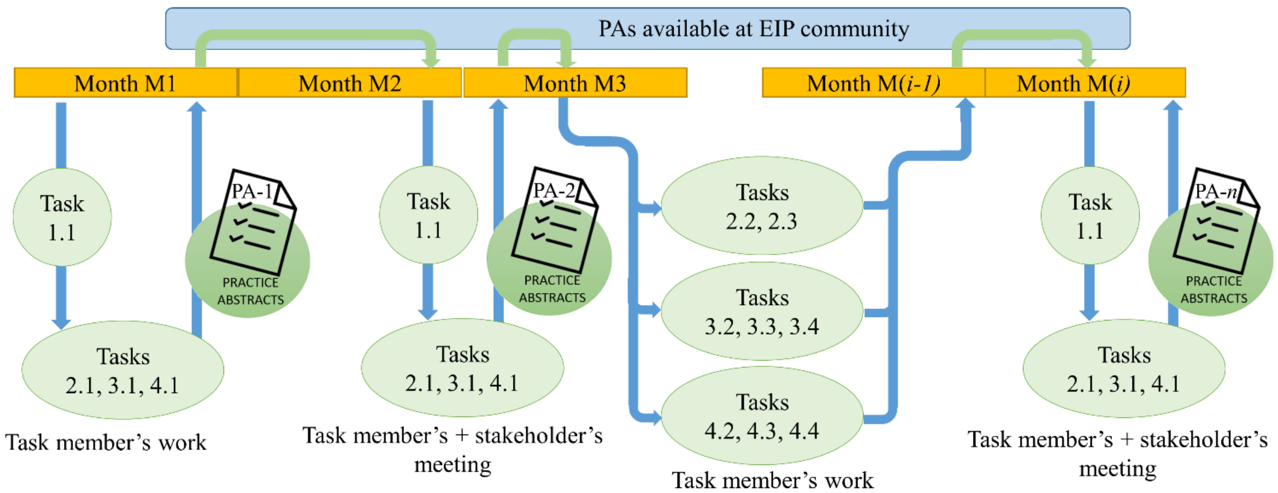


Fig. 3.1. Multi-actor involvement procedure (scheme for initial tasks)

This plan allows, using the EIP common formats (Practice abstracts), to involve stakeholders in the developing loop. Involvement is meant as continuous activity.

3.2. Overview of Multi-actor involvement procedure in the project

In the first period the following steps of the Multi-actor involvement procedure were carried out:

STEP 1 – At the beginning of the project (October 2020), partners involved in the scientific and technical developments (WP2 to WP5) elaborated information related to the expected characteristics of the subsystems and components, as well as the complete system. This information was summarised as an EIP Practice Abstract (PA-2 draft), and issued at the end of October 2020.

STEP 2 – At the end of November 2020, a technical meeting was held to discuss the preliminary equipment characteristics advanced in PA-2 draft. A preliminary list of groups and stakeholders (potential readers of the Practice Abstracts) was prepared at the end of October 2020. Protection of databases personal information according to rules and information storage – see D.8.1-"POPD - Requirement No. 1".

Stakeholders were invited to attend the meeting to discuss the content of PA-2 draft through the organization of the **First WeLASER Stakeholders' Event**. The outcomes of the meeting produced the final version of the abstract (PA-2), which was the starting point of the technical developments (beginning of December 2020).

STEP 3 – focused events were organised including: **Second WeLASER Stakeholders' Event** in May 2021, **Third WeLASER Stakeholders' Event** on November 19th 2021, **Fourth WeLASER Stakeholder's Event** on November 24th 2022. The **Fifth Stakeholder Event** on July 26th 2023 was oriented on evaluation of the WeLASER project and field demonstration of the machine. Questionnaire was distributed among the stakeholders and the responses served the purpose of preparing the D1.4. The outcomes of the meeting were summarised in PA-11, PA-20, PA-41, PA-53 accordingly.

STEP 4 – Involvement and interactions with stakeholders have been maintained continuously. A periodic revision of the list of stakeholders in each country and at EU level has been carried out. Also, stakeholders have been informed of the evolution of the project, for instance, every six months through the newsletter or thanks to specific activities like the Demonstration Field Days in July 2023, August 2023, and September 2023. Stakeholders were invited and participated in these activities providing feedback and proposing ideas to improve the final prototype and for further developments.

4. Identification, involvement, coordination and knowledge exchange with stakeholders and other entities

WeLASER uses a multi-level approach to develop and assess its innovative technology in order to deal with multiple effects in different domains, including environmental, economic and socio-cultural considerations, forecasting system behaviour and technology evolution, uncertainties and risks. This activity performed within Task 1.1 according to DoA is led by COAG with support of IETU and involvement of all partners.

4.1. Identification and involvement of stakeholders

Identification and involvement of stakeholders in WeLASER are key aspects because the project intends to offer practical equipment and the knowledge and recommendations from practitioners are critical for developing useful equipment. Stakeholders provide understandings of circumstantial factors not covered by the project consortium (societal disputes, gender and cultural local aspects, etc.) that are critical for the exploitation of the equipment.

With these aspects as cornerstones, identification of appropriate stakeholders with a balanced perspective was developed.

In the first period a coordinated action plan was proposed and set up on a WP1 WeLASER virtual meeting on October 26th 2020. A first identification of stakeholders was carried out by all the WeLASER partners until mid-November. Identification was continued along the duration of the project.

Stakeholders were identified and selected from four different groups:

- Governments: Regional and local governments, EU policy-makers.
- Institutions: Research, high education and standard institutions.
- Businesses: Industry (manufacturers, users), investors, etc.
- Civil society: NGOs, general public, etc.

Territorial balance was also taken into account and representatives from eight different EU countries were included (Poland, Italy, Spain, Belgium, The Netherlands, Denmark, Germany and France). Representatives at EU level were also present.

Once stakeholders were identified, they were invited to participate in WeLASER co-designing process from the beginning to the end of the project. They were informed of WeLASER general objectives and conditions and advantages of joining, mainly participating in a multi-stakeholder decision process, with access to first-hand information and access to networking and other incentives. The process was quite successful and a first list of balanced stakeholders was delivered. The list of stakeholders that are involved in the multi-actor strategy of the WeLASER Project has been growing during the process and more than 50 entities are now included, keeping a correct geographical and background balance (Figure 4.1).

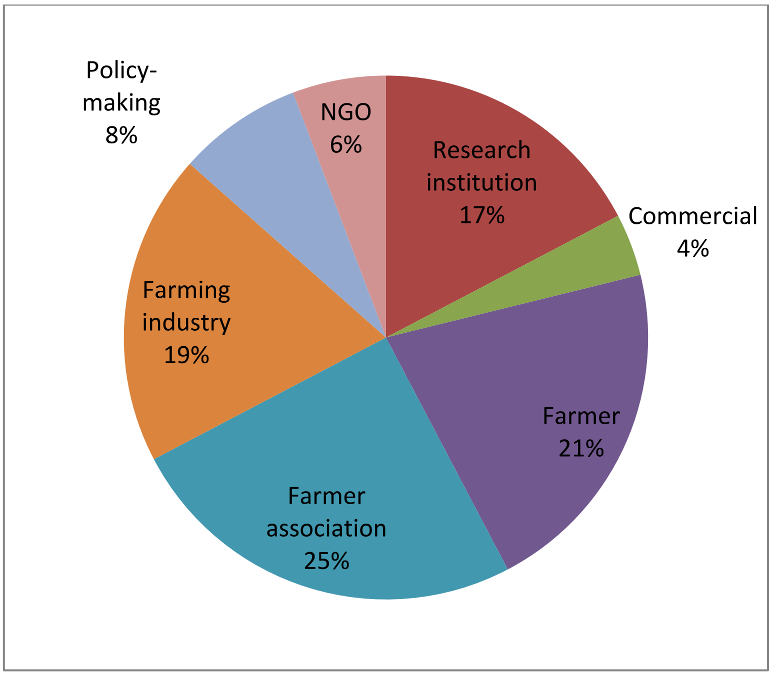


Fig. 4.1. Classification of stakeholders by area of competence

The **First WeLASER Stakeholders' Event** was organised on November 26th 2020, as a virtual event (videoconference) due to the situation caused by Covid-19. The results of this event were shared with stakeholders, presented in PA-2, and taken into account for the next stakeholder events. Identification and engagement continued after the first stakeholder event with the multi-stakeholder process loop with their participation in **the Second WeLASER Stakeholders' Event** organised online on May 25th, 2021. The event was focused on issues related to the successful application of agricultural robots using laser techniques for weeding operations. The results were communicated in PA-11.

During the second period, the multi-actor approach was developed to follow up the previous activities and the project flow as established in the planned strategy. Continuous contact with and between stakeholders were held and specific measures were deployed:

The **Third WeLASER Stakeholders' Event** was organised on-line on November 19th, 2021. It was focused on key environmental requirements in relation to farmers' and societal needs and respective EU policies. The main key points raised by the stakeholders were summarised in the Practice Abstract 20.

The **Fourth WeLASER Stakeholders' Event** was organised on-line on November 24th, 2022. It was focused on the results of the WeLASER machine integration, its testing, its key features, functionalities and efficiency, as well as key factors and strategies for its successful implementation. The main key points raised by the stakeholders were summarised in the Practice Abstract 41.

The **Fifth WeLASER Stakeholders' Event**. The fifth, and last, Stakeholder Event was organized by

COAG and held in the Centre for Automation and Robotics, CSIC (Arganda del Rey, Madrid, Spain) on July 26th, 2023. The main objective of this Stakeholder Event was to address the implications of the future Regulation on the sustainable use of plant protection products (SUR Regulation), as well as the future alternatives in crop protection products. The main key points raised by the stakeholders were summarised in the Practice Abstract 53.

Apart from WeLASER events, four focus Group Interviews were carried out.

- **Focus Group Interviews**. Four Focus Group Interviews were organised as on-line events to exchange with stakeholders about the future implementation of precision agriculture techniques such as WeLASER in weed control:

- International - European dimension - 2nd of December 2021
- Poland – 3rd of February 2022
- Netherlands/Belgium – 10th of February 2022
- Spain – 24th of February 2022

Over 50 stakeholders participated in the events, including farmers, farmers' association representatives, research and agricultural institutions, and machinery producers. Four Practice Abstracts were delivered based on the results (PA 22, 27, 28 and 29).

Apart from the events, all partners were involved in knowledge exchange with stakeholders during events such as fairs, workshops and conferences dedicated to innovative agricultural technology as well as through informal contacts with relevant organisations and experts.

A specific example of mutual enrichment is covered in Practice Abstract 34. Institutions, such as OECD, are working on security aspects and the WeLASER consortium must be aware of future indications of those committees with influence in agriculture. The “Estación de Mecánica Agrícola” is an active stakeholder in the WeLASER project and, as the official laboratory of the Spanish Ministry of Agriculture, Fisheries and Food, participates in the OECD Tractor Codes committee, which is working on the standardisation and testing of systems related to the safety of these machines. The role of the WeLASER stakeholders is key in this regard, within the framework of the multi-actor approach, so that the evolution of the technological solution is adapted to the reality and the sector practical and legal needs.

The balance of the multi-actor process during the whole development of the project is positive. The multi-actor approach has shown its potential. As explained, several exchanges have been held: for instance, five stakeholder events and four focus groups. They have been determinant in defining the preliminary system characteristics (for example, to use a 3-point hitch or to increase the implement width), regarding security and safety issues (to include safety systems switching off the machine in unexpected conditions), or barriers and economic opportunities (for instance, flexibility of the application and its modularity, ease of use or proof of cost-effectiveness).

The effective interaction with stakeholders provided information to the Consortium about key performance parameters for further improvement. WeLASER project considered these contributions during the final stage of the project but also will take them into account for possible future implementations of the invention:

- Autonomous continuous work of the robot during the day and night is potentially one of the key benefits.
- The most efficient way of its application is to combine WeLASER in-row weeding with mechanical inter-row weeding.
- Sustainability issues such as energy performance, use of renewable energy and durability should be considered.
- There are limitations to the use of the machine the type of crops, way of production, e.g., low tillage, stage of growth and its use must be wisely planned.
- Strategies of WeLASER commercialisation can depend on socio-economic factors, with leasing and buying of the machine as the most viable implementation strategy, with large-scale farmers or organic farms seeking to acquire the equipment with a one-time payment and small- scale farmers who prefer temporary access to the equipment for a predefined period, offering flexibility to fit their budget.

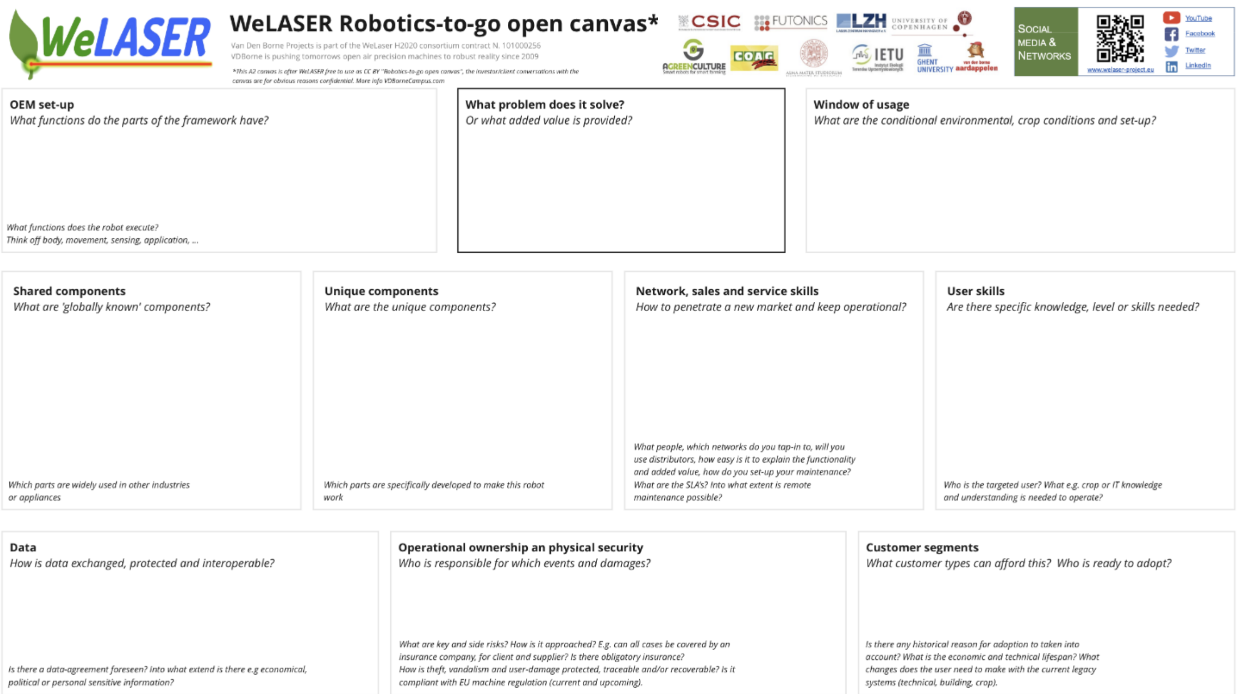
Stakeholders also remarked that some important elements to take into account for further technical developments and innovations, for example:

- Today, chemical control is the most used and cost-effective measure for many farming problems.
- Promoting the sustainable use of herbicides and developing viable alternatives, like organic or non-chemical methods, for farmers is really important.
- Developing and financing public research and innovation for conventional and alternative methods is a key element for the future of farmers and European agriculture.

During the project, all partners interacted intensively within their already established networks or with new parties and organisations expressing interest in WeLASER. Actions were undertaken to use project results as a basis for further development of the invention as a commercial product to be applied in practice in various sectors (see Table 4.1).

Table 4.1. VDBP activities related to the commercialisation of WeLASER

Market oriented activities – Netherlands' example
VDBP has been interacting with robot builders and machine developers over the years. Some of them were participating in WeLASER's Stakeholder Events and field demonstrations. They actively reviewed documentation available on the WeLASER website and discussed it with VDBP. VDBP has developed 4 interest groups: Arable Land, High Tech Community gardens, City management and Green rooftops maintenance. Because in the initial talks, there were too many loose ends the team realised that they have needed a 'canvas' like the open business model canvas (see below).



WeLASER Robotics-to-go open canvas*

Van Den Borne Projects is part of the WeLaser H2020 consortium contract N. 101000256
VDBorne is pushing tomorrows open air precision machines to robust reality since 2009

*This A2 canvas is after WeLASER free to use as CC BY "Robotics-to-go open canvas", the investor/client conversations with the canvas are for obvious reasons confidential. More info VDBorneCampus.com

OEM set-up
What functions do the parts of the framework have?
What functions does the robot execute? Think off body, movement, sensing, application, ...

What problem does it solve?
Or what added value is provided?

Window of usage
What are the conditional environmental, crop conditions and set-up?

Shared components
What are 'globally known' components?
Which parts are widely used in other industries or appliances

Unique components
What are the unique components?
Which parts are specifically developed to make this robot work

Network, sales and service skills
How to penetrate a new market and keep operational?
What people, which networks do you tap-in to, will you use distributors, how easy is it to explain the functionality and added value, how do you set-up your maintenance? What are the SLA's? Into what extent is remote maintenance possible?

User skills
Are there specific knowledge, level or skills needed?
Who is the targeted user? What e.g. crop or IT knowledge and understanding is needed to operate?

Data
How is data exchanged, protected and interoperable?
Is there a data-agreement foreseen? Into what extend is there e.g economical, political or personal sensitive information?

Operational ownership an physical security
Who is responsible for which events and damages?
What are key and side risks? How is it approached? E.g. can all cases be covered by an insurance company, for client and supplier? Is there obligatory insurance? How is theft, vandalism and user-damage protected, traceable and/or recoverable? Is it compliant with EU machine regulation (current and upcoming).

Customer segments
What customer types can afford this? Who is ready to adopt?
Is there any historical reason for adoption to taken into account? What is the economic and technical lifespan? What changes does the user need to make with the current legacy systems (technical, building, crop).

There is also another segment of golf lanes under discussion. The team at VDBP co-developed in the past the GreenBot by Precision Makers and learned that the hard way investors need results provided in cost per unit and the only way to achieve it is to help suppliers create new markets for their parts, so the cost per unit goes down. Examples of further activities are presented below:

Example 1:
In 4 months, a lot of time was spent helping an industrial designer who is interested in combining WeLASER result with his 30-meter circle farm prototype. Wageningen University Research is interested to write a proposal of a project regarding this application - the consortium will be informed. A work package is proposed to see if WeLASER results can be combined with the circle farming concept and if successful a spinoff can be launched. For this activity WeLASER consortium has to be involved.

Example 2:
After the WeLASER Precision Days and press coverage in the Netherlands there are many farmers calling VDBP who saw WeLASER and asked about its availability. It seemed that the price was not an important issue. A big vegetable grower in our arable land group expressed the view that he can't wait and he asked Carbon Robotics to provide demo and finally ordered it. VDBP using the wisdom inside WeLASER portal also helped with this business case. There is an interest to compare WeLASER and CarbonRobotics and an appropriate funding is sought. For this purpose, VDBP is looking at Dutch-Belgium-German ambition to work more together on testing, validating, developing as the farmers have the same brands and the same type of fields.

Example 3:
Weed Control being the participant of the Dutch network and active WeLASER's Stakeholder is interesting in application of WeLASER solution in cities for weed removal in green spaces.

Example 4:
A new idea is to explore WeLASER as weeding technique for maintaining rooftops. Appropriate setup has to be designed with separation of the heavy part of energy supply and high-power laser which does not have to be moved to the rooftop and the targeting system used on the rooftops.

Informed Consent Process (ICP) rules were elaborated for the multi-stakeholder activities. The events organised took into account the voluntarily consent of the participants to the collection and use of their information according to the developed privacy policy/other written documentation provided to them. For these purposes, the Informed Consent Forms are used. Personal data provided by participants of workshops and project events have been used and stored in accordance with the General Data Protection Regulation. - Gender aspects were monitored and controlled throughout the project duration.

4.2. Coordination and knowledge exchange

4.2.1. First WeLASER Stakeholders' Event

The first event with the identified stakeholders was organised by COAG on November 26th, 2020. The main aim was to stimulate involvement and to include stakeholders in the decision loop regarding the definition of system characteristics. Detailed information was provided to stakeholders about the project and the main features of every subsystem to conclude with the specifications of the overall weeding equipment. It was also provided an overview of the multi-actor strategy, the role of the stakeholders in the project, specific ways to cooperate and different benefits of being involved.

An animated discussion was held, with numerous interventions from stakeholders and consortium members, about the overall WeLASER project with a specific focus on the opportunities and barriers for market adoption of this technology, but also on specific questions on system characteristics. Also, some polls were carried out to optimize participation in this online event.

A very good evaluation was received from participants. Twenty-one (21) stakeholders participated in the event in a well-balanced representation from a regional and background point of view. End-users' participation was relevant and, according to the multi-actor strategy, stakeholders' contributions are taken into account in the definition of system characteristics, but also in the design of future activities of WeLASER. As the event was held through an online platform, physical information and engagement material was sent to stakeholders two weeks after to enhance their commitment and to prepare future actions.

4.2.2. Second WeLASER Stakeholders' Event

The Second WeLASER Stakeholders' event was organised by IETU and held virtually on May 25th, 2021. Over 40 interested professionals representing end users, industry, researchers, policy makers and NGOs interested in this project got together to discuss the WeLASER issues related to successful application of agricultural robots using laser techniques for weeding. These included the security and safety issues, infrastructures needed for efficient performance of the robot, barriers and economic opportunities for implementation of the invention in practice. Invited experts and consortium members presented legal and practical aspects of agro-robotics safety, efficiency of the machine and economics. The panel discussion was held with representatives of farmers with the focus on barriers and challenges for real-life application of WeLASER invention with general discussion following up.

General discussion with participation of stakeholders and consortium members was focused on potential barriers and bridges of WeLASER application in practice related especially to infrastructural requirements, safety issues, legal, policy and economic aspects. Stakeholders expressed positive view on application of WeLASER invention in practice and provided valuable insight into potential problems. Some polls were carried out to stimulate discussion in on-line event.

A good evaluation was received from participants. Stakeholders participated in the event in a well-balanced representation from a regional and background point of view. Stakeholders' contributions are taken into account in further development of the system and in preparation of further activities of WeLASER project. The minutes and presentations were sent to the stakeholders.

4.2.3. Third WeLASER Stakeholders' Event

The Third WeLASER Stakeholders' Event was organised by IETU as a virtual event (videoconference) on November 24th, 2022. The agenda of the event and general information on attendees is included in Annex 1. Twenty (20) stakeholders participated in the event in a well-balanced representation from a regional and background point of view. The event was a new opportunity to involve stakeholders in the project activities. It was focused on key environmental requirements in relation to farmers' and societal needs and respective EU policies.

The discussion was predominantly based on views of the experts who presented key environmental aspects of WeLASER invention and outlined environmental and health benefits of WeLASER. A feedback from an interview of farmers in the Kymi Organic Coop in Finland related to WeLASER technique was delivered. Environmental aspects were also highlighted during presentations of the work performed in particular work packages. Environmental and health benefits in WeLASER system application should be enhanced as the enablers of its wide application. It was expressed by the participants that environmental issues in WeLASER constitute a significant aspect in further development of the invention and its practical applications. Lesser environmental contamination is viewed as the key benefit. Healthy food was also indicated as a relevant consideration. The minutes and presentations were sent to the stakeholders. Stakeholders' contributions are taken into account in further development of the system and in preparation of further activities of WeLASER project.

A good evaluation was received from participants. The minutes of the event were sent to the stakeholders.

4.2.4. Fourth WeLASER Stakeholders' Event

The Third WeLASER Stakeholders' Event was organised by IETU as a virtual event (videoconference) due to the situation caused by the Covid-19 on November 19th, 2021. The agenda of the event and general information on attendees is included in Annex 1. Forty (40) participants take part in the event including farmers, representatives of research and agricultural institutions, policymakers, NGOs and project partners. The event was an opportunity to present the key developments in the project and discuss the future implementation of the invention. It was focused on the results of WeLASER mobile robot integration and field tests. participated in the event in a well-balanced representation from a regional and background point of view. The discussion was based on experts' presentations from consortium who overviewed the status of development aspects of WeLASER for particular components of the invention and outlined social benefits of WeLASER application. Experts and stakeholders pointed out the need for further improvement of the key performance parameters related to the efficiency of the weed recognition system as well as the high-power laser developed in a flexible way to meet specific expectations of farmers and other potential users. Also, the potential opportunities for efficient use of the weeder such as night and day work, combination of WeLASER in-row weeding with mechanical inter-row weeding were discused. Sustainability issues were raised with energy performance as the crucial determinant. The stakeholders pointed out at some limitations to the use of the machine, the type of crops, the way of their production, e.g., low tillage, stage of growth, etc. There is a need for strategies of WeLASER commercialisation depending on socio-economic factors with leasing and buying of the machine as the most viable implementation strategy. A good evaluation was received from participants. The minutes of the event were sent to the stakeholders.

4.2.5. Fifth WeLASER Stakeholders' Event

The fifth and last Stakeholders' Event was organised by COAG and held in the Centre for Automation and Robotics, CSIC (Arganda del Rey, Madrid, Spain) on July 26th, 2023. The main objective of this Stakeholder Event was to address the implications of the future Regulation on the sustainable use of plant protection products (SUR Regulation), as well as the future alternatives in crop protection products. More than 40 experts from European institutions, national authorities, NGOs, the crop protection industry, farmers, farmers associations and other agents provided their visions. Implications for EU production of the Regulation on the sustainable use of plant protection products

A round table about implications for EU production of the Regulation on the sustainable use of plant protection was chaired by Manuel Linares, the WeLASER Dissemination Manager (COAG), and attended by José Manuel Roche (European Economic and Social Committee), Patricia de Almandoz (COPA-COGECA) and Carlos Romero (Spanish Ministry of Agriculture, Fisheries and Food).

The following conclusions were dropped after short presentations of the round table members and a general discussion with the event attendees:

- SUR proposal has helped raising awareness and to achieve a more rational and sustainable use of pesticides,
- Transition should include real and cost-effective alternatives for farmers, like new technologies and improving the funding for R&D,
- Some criticisms were raised against the SUR proposal: excessive ambition, lack of scientific basis and agronomic balance, complex implementation in sensitive areas, or not including socio-economic sustainability

A round table about future alternatives in crop protection products was chaired by Janusz Krupanek, leader of the Multi- actor Approach for WeLASER (IETU), and attended by Evelyne Alcázar (IFOAM-

International Federation of Organic Agriculture Movements), Carlos Palomares (CROPLIFE EUROPE), and Andrés Góngora (COAG).

The following conclusions were dropped after short presentations of the round table members and a general discussion with the event attendees:

- Today, chemical control is the most used and cost-effective measure for many farming problems.
- Promoting the sustainable use of herbicides and developing viable alternatives, like organic or non-chemical methods, for farmers is significant.
- Developing and financing public research and innovation for conventional and alternative methods is a key element for the future of farmers and European agriculture.

4.2.6. Focus Groups Interviews

As part of the knowledge exchange with different stakeholders through the multi-actor approach, four Focus Group Interviews were organised during the second period:

- International - European dimension - 2nd of December 2021 carried out by IETU together with UGENT
- Poland – 3rd of February 2022, carried out by IETU
- Netherlands/Belgium – 10th of February 2022, carried out by UGENT
- Spain – 24th of February 2022, carried out by COAG

The aim was to get valuable insight regarding the future implementation of precision agriculture techniques such as WeLASER in weed control. These online events gathered over 50 stakeholders, including farmers, representatives of farmers associations, research and agricultural institutions, and machinery producers. Valuable information for successfully implementing the WeLASER technique was obtained during the workshop. In the events, focus group discussion and SWOT analysis were conducted to identify the main factors that impact the implementation of the WeLASER technique. SWOT analysis methodology was used with the application of online tools. For a more detailed information, see Section 8.

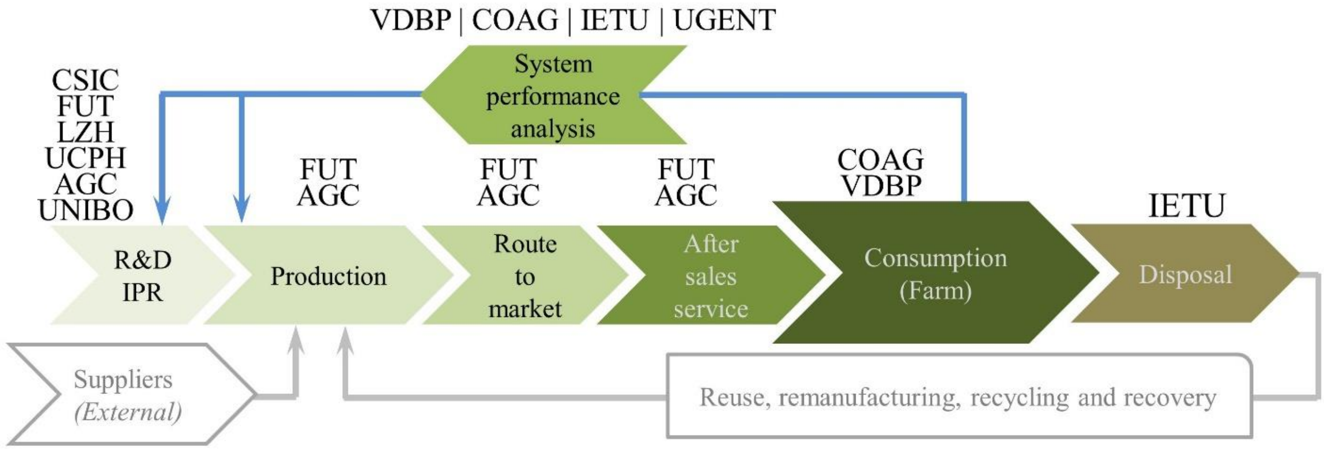
5. Scientific and Technical Continuous Assessment – Value Chain Follow-up

TASK 1.2 in the DoA was devoted to carrying out the continuous scientific and technical assessment of the WeLASER project. This task was led by CSIC and supported by all the project partners. The activities started in M5 (February 2021) and continued until the end of the project development in M39 (December 2023).

This task was devoted to monitoring all the aspects included in the value chain presented in Fig. 5.1 (see Fig. 1.1 in the DoA of the Grant Agreement), which comprises

- the scientific-technical and evaluation activities and

- the monitoring of all the topics related to financial marketing opportunities to deploy the system in the market
- The project partners could cover the steps in the value chain illustrated in Fig 5.1; however, interested stakeholders and institutions were involved in the activities to feedback on the decisions to be made to achieve the proposed results. The identification, involvement, and coordination of the stakeholders, both individuals and institutions, is presented in Section 4 above.
- According to the DoA, the task is divided into two subtasks to provide a separate evaluation of equipment and procedures: Subtask 1.2.1 – Assessment of the equipment development and tests and Subtask 1.2.2 – Assessment of the procedures (communication, dissemination, exploitation, and risks).



Note: The activities in grey (text and links) were out of the scope of the project

Fig. 5.1. WeLASER value chain

5.1. Assessment of the equipment development and tests

The objective of this task was to supervise (from the point of view of the multi-actor approach strategy) the individual system evaluations (Tasks 2.4, 3.5, and 4.5) and the final equipment evaluation (Task 5.3) to detect possible failures or shortcomings and propose corrections. These activities and their consequences were reported as a part of D2.1, D3.1, D4.1, and D5.3 as well as in this deliverable "D3.1-Multi-actor involvement plan and activities".

During the first three years of project development (M1 to M36), the consortium developed the different subsystems. These subsystems are finished and evaluated, and the estimation of their status of development is in Table 5.1.

Table 5.1. Status of completion of the subsystems at month 39

Subsystem	Component	Leader	Status of design/ Implementation (%)			Comments
			M12	M24	M39	
Laser-based weeding system	Laser source	FUT	40	70	90	Design: 100 % Implementation: 100 % Validation: 70 %[1]
	Diode Power supply	FUT	60	80	100	Design: 100 % Implementation: 100 % Validation: 100 %
	Chiller	FUT	40	80	90	Design: 100 % Implementation: 100 % Validation: 70 %
	Targeting system	LZH	40	65	95	Design: 100 % Implementation: 95 % Validation: 85 % The system is almost fully developed. Validation has not been fully completed. Any changes that may result from full validation will result in additional work in implementation, resulting in a 5% shortfall.
	Tests on crops and living organisms	UCPH	25	50	90	UCPH could only do some of what it expected to do because the weeding tool did not work during its stay in Denmark and Spain. In any case, UCPH did some unexpected tasks in providing annotated pictures to LZH to train the perception system and provided more PA and publications than scheduled so that UCPH used all the allocated costs.
	Laser safety	LZH	30	60	90	Design: 100 % Implementation: 90 % Validation: 70 % A thorough evaluation of all the safety components could

[1] The diode power supplies were tested and integrated. During operation no defects or failures were observed. Two chiller systems with modified electronics were integrated in the final test system on the robot. One work and one failed due to overheating of electronics during operation. The chiller has to be checked when it is back at Futonics and the environmental boundaries (temperature, airflow) for stable long-term operation have to be determined.
Two laser sources were implemented for final tests on the robot. One system worked without failures, but the other got defect after some operation time. Validation experiments with additional systems in the lab showed still some problems with the fibre components during continuous high-power operation. Futonics is improving the quality of the fibre components and cooling and is actually determining the safe operation boundaries (maximum power, pulse length at different power levels) for the laser systems developed during the project.

						not be carried out due to staff shortages and delays in delivery. As a result, not all of the ambitious safety objectives could be fully achieved. In order to ensure the suitability of the system for demo use, the systems directly affecting this were implemented and validated first.
Weed-meristem perception system	Weed-meristem perception device (Hardware)	LZH	100	100	100	According to plan
	Crop/weed discrimination algorithms	LZH	32	66	95	Design: 100 % Implementation: 95 % Validation: 85 %
	Impact-point AI-vision system and weeding control system	LZH	20	56	95	Design: 100 % Implementation: 95 % Validation:85 % Technical difficulties and a lack of time due to a shortage of specialised personnel during the demo days prevented a thorough validation of the detection systems. These validation steps were carried out in subsequent trials, but validation of the complete system is still desirable.
Autonomous vehicle for laser weeding	Mobile platform	AGC	60	80	100	The robotic platform is complete and safe.
	Smart navigation manager	CSIC	30	60	100	The Smart navigation manager consists of (see D5.1) the central controller; the Agri-decision support system (Agri-DSS), whose name was changed to Smart Operation Manager SoM (see D4.1); the planner and the supervisor; the IoT sensor network; and the cloud computing structure. All subsystems were adequately developed and integrated within the autonomous vehicle.
	IoT system	UNIBO	40	65	95	Design: 100 % Implementation: 100 % Validation: 85 %
	Cloud computing	UNIBO	40	65	100	According to the plan
System	Mass	CSIC	15	75	100	In the final integration, the

integration	distribution					platform's stability was verified, confirming the correct distribution of masses.
	Mechanical integration	CSIC	--	90	100	All subsystems were properly integrated mechanically in the final integration.
	Electrical integration	CSIC	--	90	100	All subsystems were properly integrated electrically in the final integration.
	Communication integration	CSIC	--	70	100	All communication protocols between the different subsystems were properly implemented.

A partial assessment of the scientific and technical aspects of the development of the different subsystems was made through the consortium meetings (Steering Committee Meetings and General Assemblies) listed in Table 5.2. Table 5.3 indicates several additional technical meetings to discuss technical questions and define subsystem interfaces, processes, interactions among subsystems, integrations, and evaluations. These meetings were used also for scientific and technical assessment purposes.

Table 5.2. Consortium meetings

Num.	Meeting	Date
1	Online meeting 1 – Steering Committee Meeting and General Assembly	13-10-2020
2	Online meeting 2 – Steering Committee Meeting and General Assembly	17-12-2020
3	Online meeting 3 – Steering Committee Meeting (Summer 2021)	9-07-2021
4	Online meeting 4 – Steering Committee Meeting (Autumn 2021)	27-10-2021
5	Online meeting 5 – Steering Committee Meeting (Winter 2022)	31-01-2022
6	Onsite meeting - General Assembly (Spring 2022)	27-03-2022
7	Onsite meeting - Review meeting	13-06-2022
8	Steering Committee Meeting (Hannover 2022)	20-10-2022
9	Steering Committee Meeting (Toulouse 2023)	10-03-2023
10	Online meeting 6 – General Assembly	24-05-2023
11	Online meeting 7 – Steering Committee Meeting & General Assembly	05-09-2023
12	Online meeting 8 – Scientific and Technical Committee & General Assembly	15/12/2023

Table 5.3. Technical meetings used for scientific and technical follow-up

Participants	Topic	Venue	Date
LZH, FUT, UCPH, CSIC	Laser trial in Denmark	online	25/03/2021
AGC, CSIC	Integration of mobile platform and navigation manager	Toulouse	8 – 9/04/2021
LZH, FUT, UCPH, CSIC	WP2 Tech meeting - discussion on Subtask 2.5.3-Risk assessment of large organisms (rodents, humans)	online	06/05/2021
LZH, AGC, CSIC	Three-point hitch discussion	online	28/05/2021
UNIBO, CSIC	Interaction among Smart Navigation Manager, IoT network and Cloud Computing System	online	18/06/2021 and 28/06/2021
All	Steering committee meeting – Project follow-up	online	09/06/2021
UNIBO, CSIC	Interaction of Smart Navigation Manager and Cloud Computing System	online	26/01/2022
UNIBO, CSIC	Interaction of Smart Navigation Manager and Cloud Computing System	online	24/02/2022
CSIC, UNIBO	IoT system integration	Madrid	27-31/03/2022
CSIC, UNIBO	Cloud computing system integration	Madrid	11-13/04/2022
FUT, LZH, AGC, CSIC	Integration of Laser source, power source, weeding implement	Madrid	25-28/04/2022
CSIC, UNIBO, FUT, LZH	Final system integration	Madrid	5-8/06/2023
CSIC, UNIBO, FUT, LZH	Final system integration	Madrid	18-25/07/2023
CSIC, UCPH	Field works at Taastrup (Denmark)	Taastrup	12-14/06/2023
CSIC, VDBP	Field works at Reusel (The Netherlands)	Reusel	14-16/06/2023
VDBP, LZH, CSIC	Organising the field day in Reusel (The Netherlands)	Online	30/06/2023
CSIC, FUT, LZH, AGC, UNIBO, IETU, UGENT, VDBP	Field Day 1, Madrid (Reintegration and tests)	Madrid	24-26/07/2023
CSIC, FUT, LZH,	Field Day 2, Taastrup (Reintegration	Taastrup	15-18/08/2023

AGC, UCPH, UNIBO, UGENT,	and tests)		
CSIC, FUT, LZH, AGC, UNIBO, IETU, UGENT, VDBP	Field Day 3, Reusel (Reintegration and tests)	Reusel	22-26/08/2023
CSIC, FUT, LZH, UCPH, UNIBO, IETU, UGENT	Field Day 4, Madrid (Reintegration and tests)	Madrid	23-26/09/2023

5.2. Assessment of the procedures (communication, dissemination, exploitation and risks)

The objectives within subtask 1.2.2 were to supervise the procedures indicated in section 2.2 of the DoA and monitor the expected impact (Tables 2.7 and 2.12 of the DoA).

The key performance indicators used to follow up the communication, dissemination, exploitation and risk management activities are detailed and analysed in deliverables D6.2 to D6.4 and D7.1 to D7.6. As a summary of the activity carried out in the first two years, some information taken from D6.4 and D7.6 is repeated in the following tables.

Table 5.4. Key performance indicators for communication and dissemination assessment

Key Performance Indicators				
Target audience	Type of dissemination activity	Measurement	Months 1-39	
			Current measures	Grant Agreement
The Scientific Community	Journal articles	Number of articles	11 Forthcoming: 7	30
		Number of references	>74	30
		Text views	>42039	
	International conference papers and presentations	N. of papers/presentations	23	30
	Summer School	Number of students	59	30
Student community	Lectures in MSc courses	Number of courses	4	17
	Lectures in PhD courses	Number of courses	1	17
The Industrial Community	Patents	Number of applications	2	2
	Participation at external related events	Number of events	8	5
The end users	Dissemination to farmers	N. of field and training days	3	3
	Newsletter	N. of copies	- 254 views on	300

The general stakeholders		sent/downloaded/views	the project website. - 220 offices and 31 organisations - 25 stakeholders	
	The project flyer and posters (Flyer and Poster)	N. of copies sent/downloaded	- 220 offices and 101 organisations	1500
	Project Website	Website visits	17,4K views 6.6K users	11000
	Practice Abstracts	Number	74	72
	Social media	Followers/tweets/ etc.	Twitter: 214 Followers 586 tweets Youtube: 39 subscribers 42 videos 4386 views Facebook: 38 followers Linkedin: 358 followers	
	Professional media	Number of messages/videos/ Press releases	1.750	1750
	General media	Evidence of debates in the media	5	10

Some of these measures are lower than planned. The consortium made an extra effort to achieve the total planned measures at the end of the project, but some of them could not be completed.

Regarding risk assessment, Deliverable D7.6 collects the foreseen and unforeseen risks during the project's first three years. Table 5.5 summarises the unforeseen risks under management.

Table 5.5 Unforeseen risks identified in the first three years

Risk	Description
1	Delays in the delivery of subsystems due to the delay in component supply because of COVID-19.
2	Delays in the preliminary integration if COVID-19 persists.
3	As the optical scanner hardware was not designed for outdoor conditions, the scanner hardware is possibly not robust enough for this application.
4	Laser safety for outdoor operations cannot be guaranteed sufficiently.
5	Due to the complex perception task and conditions, the development time for the perception software (algorithms, training, etc.) could take longer than expected.
6	The training data set for weed identification/meristem localisation does not sufficiently cover the possible environmental conditions on the field.
7	Due to unexpected insufficient compatibility of components or too slow communication of the implements' elements, the integration and completion of the final perception system could be delayed.
8	Reflection from a hit stone may harm the environment outside the covered area.
9	Heating dry organic matter (straws, leaves, lost paper) in the field may result in fires.
10	The working capacity (ha/hours) is insufficient to compete with other weed control methods.
11	The separation of weeds and crops is not sufficiently precise, resulting in the killing of crop plants or insufficient control of the weed plants.
12	Larger stones and deep tractor tracks may result in tilting or overturning of the robot, and laser beans may hit outside the covered area.
13	Difficulties in finding appropriate companies for CATI surveys in three partner countries
14	Non-target organisms (e.g., flying insects (bees, flies, aphids), spiders, beetles, mice, earthworms) will be harmed if they fly or move directly into the laser beam.
15	The laser source is not operative or breaks during the tests and demos.
16	The weeding tool (AI-vision system & laser scanners) is not operative or breaks during the tests and demos.
17	The mobile platform breaks during the tests and demos.
18	The Central Controller is not operative or breaks during the tests and demos.
19	The IoT sensor network is not operative or breaks during the tests and demos.
20	Cloud Computing System is not operative or breaks during the tests and demos.
21	The drought in Europe and especially in Spain, prevents the achievement of crops for tests and demonstrations
22	Many deliverables have been delayed longer than a month so far. This is especially critical at the end of the project because time slots for the reaction are shorter, and there is a risk of issuing only some of the deliverables within the project period.

6. Economic assessment and risk management in farms

To evaluate the economic viability of the WeLASER solution, a comprehensive analysis was undertaken, encompassing both investment and operational expenditures, alongside the description of economic gains for farmers. This evaluative process drew upon a synthesis of diverse data sources to ensure a robust and holistic assessment. To calculate the investment and operational costs, a survey was distributed to the project partners in order to gather cost data on the different components of the WeLASER solution. Notably, the iterative nature of this process allowed for dynamic updates to the cost data throughout the project's duration. Meetings with the project partners were scheduled to discuss and improve the collected data. Data regarding economic benefits was extracted from the adoption survey developed and carried out in WP6. A total of 298 valid responses from the survey in Belgium, the Netherlands, Germany, Denmark, Italy, Poland and Spain were collected. Furthermore, figures regarding the cost of conventional weeding were found in scientific literature.

6.1. Cost of producing the WeLASER solution

The total cost of producing one WeLASER machine that can handle 4 rows is shown in Table 6.1. At the moment, the production of one WeLASER machine would cost around **382,311** euro.

As a sensitivity analysis, the cost of the WeLASER solution is calculated in case higher production levels are reached. When producing a higher number of machines, the production cost decreases significantly. The production of a WeLASER machine would cost **161,357 euro** and **121,929 euro** when production levels reach 100 units and 1000 units, respectively (Table 6.1). Due to confidentiality issues, the costs of subsystems could not be shown in this deliverable. The following assumptions were made for the cost calculations:

- When production levels of fibre-lasers reach 100 units per year, one fibre-laser costs much less. Costs per unit further decrease when 1000 units per year are produced. Four lasers per WeLASER vehicle are needed. The cost below 100 units is equal to the cost for one unit and the costs between 100 and 1000 units is equal to the cost for 100 units.
- The production costs for the meristem perception system, controller, autonomous vehicle and laser scanner, and the integration costs decrease by 5% for every 100 units produced.
- The costs for the cloud computing license will decrease tremendously when 100 and 1000 licenses are sold. Costs for the cloud computing system decrease per additional unit and can be calculated by extrapolating the numbers for 1, 100 and 1000 units.
- It is assumed that labour costs stay constant due to two opposing trends. On the one hand inflation over the years is expected, which translates in increasing wages (Eurostat 2023). On the other hand, the increased production leads to lower labour costs/unit. To

simplify the calculations, it is assumed that both (more or less) cancel each other out.

Table 6.1. Costs of Goods Sold (COGS) per WeLASER production levels.

Manufactured units per year	Total COGS (€)
1	382,311
50	232,661
100	161,357
250	150,625
1000	121,929

6.2. Sales price of the WeLASER solution

In order to calculate the economic feasibility for manufacturers, the sales price of the WeLASER solution should be known. The sales price can be determined in multiple ways: (1) by calculating the production costs and adding a profit margin, (2) by looking at farmers' willingness to pay for the machine and (3) by considering the competitive landscape for WeLASER.

To assess the willingness to pay (WTP), questions regarding the sales price of the WeLASER solution were added to the survey that was developed and carried out in WP6. In this case the WTP assessment is not suitable to determine the sales price for WeLASER since WeLASER is still an unknown product to them. However, some important information regarding potential customers could be extracted from the survey results. The mean willingness to pay is around 150,000 euro. When the sample is divided in Northern (Belgium, the Netherlands, Germany and Denmark), and Southern and Eastern (Italy, Spain and Poland) Europe the mean willingness to pay is 175,000 and 118,000 euro, respectively. When production increases and production costs decrease the price that farmers in North-European countries are willing to pay almost equals the cost of production. The willingness to pay estimates consider both conventional and organic farmers. The exploitation plan identified that organic farmers are willing to pay around 35,000 euro more than conventional farmers. Thus, WeLASER might be a viable solution for weed control in organic farming. Other determinants of farmers' willingness to pay for WeLASER are discussed in the exploitation plan.

Similar as for existing agricultural machinery manufacturers, a gross profit margin of 20-30% is preferred. This means that the selling price, when production levels reach 100 and 1000 machines, should be from €166,264 to €209,764 and from €146,315 to €158,508, respectively.

Considering the competitive landscape of the WeLASER solution, a sales price range between €250,000 and €300,000 seems reasonable, which would make the production of WeLASER machines profitable if produced in larger quantities. There are many technical differences between competitors in the current market and hence their prices, ranging from 350,000 euro for WeedBot and up to more than 1 million euro for Carbon Robotics. More information regarding competitors and pricing can be found in the Exploitation Plan (2. Competitive analysis and 4. Marketing plan). This price range also makes the investment in the WeLASER solution feasible for farmers. This will be shown in the Exploitation Plan.

6.3. Manufacturers' profitability analysis

Production becomes profitable when 100 units per year are reached, considering a sales price of 250,000 euro (Table 6.2). Besides the production costs, other costs such as administration costs, R&D, etc. need to be taken into account. It is assumed that these costs are 13% of the sales revenues (based on the cost structure from John Deere company According to the exploitation plan production is expected to reach 100 units/year in 2027 and 1000 units/year in 2036. A more in-depth profitability assessment, considering both sales and renting revenues, is described in the exploitation plan. In conclusion, it is assumed that WeLASER becomes profitable from 2027 onwards, taking into consideration that there is no commercial production yet in 2024 and 2025.

Table 6.2. Profitability of WeLASER.

#WeLASER	1	50	100	250	1000
Year		2026	2027	2030	2036
COGS per WeLASER	382,311 €	232,661 €	161,357 €	150,625 €	121,929 €
Production costs (€1k)	382 €	11,633 €	16,136 €	37,656 €	121,929 €
Sales revenue (€1k)	250 €	12,500 €	25,000 €	62,500 €	250,000 €
Other costs: General, admin, sales, and R&D (13% of sales)	32,5 €	1,625 €	3,250 €	8,125 €	32,500 €
Profits (1000 €)	-164,5 €	-758 €	5,614 €	16,719 €	95,571 €

6.4. Cost for farmers

A sales price of 250,000 euro is considered reasonable in light of the competitive landscape for WeLASER. In addition to the initial investment cost, the utilization of WeLASER incurs operational expenses. The operational costs encompass fuel, maintenance, and repair costs. The maintenance cost for the autonomous vehicle and lasers is 800 and 500 euro per year, respectively, while the other components of WeLASER do not require any maintenance. WeLASER project partners estimated the depreciation period for the autonomous vehicle and lasers to be 5 years. The costs/ha were calculated for three scenarios in the exploitation plan and are shown in Table 6.3.

Table 6.3. WeLASER costs per hectare for optimistic, pessimistic and realistic scenario.

Item	Formula	Optimistic	Pessimistic	Realistic
Equipment purchases price (€)	A	250,000	250,000	250,000
Intended years of ownership[2] (year)	B	5	5	5
Work rate (ha/day)	C	9	3	6
Treatment window (day/season)	D	15	15	15
Number of times for each field (ha)	E	3	3	3
Total ha treated per season (ha)	CxD/E=F	45	15	30
Total ha treated per year (ha), 2 seasons/year.	Fx2=G	90	30	60
Estimated value at resale[3] (€)	H	50,000	50,000	50,000
Fuel cost				
Price of fuel (€/litre)[4]	L	1,8	1,8	1,8
Average fuel cost (€/ha)	M	100	100	100
Fuel cost per year (€)	MxG=V	9,000	3,000	6,000
Repair (€/year)	N	1,000	1,000	1,000
Maintenance cost (€/year)[1]	O	1,300	1,300	1,300
Depreciation (€/year)	(A+H)/B=R	40,000	40,000	40,000
Total equipment cost (€/year)	V+N+O+R=T	51,300	45,300	48,300
Cost per ha (€)	**T/G**	**570**	**1,510**	**805**

Smaller farms, constrained by financial considerations, may find it challenging to purchase a WeLASER machine. In light of this, alternative economic models such as machine renting or subcontracting should be considered. Stakeholders also pointed out the importance of alternative economic models during the focus group discussions conducted in WP1. Farmers who rent the WeLASER equipment do not pay for operational expenses themselves. However, it is assumed that renting the WeLASER solution is 10% more expensive per hectare due to the additional service provided (transport, maintenance, etc.). Hiring a subcontractor to use the WeLASER is also more expensive. It is assumed that, compared to buying the equipment, subcontracting is 20% more expensive. The main benefits of hiring a subcontractor is the additional service provided (transport, maintenance, etc.) and that farmers do not need to worry about operating the equipment at all and thus saving valuable time. Costs per hectare for the three economic models are shown in Table 6.4. Three scenarios are considered for each economic model, the optimistic, pessimistic and realistic scenario with a varying work rate of 9, 3, 6 hectare per day, respectively, for the WeLASER machine. More information regarding the calculation of costs can be found in the exploitation plan (D6.4-

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[2] Based on the depreciation time of laser systems and the autonomous vehicle is 5 years. After 5 years, the maintenance is expected to increase.

[3] Based on the similar salvage cost of tractors. See more here.

[4] Based on the Average diesel price in several Western EU countries.

Communication, dissemination, and exploitation activities).

Table 6.4. Costs per hectare for buying, renting and subcontracting the WeLASER.

Economic model	Optimistic	Pessimistic	Realistic
Buying (€/ha)	570	1,510	805
Renting (€/ha)	627	1,661	886
Sub-contracting (€/ha)	684	1,812	966

6.5. Comparison against conventional weeding methods

The exploitation plan (D6.4) identified the main target group for WeLASER as organic farmers. Manual weeding is often used in organic farming practices. The cost of manual weeding depends on multiple factors like the labour cost and the amount of hours needed per hectare. Manual weeding on a sugar beet field with a hoe takes around 75-85 hours per hectare (Shang, Pahmeyer et al. 2023). When considering a labour cost of €20-30 per hour in Northern countries for manual weeding, one-hectare costs €1500-2550. In practice, manual weeding is often combined with mechanical weeding practices, lowering the cost per hectare. In conclusion, using the WeLASER machine that is bought, rented or operated by a subcontractor, is more cost-efficient for organic farmers.

Chemical weeding for one hectare of sugar beet field in Germany costs between 300 and 400 euro and includes herbicides, fuel, depreciation of machinery, labour costs, interests and maintenance of machinery (Gerhards, Risser et al. 2023). Compared to weed control using WeLASER, chemical weeding is still cheaper. As a result, conventional farmers might be less inclined to choose for WeLASER. However, the problems related to herbicide-resistant weeds are increasing and regulations regarding herbicide use are becoming more strict (Petit et al., 2015; Westwood et al., 2018). This could make the WeLASER weeding system a suitable alternative in the future for conventional famers.

7. Health and environmental issues

According to DoA health and environmental issues are the subject of Task 1.4 led by IETU with support from all partners. The activity started in February 2021 (M5) and was scheduled till September 2023 (M36). The main objective is to consider all the aspects, direct and indirect, that could potentially affect the health and environment associated with commercial application of the new technology. Health and environmental issues for the innovative technology are assessed through the Life Cycle Assessment (LCA) and interaction with experts and stakeholders. Activities carried out in the task are as follows below.

7.1. General overview of activities

First reporting period (October 2020 to September 2021)

- Stakeholders interaction regarding health and environmental issues included Second Stakeholder Event. It was dedicated to safety issues, legal aspects and infrastructural requirements for efficient operations. The results were useful for designing of invention and further planning and carrying out work in this task.
- Basic assumptions for LCA were elaborated according to literature on LCA for agricultural practices in weed control (Table 7.1.). They included the goal, system boundary and functional unit.
- SimaPro tool and EcoInvent v3 database was updated and reviewed for the purpose of LCA application.

Table 7.1 Key assumptions for WeLASER invention Life Cycle Assessment

LCA key assumptions	
LCA methodology based on the ISO 14040:2009 standard and guides (ILCD Handbook(EC-JRC, 2011a), PEF Guide. The following impact categories are investigated as baseline according to ReCiPe 2016 method:	
• Particulate matter • Tropospheric ozon formation • Ionizing radiation • Stratospheric ozon depletion • Human toxicity (cancer) • Human toxicity (non-cancer) • Global warming • Water use • Freshwater ecotoxicity • Freshwater eutrophication	• Tropospheric ozon (ecology) • Terrestrial ecotoxicity • Terrestrial acidification • Land use/transformation • Marine ecotoxicity • Mineral resources • Fossil resources
In the assessment WeLASER system is compared with reference scenarios. The assessment is to be carried out for an application model and/or variants of WeLASER invention worked out during WP1 events. The application model has to refer to the technical parameters, stakeholder interactions and the pilot case application settings.	

Second reporting period (October 2021 to September 2022)

- The Third Stakeholders' Event which was organised in November 2021 was focused on environmental issues including environmental performance, key benefits and potential impacts related to WeLASER application in practice. The results helped in focusing the aim and scope of assessment.
- WeLASER invention was characterised based on D5.1 information and literature data for agricultural systems and devices, literature review on LCA for key components of WeLASER and interaction with partners related to key features of the robot,
- Model of WeLASER application in three test crop systems was developed and WeLASER application scenarios application scenarios defined including baseline scenario and best-case scenarios. The three crop production systems were characterised using EcoInvent v3 data. Additionally, relevant literature was consulted and the data accordingly adjusted.

- Simplified Life Cycle Inventory for WeLASER technique and competing techniques was prepared, based on data delivered by WeLASER partner/partners, Ecoinvent v3 database, literature review and D5.2.
- Simplified LCA assessment of WeLASER application in three crop systems was carried out.

Third reporting period (October 2022 to December 2023)

- In-depth Life Cycle Inventory for the key components of the machinery was done, based on WeLASER characterisation. It covered materials and processes used in production, operational weeding performance parameters and characterisation of machinery dismantling and disposal. Partners' information related to key features of WeLASER and literature data for analogous agricultural systems and devices were used.
- Life Cycle Assessment of WeLASER was performed for the robot and broken down into the four main components:
    - Autonomous mobile platform.
    - A weed meristem perception system.
    - A smart central controller.
    - A laser-based weeding tool with a high-power laser source and a meristem targeting system (see chapter 7.1).
- WeLASER was compared with other techniques based on Ecoinvent 3.0 data. The functional unit applied was one hectare of field under weeding, one passage operation.
- Revision, based on the final WeLASER characterisation, of LCA was prepared for WeLASER application in three crop systems – functional unit 1 kg of crop produced.

Safety issues related to WeLASER application were researched by partners UCPH, FUTONICS and AGC in the specific areas of competence. Information on environmental protection was also be reported in "D8.3 – EPQ-Requirement No. 3" of WP8. The appropriate standards related to agricultural machinery, autonomous platforms and laser use were observed and potential risks identified with adequate measures applied. Labour issues, health and risk management in farms were also discussed during interaction with experts and stakeholders and conclusions used in S-LCA, LCC and LCA. These issues were communicated in practice abstracts, newsletters, during conferences and in publications.

7.2. Life Cycle Assessment

The Life Cycle Assessment (LCA) study is a preliminary assessment of a prospective commercial product to be applied in future weeding practices based on the prototype developed in WeLASER project. LCA is a methodology for assessing environmental impacts associated with all the stages of the life cycle of a commercial product, process, or service. It comprises the following steps (see Fig 7.1):

- Definition of goal and scope,
- Inventory analysis,
- Impact assessment,
- Interpretation of results.

The main goal of the study is to assess the environmental performance of the WeLASER weeding technique and specifically (1) to identify key environmental benefits and impacts which can be stimulators or barriers to its wide implementation in crop production, (2) to identify the relevance of particular components for environmental performance in a life cycle perspective, and (3) to compare the environmental performance of WeLASER with other weeding techniques.

Based on the results, indications of its key advantages and disadvantages were provided and recommendations for improving the invention's sustainability. The results are meant to guide the developers and prospective producers in the second phase of commercialization, which can help improve the weeding tool's environmental performance and help farmers optimize its use.

The assessment was carried out as a cradle to grave analysis for a prospective four lasers weeder (see Fig 7.2), which model was developed based on the prototype characteristics provided by the consortium. The environmental impacts were expressed per 1 hectare of weeded field in one passage as the basic functional unit. Additionally, in the comparison of weeder application in the context of whole crop (sugar beet, maize, winter wheat) production systems 1 kg of product was used. The Life Cycle Inventory was prepared based on data provided by the consortium, literature and industrial information on specific components and Ecoinvent 3.0 database. The assessment was performed using SimaPro tool.

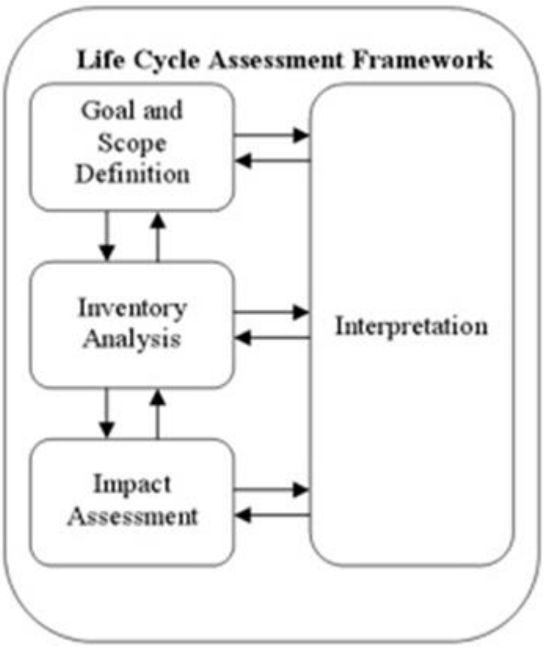

Fig. 7.1. LCA methodology according to ISO 14040

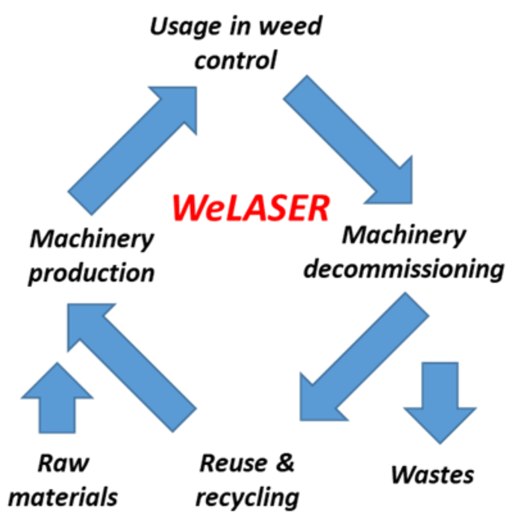

Fig. 7.2. Scope of WeLASER assessment

The Endpoint ReCiPe 2016 method (egalitarian perspective) was used for the interpretation of the results. This method translates emissions and resource extraction into limited environmental impact scores. These indicator scores express the relative severity of each environmental impact category. The results are expressed in Points (Pt) or miliPoints (mPt).

The main findings of the LCA study are as follows:

- It was concluded that the LCA study clearly indicate that the WeLASER technique is potentially a viable environmental solution. Despite its complexity, it does not entail much burden to the environment. It was stated that the main environmental impacts of WeLASER in the whole life cycle (cradle to grave) are: human toxicity (26% share of the total score for all impacts), climate change human health (24%), climate change ecosystem (19%), fossil depletion (25%) and to a lesser degree: metal depletion and particulate matter.
- The main impacts are attributed to the phase of WeLASER use and are mostly related to energy generation in diesel engine, which is needed for the high-power laser operation and machinery traction (see Fig 7.3). Climate change and particulate matter impact categories are the most relevant in this regard representing a typical profile for non-renewable energy generation.
- Relative high impact observed in the human toxicity category is the most important in the production phase. It is related predominantly to production of metals from raw materials, especially copper (burdens related to tailing ponds). The dismantling and disposal phase is characterised with a positive impact related to recycling of materials, reuse of components and reasonable extension of the components life time. Production of the laser-based implement is slightly more impactful (57% of the total score calculated for all impacts) in comparison with the mobile platform. The most pronounced subsystem in this regard is laser power source and to a less degree the targeting system. Weed meristem perception and the control units have the least impact.

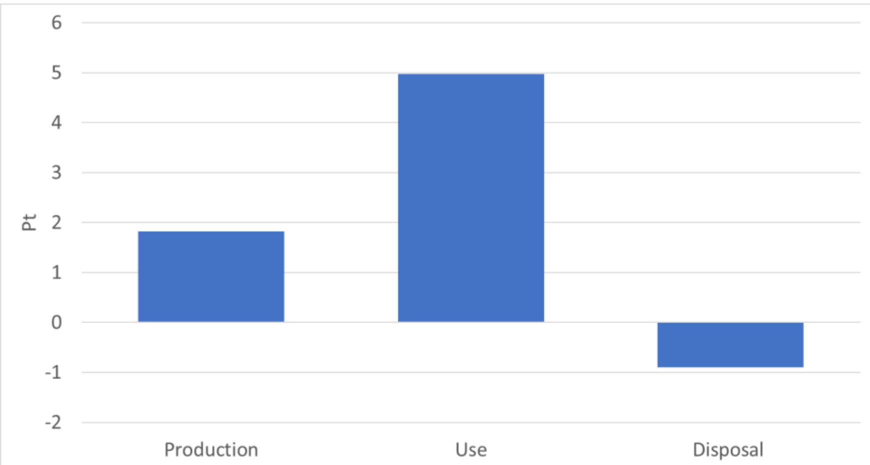

Fig. 7.3. Environmental impact of WeLASER application in the whole life cycle broken down into phases. Pt – Point indicator (All impacts integrated as a total score)

- When comparing the environmental impacts of particular subsystems in the use phase the highest impact has the power laser source and to a lesser degree the autonomous platform. The impact is directly linked to the energy demand by these two subsystems and its generation in diesel -electric system. The other subsystems are of lesser importance.
- The energy demand of the high-power laser weeding implement and the subsequent environmental impact depends on the weed density. The current pilot version of the weeder has the optimal capability to effectively eliminate weeds - from environmental point of view - at the density of 60 weeds per square meter of field. The maximum density can be set at the level of 120 weeds assuming the baseline characteristics of the prototype. For higher densities the machinery has to be redesigned. There are opportunities for improvement of the energy performance of the laser systems including cooling and energy transformation between thermal – electric - optical. The impact in the use phase is also sensitive to other parameters including distance for machinery transportation energy required for eliminating the weeds number of hours of the weeder operation during the life time.
- The assessment of WeLASER weeder is in general positive in comparison to current weeding practices (chemical/mechanical weeding) characterised in Ecoinvent v3 database.
- Comparison of WeLASER with other techniques related to weeding gave an insight into key factors determining weeding strategies. The comparison was performed for one passage of weeding and for whole specific crop production systems. In both cases WeLASER impact is slightly higher than in mechanical weeding and chemical weeding but much less in cases of certain mechanical techniques such like tillage – chiselling (see 7.4). As in the case of WeLASER weeder, for mechanical and chemical techniques, the dominant factor of environmental performance is fuel consumption during weeding operation. The results indicate that the commonly used weed control methods differ in the total impact and in the particular impacts categories (human toxicity, climate change human health, climate change ecosystem).

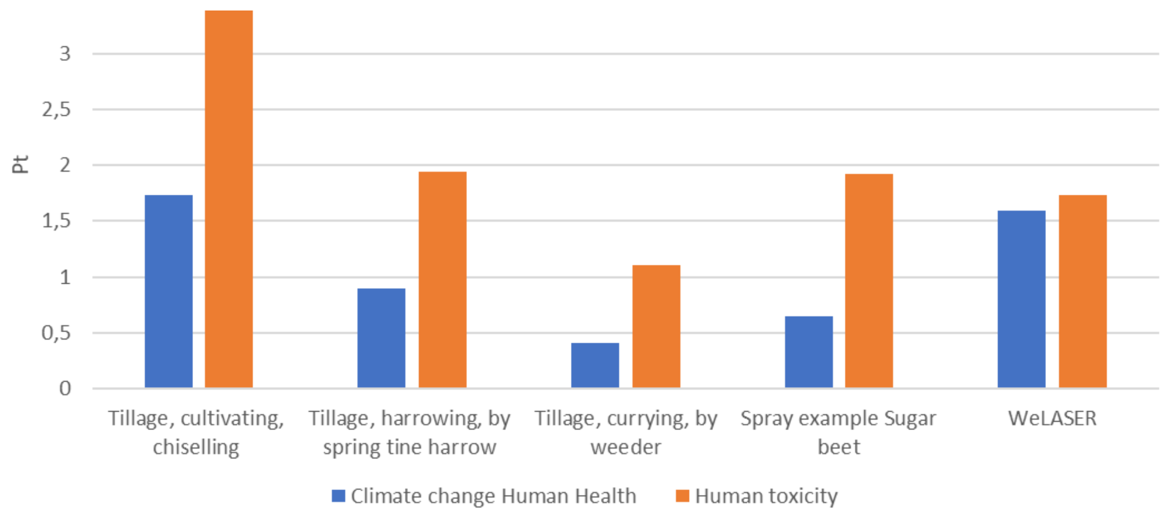

Fig. 7.4. Assessment of WeLASER application for selected impacts related to human health. Pt – Point indicator

- It has to be underlined that WeLASER weeding operation has relatively low share in the total impact of the analysed crop production systems. Moreover, the potential benefits related to reduction of chemical use in agriculture might not be sufficiently reflected based on Ecoinvent 3.0 database.
- Appropriate design of the robot and its management are important factors for extending the work life of the machinery lowering the impacts of production phase.

Results of the study allowed to formulate key policy implications and key design recommendations:

- Optimize and reduce energy demand for the robot activity (high power laser) and use alternative, renewable energy sources for powering the weeder.
- Provide an opportunity for reducing and optimizing performance of components with high environmental impact, extending their life time, reusing particular components by securing their durability, safety, and resistance to harsh conditions (e.g., electronics) and for final disposal through recycling-oriented waste processing scenario.
- Enhance opportunities for intelligent weeding approaches based on combinations of techniques, integration of various techniques in the operational machinery and planning of the weeding operations based on prior field investigation (e.g weeding implement to be used in common tractor, autonomous platform allowing for the whol,e range of activities)

Key policy implications:

- Use of WeLASER requires conditions for proper disposal, dismantling, maintenance, and appropriate services must be well developed and commonly available in the farming sector.
- There are important opportunities for application of renewable energy, electricity, bioethanol or hydrogen in agriculture and dedicated fuel value chains should be developed in the sector.
- The value chain of production business models can provide opportunities for optimization of the machinery construction and lowering of related environmental impacts.
- For smart use of the WeLASER robot, there is a need for well-designed, efficient, and optimized weeding strategies applied in practice by farmers, considering the type of crops, scale of production, and combination with other techniques.

Based on the results, a manuscript titled **“Environmental performance of autonomous laser weeding robot – a case study**” was prepared, containing detailed description of the results, and is intended to be published in an open-access journal.

8. SOCIAL ASPECTS CONCERNING WELASER ADOPTION

According to DoA, social aspects concerning the adoption of novel techniques are the subject of Task 1.5 led by IETU with support from all partners. Although, the activities were carried out by the partners UCPH, IETU, UGENT, COAG, the whole consortium was proactive in involving both key stakeholders and interested institutions in the discussions. This activity started in February 2021

(M5) and concluded in December 2023 (M39). The main objective was to assess the social and socio-economic aspects of innovative weed control system and its potential positive and negative impacts along its life cycle encompassing manufacturing; distribution; use; re-use; maintenance; recycling; and final disposal. The aim of the social analysis was to assess the impact of implementing WeLASER innovative technology on selected socio-economic aspects in EU countries. The research includes analysis of existing data (literature study) and quantitative and qualitative research using the social sciences methods (CATI survey and Focus Group Interviews – FGI, see Table 8.1). Apart from S-LCA, Life Cycle Costing was planned. In the analysis, results of economic assessment are incorporated. The assessment is based on LCI environmental model and economic characterization of the system. The monetized environmental impacts serve as comprehensive information on the costs to society. The whole package of activities provide insight into behavioural, legal and agricultural system conditions.

Table 8.1 Basic assumptions for social studies

Social studies
During the project, FGI workshops are carried out to explore different dimensions of the introduction of the new technology on the market and in agricultural practices. Three stakeholder events in the format of workshops focuses on (i) technical, functional and economical aspects of the development and application of the new technology; (ii) social and behavioural, legal and system conditions affecting farmers' adoption of the innovative technology; and (iii) environmental impact of the innovative technology and the requirements concerning labour, health safety and risk management in farms. For FGI surveys and workshops stakeholders are selected according to the relevance to the specific project aims including: individual farmers, agricultural advisory centres, SME's, organisations, associations, research institutes and academia. A qualitative survey uses the focus group interviews (FGI) is carried out in the three project partners' countries as an initial stage of research leading to a wider qualitative analysis Planned discussion and interviews with a small group of stakeholders (5 – 15 stakeholders) is to be conducted by a moderator in the three project-partner countries. Quantitative survey (CATI) is carried out to verify the information obtained in the qualitative survey.

The activities carried out in the whole duration broken down into reporting periods of the project are presented below:

8.1. General overview of activities

First reporting period (October 2020 to September 2021)

- Second Stakeholder Event was organised and dedicated to safety issues, legal and economic aspects. The results were used in preparing S-LCA methodology and social studies.
- S-LCA methodology was reviewed based on literature related to S-LCA studies on innovation in agricultural sector (see Table 8.2).
- Social studies (FGI and CATI) by IETU and UGENT were planned with preparation of question bank, FGI scenario and working materials.
- Key stakeholder groups were defined and their representatives identified including: farmers, local communities, machinery industry, service providers, farm workers, general community.

Table 8.2 Basic assumptions for Social Life Cycle Assessment of WeLASER invention

S-LCA
A social life cycle assessment (S-LCA) is a method that can be used to assess the social and sociological aspects of products, their actual and potential positive as well as negative impacts along the life cycle. Social Life Cycle Assessment addresses social, economic and environmental themes and impacts. To carry out the study, application models in the social context are being developed. Selected Impact categories are defined for various stakeholders' perspectives: farmers, local societies, general society For Social – LCA, the results of the social surveys (CATI survey, Focus groups, expert interviews) are used with quantified statistics based on targeted surveys of farmers (3 surveys in 3 countries: Spain, Netherlands/Denmark, Poland) and qualitative analysis based on topical interviews (3 topics: social, economic, environmental) The results are to be used to identify the potential of improvement of the social sustainability of the WeLASER system. It is expected that the impacts in the particular categories and the overall assessment of WeLASER will be at least comparable with other techniques but the ambition is that they will be better than the reference scenarios of weed control. Because in some impact categories there might be expected drawbacks and in other categories improvements, appropriate trade-offs between the categories has to be evaluated by stakeholders.

Second reporting period (October 2021 to September 2022)

- Four FGI workshops were organized and completed (see Section 8.1). In the FGI events the following issues were discussed: benefits for farmers and local society, factors that will encourage farmers to implement innovative weeding technologies such as WeLASER, the conditions that could encourage farmers do adopt the innovation. Moreover, experts have developed the SWOT analysis of the wide implementation of WeLASER technology in agricultural practice. The results of the FGIs formed the basis for formulating questions for in-depth interviews with experts in S-LCA study.
- Methodological approach for S-LCA was elaborated, based on literature, experts interviews and the results of the FGI workshops. There were defined stakeholders' perspectives, impact categories, subcategories and indicators.
- CATI (computer-assisted telephone interviewing) questionnaire was developed. Aim of the study was focused to get insight into socio-economic aspects of WeLASER application. CATI (joined efforts in tasks 1.3&1.5) and to provide input to Social LCA and economic assessment. Three CATI surveys in case countries were planned: Spain, Denmark, Poland.
- Contracting procedure for company to carry out the surveys was started based on public procurement materials. The initial plan (total number of respondents: end-users - farmers up to 450, 150 per country) was revised.
- Life Cycle Costing approach was developed based on literature overview as well as of cost categories that will be incurred during the lifetime of the product or service were identified.

Third reporting period (October 2022 to December 2023)

- CATI methodology was modified due to constraints of the market opportunities out of CATI services. The survey was performed by the contracted party and the results were analysed by IETU team. Results were used in S-LCA analysis in verification of the findings of the social life cycle assessment study.

- S-LCA was carried out together with Life Cycle Costing assessment. Questionnaire for experts was prepared according to structure of impact categories and subcategories. The questions were grouped in three perspectives: farmers, business, and society including organizations and policy makers. Fifteen (15) experts were selected representing three perspectives of the key stakeholder groups. Experts evaluated socio-economic impacts according to the set of criteria during interviews as well as assigned to them weights during dedicated workshops. Obtained data were processed in Analytical Hierarchy Process (AHP) method.
- Using Life Cycle Inventory data, results of socio-economic analyses and economic assessment of WeLASER weeder, Environmental Life Cycle Costing was performed as complementary analysis to LCA and S-LCA. Life cycle aspects of the WeLASER application including environmental impacts were analysed in economic terms.

8.2. Focus Group Interviews

The aim of the FGIs was to get valuable insight into the future implementation of precision agriculture techniques such as WeLASER in weed control. SWOT analysis methodology was used with application of on-line tools

Four Focus Group Interviews were organized as on-line events:

- International - European dimension - 2nd of December 2021 carried out by IETU together with UGENT
- Poland – 3rd of February 2022 carried out by IETU
- Netherlands/Belgium – 10th of February 2022 carried out by UGENT
- Spain – 24th of February 2022 carried out by COAG

In the events of over 50 stakeholders participated including farmers, representatives of farmers associations, research and agricultural institutions, machinery producers. Good input from discussion and SWOT analysis to tasks 1.3, 1.4, 1.5 was obtained. Four Public Abstracts were delivered based on the results.

8.2.1. International Focus Group Interview (FGI) Workshop

The FGI workshop was held on 2nd December 2021 gathering over 10 participants including farmers, representatives of farmers associations, and researchers. The workshop provided valuable insights into the future implementation of precision agriculture techniques in weed control. After a fruitful discussion, a SWOT analysis was followed to identify the main factors that impact the WeLASER application.

Main findings of discussion are as follows:

- The current main problems related to weed control are (1) low accuracy and efficiency of conventional weeding machines, (2) negative impact of herbicides on the environment and food quality, (3) labour-intensive workload, and (4) high production cost.
- The WeLASER solution can potentially bring new opportunities for agricultural development,

organisation of farming activities, production of high-value food, meeting consumer expectations, and achieving sustainability.

- The crucial factors for the implementation of WeLASER are the flexibility of the application and its modularity, ease of use, handling safety assurance, and proof of cost-effectiveness.
- Farmers can adopt innovative weeding technologies by considering the cost-effectiveness of the solution, its working capacity, its business model, and the potential financial supports related to each weed control approach.

It was agreed that the WeLASER solution can potentially bring new opportunities for agricultural development, organisation of farming activities, production of high-value food, meeting consumer expectations, and achieving sustainability. The crucial factors for the implementation of WeLASER are the flexibility of the application and its modularity, ease of use, handling safety assurance, and proof of cost-effectiveness. The results are summarized in Practice Abstract 22.

8.2.2. Focus Group Interview in Netherlands/Belgium

The Belgian/Dutch Focus Group Interview (FGI) workshop was held on the 10th of February 2022 gathering 13 participants from Belgium and the Netherlands including farmers, representatives of farmers associations, agricultural machinery dealers, consultants, and researchers. Valuable information for the successful implementation of the WeLASER technique was obtained during the workshop. After the focus group discussion, a SWOT analysis was conducted in order to identify the main factors that impact the implementation of the WeLASER technique.

Main findings of discussion:

- The current main problems related to weed control are (1) herbicide resistance, (2) difficulties with in-row weeding when using conventional mechanical weeding methods (3) very labour-intensive methods, and (4) stricter policies regarding the use of chemicals.
- In order for farmers to implement innovative weeding technologies, the technology should be profitable, user-friendly and have sufficient capacity.

The WeLASER technique has many opportunities and possibly a huge market potential due to increasingly stricter policies regarding chemicals, the rising demand for agri-food systems to become more sustainable and the potential to improve the public image of agriculture. Cost-effectiveness, user-friendliness, sufficient capacity, and the possibility of multifunctional usage are crucial factors for the future implementation of the WeLASER technique. Based on the results Practice Abstract 27 was produced.

8.2.3. Spanish Focus Group Interview

On the 24th February 2022 an online Focus Group Interview for Spanish stakeholders interested in this project. The objective was to exchange valuable insights regarding the future implementation of precision agriculture tools in weed control, with special attention to WeLASER technique. Results help to improve the design and develop of business models of precision agriculture application in weed control and provide European policy recommendations. In the event, eleven (11) participants took part with good gender balance (64% men, 36% women) and good profile balance: Farmers 1, Machinery association 1, Farmer association/cooperative 4, Research/Education institution 1, Public administration/policy makers 2, Farming industry/Industry 2.

Participants were very interested in the topic and very active during the discussion and in the SWOT analysis. They considered that, in an environment with herbicide-resistant weeds, less active substances available, lower dose allowed and high cost / lack of non-chemical alternatives, precision farming techniques in weed control, with less environmental impact, less impact on soil and improving biodiversity are warmly welcomed. However, those technologies should be cost-effective, user- friendly and harmless to the crop. Public support is needed to stimulate the use of low environmental impact technologies and appropriate training is needed.

The main strengths underlined in the SWOT analysis were that WeLASER solution helps in the achievement of environmental strategies and to improve food safety, which is in line with the principal opportunity pointed out: a greater demand for more sustainable products. Regarding the threats, the possible lack of public support for this type of innovation and the lack of companies opting for these technologies for commercial purposes were the two main conclusions. Finally, the cost of the equipment was the principal weakness considered. Public abstract 28 was delivered based on the results.

8.2.4. Polish Focus Group Interview

The FGI workshop was held on the 3rd of February 2022 gathering 16 participants from Poland including farmers, representatives of farmers associations, agricultural advisors, consultants and researchers. The workshop provided valuable insights into the future implementation of precision agriculture techniques in Poland. After the focus group discussion, a SWOT analysis was conducted in order to identify the main factors that impact the implementation of the WeLASER technique.

Main findings of discussion:

- Currently the main issues related to weed control are: (1) lack of workforce for labor-intensive methods, (2) high reliance on herbicides as the best option, difficult to be replaced (3) effective removal of perennial weeds (4) integration of weed removal techniques in rows and inter-rows.
- In order to implement innovative weeding technologies by farmers, the technology should be economic, efficient, reliable, flexible in use and appropriate advisory support has to be provided.

The WeLASER technique prospectively can be a good solution for crops and agriculture systems. The implementation can be driven by stricter policies and legislation regarding plant protection products. There is a need for reliable information related to WeLASER performance including cost-effectiveness, energy efficiency and its functionalities with regard to specific crops and recognition of practical conditions of its use in the farms. The results were summarized in public abstract 29.

8.3. CATI survey

The overall goal of the CATI survey is to provide insights into key factors of farmers' attitude towards the innovative (laser) weed control tool (device - autonomous robot using laser) being the subject of the survey, to get knowledge whether farmers see an opportunity or not to implement it and what are the stimulators and opportunities of implementing the device in practice. The survey was carried out for three countries: Poland, Denmark and Spain. In each country 100 respondents were surveyed, 300 respondents in total. Based on the adopted goal of the CATI survey, assumptions regarding the analysis and the number of cross-sections the following assumptions (sample selection criteria) for the survey were assumed:

- farmers are engaged in the production of crops, vegetables, and horticulture
- cross-section for the farms of the surface over 1 ha: 50% of farms from 1-49 ha and 50% for farms over 50+ ha.
- farmers have made modernization investments on their farms in the last 10 years.

In addition to these sample selection criteria, other parameters including type of farm, age/gender of the manager, and level of education were obtained randomly, allowing for cross-sectional analysis depending on the results. In the respondents profile the most important parameter was the size of farm (see Fig 8.1), Most of the respondents were primary decision makers and male. At the same time the percentage of conventional farms was high: Poland - 71, Spain - 79 and Denmark – 86. The other farms were of mixed agriculture or organic type.

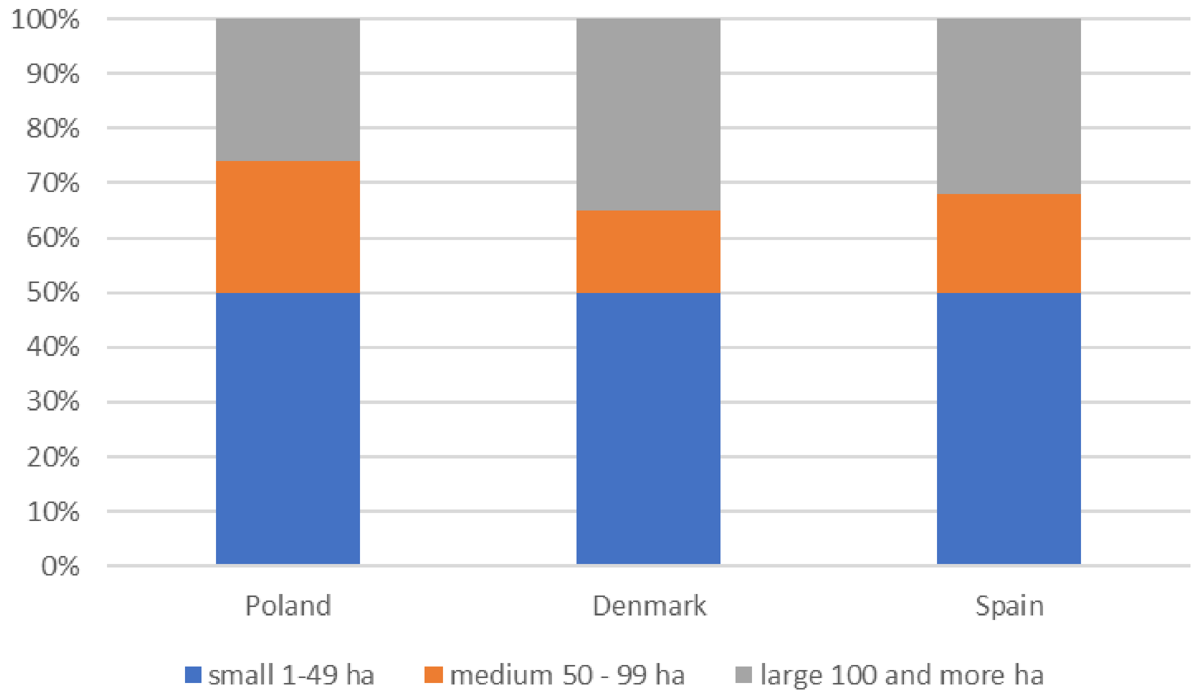

Fig. 8.1. Farmers' profile: size of the farm

The questionnaire contained 12 questions and respondents' characteristics (see table 8.1). Questions were grouped in two parts related to: 1. Farmers' perception of already applied innovative technologies in agriculture and 2. Framers' perception of potential application of WeLASER weeder in farming practices.

Table 8.1. Questions prepared for CATI survey

CATI questions	
Q1	Do you use innovation on your own farm?
Q2	What is your opinion on the ease of use of innovative technologies? Which of the following opinions would you subscribe to?
Q3	How do you evaluate the quality and reliability of innovative technologies (machines and specific implements) available on the market?
Q4	Which attributes of your farm are important for use of innovative machinery?
Q5	Do you see essential benefits in implementing innovative technologies?
Q6	Are you satisfied with the weed control solutions available for your work?
P7	Is WeLASER weed control technology a good solution in your opinion?
Q8	Would you be interested in implementation of WeLASER weeding control technology on your farm?
Q9A	Which way of applying WeLASER weeding control technology in practice would be the most realistic from your point of view?
Q9B	Why wouldn't you decide to use the WeLASER weeding control technology?
Q10	Thinking about buying WeLASER weeding control technology in the future, what factors might influence your decision?
Q11	What would convince you or other farmers of the advantages of using WeLASER weeding control technology?
Q12	Will you be following the further development of WeLASER weeding control technology as a potential future application on your farm?

Results of CATI carried out by the contractor were analysed using statistical methods. Pearson's Chi-square test and Chi-square Likelihood Ratio test were used to test the relationship between the two selected variables expressed on a nominal scale. In calculation of the strength of the association between two crosstab variables Cramer's V was applied. The analyses were carried out for each country and comparison between statistical parameters characterizing the selected countries was performed (variance analysis).

The results showed that there was much higher cohesion in analysis of the associations between answers related to current experience of using innovation in agriculture and perception of WeLASER in Denmark in comparison with Poland and Spain. Respondents who already applied innovation perceive WeLASER positively. The innovative techniques are recognized as satisfactory mainly because they bring benefits to farmers such as: comfort in their work and economic gains. These techniques are in majority perceived as being of good quality. WeLASER in general is viewed as a promising weeding tool, although many respondents, especially in Denmark pointed out that it can only partially solve their problems with weeds (see Fig 8.2).

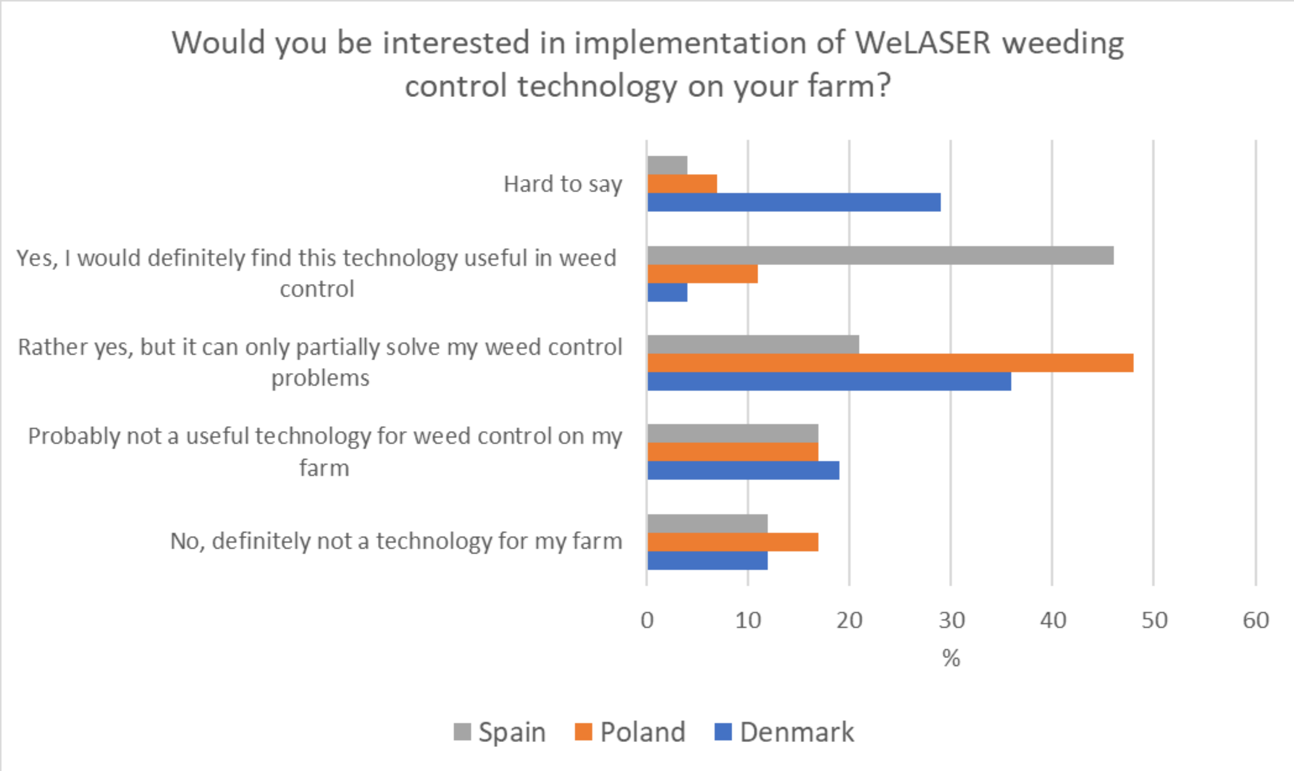

Fig. 8.2. Farmers' attitude to adoption of WeLASER weeder in their farming practices

Denmark

Danish respondents who already use innovation perceive them as usually of good quality and reliable 68% (42% of all respondents). In the majority those farmers do not perceive WeLASER to be an important technique for their farms. In case of 8% responses farmers definitely do not see the need for implementation of the technique and for 14% it might probably be not useful on their farms. Only 11% expressed the view that they might rather implement the technique, although for them it will not solve all the problems with weeds. On the other hand, there is a curiosity among respondents who do not use innovation, because 24% of those respondents are also interested in innovation and at the same time see a potential for WeLASER implementation.

Most of Danish respondents expressed the view that it is hard to say whether WeLASER is a good solution. Only 35% of the respondents thought it is a good solution. Most of the respondents express interest in implementation of WeLASER but they see it only as a partial solution to weeding problems - 90% in case of all respondents' answers. Among them renting of services is indicated by 35%, purchase with external funding 25%, joint purchase 15% and renting without service 10%.

Poland

Farmers who are already using innovation assess the innovative solutions as usually of good quality - 51% of respondents. There is also an essential statistical association between the perception of quality of innovative techniques and the level of satisfaction of weed control applied in their farms. The share of the answers that they are of good quality and that the "weed control measures are satisfactory" is 50%, For all respondents the share is 72%.

Respondents who perceive WeLASER as a good solution and would rather implement this technique as partial solution is 35% (48% all respondents). At the same time these respondents are mostly satisfied with the applied weed control 33% (48% for all respondents). On the contrary 34 % do not see the reason to implement of the technique at their farms.

Spain

Farmers who use already innovation and view WeLASER as potentially good solution constitute 55 % of all respondents and for 11% it is a definitely good solution. For all respondents it is 72 % and 17% respectively. At the same time 38% of respondents already applying innovation in their farms find WeLASER technology as definitely useful in weed control 38% (46% for all respondents) and 17% see it as solution which rather solve only partially weeding problems (21% of all respondents). Most of the farmers expressing their interest in implementation of WeLASER technique are rather not satisfied with weed control - 17% or rather satisfied - 26% respondents. At the same time for the respondents who are not or rather satisfied with weed control solutions in their farming practices, WeLASER seems a good solution - 66% and is a definitely good solution - 15%.

The main recommendations formulated base on the study results are presented below:

- The main factors determining the use of the WeLASER robot will be the type of crop, the financial health of the farm, the distribution of the fields and the size of the farm.
- It seems that computer literacy will not be a problem and farmers do not see a difficulty in learning new skills in order to use innovative solutions themselves.
- The study confirms that there is a need for reliable information on the performance of WeLASER, including its cost-effectiveness, energy efficiency and functionality for specific crops, as well as an understanding of the practical conditions for its use on farms.
- Public aid (subsidies) can be one of the main factors supporting the use of the WeLASER robot on farms.

The results of CATI survey were used in S-LCA for verification and discussion of the results and formulating the conclusions. Detailed results of the study were prepared in the form of manuscript titled **“Farmers’ perception of innovative laser-based weed control technology. Perspectives of WeLASER robot application”** to be published in an open access journal.

8.4. Social -Life Cycle Assessment

The aim of the social analysis is to assess the impact of implementing the WeLASER innovative technology on selected socio-economic aspects in EU countries. For these analyses the following social research methods were used: focused groups interview (FGI), computer assisted telephone interview survey (CATI) and expert interviews.

The methodology of S-LCA is based on ISO 14400, ISO 1444 framework, integrating participatory approach and multicriterial analysis tools. The aim of the study is focused on the assessment of social impacts of WeLASER wide implementation in agriculture. Two scenarios were compared by the experts, the baseline scenario representing current situation defined for Europe and scenario of WeLASER application.

The FGIs which were carried out in 2021 and 2022 were used as a basis for developing the S-LCA methodology. Important issues of the wide implementation of the WeLASER technology in agricultural practice were identified in SWOT analysis: for example, benefits for farmers and local society, factors that will encourage farmers to implement innovative weeding technologies such as WeLASER, the conditions that could encourage farmers do adopt the innovation. The results of the FGIs formed the basis for formulating questions for in-depth interviews with experts. According to this there were defined stakeholders' perspectives, impact categories, subcategories and indicators (see Fig 8.3).

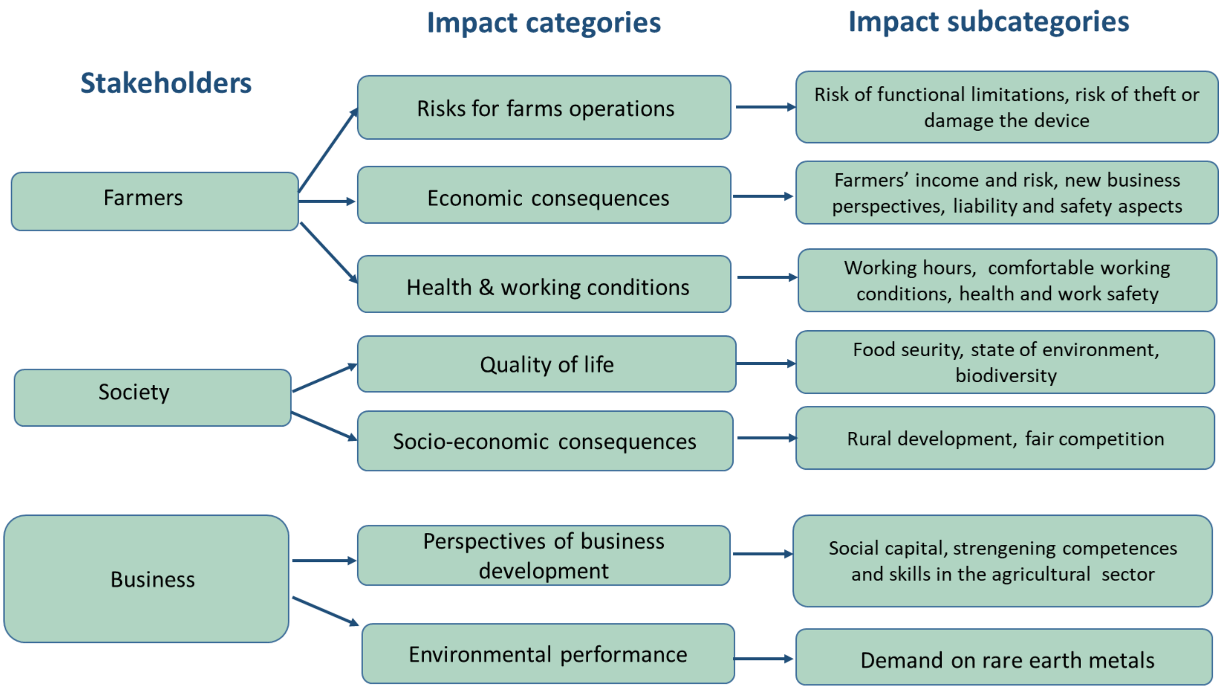

Fig. 8.3. Social LCA – general structure of analysis and key aspects of WeLASER application

CATI survey was carried out in 2023 provided insights into key factors of farmers' attitude towards the innovative (laser) weed control tool (device - autonomous robot using laser) being the subject of the survey. They provided knowledge whether farmers see an opportunity or not to implement it and what are the stimulators and opportunities of implementing the device in practice. Results of CATI surveys were used in verification and discussion of S-LCA results.

Analytical Hierarchy Process (AHP) method was applied in two stages: In the first stage interviews with experts were carried out. Experts interviews on selected socio-economic aspects were aimed to determine the impact of innovative laser weed removal technology. The interviews were carried out with 15 representatives of three stakeholder groups: farmers, society and business, including five experts representing each group. The selection was done in a way to cover a wide range of issues relevant for WeLASER implementation as well as wide regional coverage to secure European representativeness. The interviews were conducted in 2023 during individual on-line meetings. The topics of the interviews were adapted to the specificity of stakeholders:

- Farmers: health and working conditions, economic consequences and risk for farms operation.
- Society: quality of life and environment, demographic consequences and just agricultural transformation.
- Business: profitability, business risk, environmental performance and perspectives of business development.

Experts assessed the WeLASER impact on agriculture according to the defined set of criteria organized in stakeholder perspectives, categories and subcategories. Five points scale was applied in assessment expressing positive or negative impact. The questions reflected the comparison between basic scenario of current weeding practices and scenario of wide implementation of WeLASER weeder.

Experts positively assessed the impact of the device on the comfort and safety of the farmer's work. According to them, due to the elimination of the use of chemicals, the impact on health will be very positive. However, it should be emphasized that the laser used in the technology may pose certain risks related to health. An important aspect is the replacement of human work by a machine, especially that which is performed by seasonal workers. According to experts, the implementation of innovative weed control technology will improve the quality and safety of agricultural products due to the elimination of chemical residues on agricultural produce. In the long term, there will be significant improvement in the state of the environment and biodiversity. WeLASER technology can also significantly contribute to the development of organic agriculture. The impact of the device's production stage on the environment, according to experts, may be higher compared to the production of currently used mechanical cultivators. In addition, the demand for rare earth metals will increase. Experts are concerned about the potentially high investment cost of the device, which is why they indicated the need to provide financial support and consider the introduction of new business models. The technology should bring profits to the device producer and have a positive impact on the economy. Due to the introduction of the device to the market, it is expected that new jobs will appear and an increase in the competences of employees involved in the production process, service, advisors, consulting companies, sales representatives and users was indicated.

In the second stage a set of three workshops dedicated to three stakeholder perspectives were organized to present and discuss the results of the assessment, and to assign weights to the criteria in a pairwise comparison approach.

Based on the conclusions from the workshops farmers' perspective the assessment is very positive, especially for the subcategory health and working conditions, and economic consequences. It was assessed that WeLASER will have positive impact on comfort of work, health conditions, farms productivity and demand for seasonal workers. In the subcategory risks for farms operations farmers assessed the impact as neutral, perceiving the potential risks as important factors.

In the societal perspective impact of WeLASER on society is seen as positive in comparison with currently used weeding techniques. It is pronounced in aspects of quality of products, state of the environment. In the demographic consequence subcategory, the positive impact is seen especially in young people interest in farming and raised opportunities for women in agriculture. Experts assessed as highly positive the impact on development of ecological/organic farming.

Experts assessing WeLASER from business perspective indicated a neutral impact on business activities. The most positive impact was related to potential profits of the producers and new business opportunities.

Evaluation of importance of selected factors by the experts allowed to weight and revise experts' impacts assessment. From farmers' perspective the most preferred factor influencing the wide implementation of WeLASER technology are economic consequences of which the most important are production costs related to implementation of new technology. According to experts representing business the perspective of business development with particular emphasis on new prospects for the companies, development is the most important factor. Quality of life and environment is the most preferred for the society' perspective.

Life Cycle Costing

Life Cycle Costing method was applied to get a better insight into the future perspectives of the technology implementation. The Environmental LCC was performed to analyse potential of WeLASER application in practice and identify key aspects that determine its environmental and economic performance. The external and internal costs were calculated based on WeLASER project information and available literature data. The following cost categories were analysed:

- Purchase price and associated costs: delivery, installation, insurance, etc.
- Operating costs: energy, fuel and water use, spares, and maintenance
- End-of-life costs (decommissioning or disposal)
- Cost of externalities in the whole life cycle (such as greenhouse gas emissions)

Cost data for WeLASER were based on information from the consortium, literature and available information of companies producing robot components. In the assessment of monetised environmental external impacts, simplified Life Cycle Inventory data were used. LCC was meant as complementary analysis both to E-LCA and S-LCA. The three methods are the pillars of sustainability assessment.

The environmental external costs are relatively low in comparison with the internalized costs which are related mostly to energy demand and specifically to diesel use. Moreover, it can be expected that due to European policies these costs might be in the future avoided or further internalized – for example through stimulation of renewable energy sources use in agriculture. The structure of internalized costs depends on many factors related to design of the robot as to potential scenarios of its application. The most important are initial costs and fuel costs. Weed density is a crucial parameter determining the operational costs performance of the robot. There are also other parameters influencing the costs: investment cost, fuel price, lifetime and working hours per year. For a 10 years depreciation period, the internalized costs expressed as the functional unit of 1 ha of weeded field in one passage differs essentially in the range around 30 - 200 Euro per ha depending on weed density (Personnel costs are not included in the calculation). It shows that WeLASER should be considered as a tool of Integrated Weed Management (IWM), securing its smart use, providing the best performance opportunities. The results obtained in the analysis were interpreted using the literature data and reports from other studies. Based on the results certain design aspects were discussed in the context of sustainability including for example the length of life of the components.

The results of the analysis are intended as a publication devoted to the Social Life Cycle Assessment (S-LCA) of the wide-scale dissemination of WeLASER technology titled **“Social aspects of high power laser based weeding robot implementation in Life Cycle Perspective”.**

Detailed results of Life Cycle Costing are intended to be published in open access journal under the title: **Life Cycle Costing of innovative laser-based weed control technology**.

9. References

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10. ANNEXES

10.1. Annex 1 – The First WeLASER Stakeholders' Event

10.1.1. Minutes of the 1st Stakeholder Event

WeLASER

Eco-innovative weeding with laser

Sustainable Weed Management in Agriculture with Laser-Based Autonomous Tools

MINUTES OF THE 1ST STAKEHOLDER EVENT

November 26th, 2020

Due to the situation produced by Covid-19, a virtual event (videoconference) was organised by COAG using Zoom service. The agenda of the event is included in Annex 1. The slides of the presentations have already been collected and distributed to the attendees. The list of attendees is included in Annex 2. The meeting started at 9:30 a.m.

Warm up and introduction Álvaro ARETA (Event organizer)	The event organizer welcomed the participants and explains: ❖ The aim of the event: a first contact with the stakeholders and to include stakeholders in the decision loop regarding the definition of system characteristics ❖ The agenda of the event ❖ Some tips on how the event is going to work
Welcome and Project overview Pablo GONZALEZ-DE-SANTOS (Project coordinador)	The project coordinator presented a brief overview of the project highlighting the following elements: ❖ Project main aim ❖ Characteristic of the call: Multi-actor approach and Innovation action (and consequences) ❖ The opportunity the consortium had (SFS 04) ❖ Project-specific objective ❖ Proposed solution ❖ Brief description of the consortium ❖ Position of the stakeholders in the project management
Stakeholders in WeLASER – What are we going to build together? Janusz KRUPANEK (Multi-actor strategy WP leader)	The Multi-actor strategy WP leader explained the role of stakeholders in the project and ways to cooperate with special reference to ❖ EIP-AGRI and multiactor approach ❖ Aspects/issues to be considered in the project like environmental, safety, social ❖ The flow of activities and benefits of being involved

Who is present? Short presentation Álvaro ARETA	The event organizer presented all participants with particular reference to every stakeholder and to their balanced origin and profile.
System specifications: first draft Pablo GONZALEZ-DE-SANTOS	The project coordinator revised the main features of every subsystem to conclude with the specifications of the overall weeding equipment
Break	
Discussion Laura GARAU (Facilitator)	The facilitator divided the discussion into two different parts: ❖ A general discussion about the overall **WeLASER** project with specific focus on the opportunities and barriers for market adoption of this technology ❖ Specific questions on system characteristics An animated discussion was held with numerous interventions from stakeholders and consortium members. Detailed information in Annex 3
Wrap up and next steps Janusz KRUPANEK	The Multi-actor strategy WP leader summarized the main conclusions and explained the next steps of stakeholders' involvement.
Closure Álvaro ARETA	The event organizer thanked for the fruitful event and closed the meeting. Very good evaluation is received from participants (Annex 4)

10.1.2. Agenda of the 1st Stakeholder Event

WeLASER
Eco-innovative weeding with laser

Sustainable Weed Management in Agriculture with Laser-Based Autonomous Tools

AGENDA OF THE 1ST STAKEHOLDER EVENT

Virtual meeting

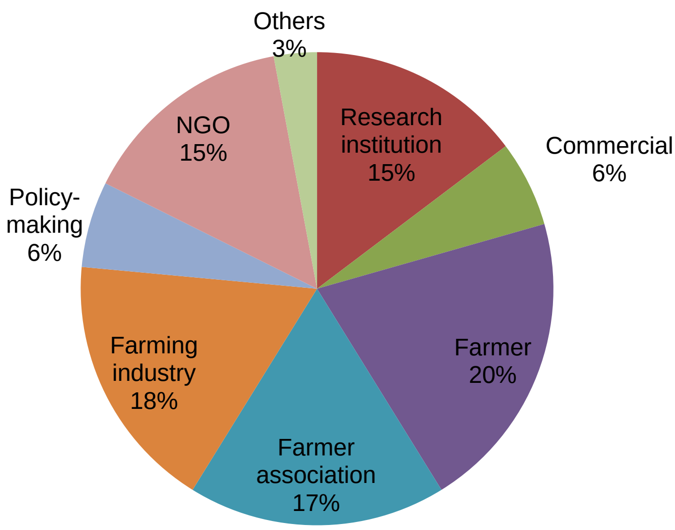
Link to the meeting: https://us02web.zoom.us/j/84881065558?pwd=Z0ZMemFMMjVKeGhBbExFbklHR1hiQT09

November 26th, 2020

09:30 – 9:35	**Warm up and introduction**	Álvaro ARETA (Event organizer)
9:35 – 9:50	**Welcome and Project overview**	Pablo GONZALEZ-DE-SANTOS (Project coordinador)

9:50 – 10:00	**Stakeholders in WeLASER – What are we going to build together?**	Janusz KRUPANEK (Multi-actor strategy WP leader)
10:00 – 10:15	**Who is present? Short presentation**	Álvaro ARETA
10:15 – 10:45	**System specifications: first draft**	Pablo GONZALEZ-DE-SANTOS
10:45 – 11:00	**Break**	
11:00 – 11:50	**Discussion**	All - Laura GARAU (Facilitator)
11:50 – 12:00	**Wrap up and next steps**	Janusz KRUPANEK
12:00	**Closure**	Álvaro ARETA

10.1.3. Overview of attendees



10.1.4. Discussion session

Some important issues raised in the discussion session:

- Most of the participants highlighted the importance of this kind of technology and the great interest in autonomous robots /vehicles for farming. One of the questions here was if the robot was autonomous enough.
- Some of the stakeholders raised the issue of an affordable price for the market. But, as the system will be expensive for the average farmers, the solution that some of the stakeholders have risen are service providers; as cooperatives or other figures of end-users. Some of the stakeholders have expressed the importance of comparing prices, for example with human capital and other applications. Square meter prices should be analysed for different crops.
- Some of the participants have seen that there is a relation between efficiency and frequency of treatment. The efficiency should not that important if the machine can be used often. How often should be treated the field? Differs from different crops and conditions. So, it could be a cost efficiency price. For bigger price, we need more efficiency in return. But also, the efficiency is not that important if the machine can be used some often. For example, in sowing the machine will be needed quite often the first weeks to kill the little plants.
- Which crops are better for the use of the WeLASER system? High value crops?
- Some stakeholders explained the importance of this technology in specific crops as sugar beets, where the technological capital is already an important one. But there is a need in the market for removing the weeds that are really close to the sugar beets plants. A farmer from Finland stresses the importance of the application in cereal farming. She thinks that the potato and vegetables crops more viable because of the row width. But she thinks that for cereal farms it is an interesting system to and should be developed for it.
- Vineyard industry: Besides the price of the system, the most important thing is the outcome. Human resources are more expensive, every time. So, if this autonomous robot has a good outcome in the market it can work. The best way to validate the product is the market, and they think that involving an association of farmers that can test the robots would be interesting. But **WeLASER** group should think what they want to achieve with and from farmers.
- **WeLASER** has to be adapted to different applications with other machineries or autonomous vehicles to combine different systems that already work for different kind of crops. For example, existing maps of possible situation of the weeds that already work.
- The idea is to use this device in a service approach. A service that can provide this technology to some farmers.
- The European Union tends to have more sustainable fields and the use of energy in the machinery is also an important aspect. The use of renewable energy, as the solar panels is a good and affordable solution.
- The system should be analyzed and tested with different weather conditions. For example, water drops or humidity.

Some other questions that have been raised in the chat:

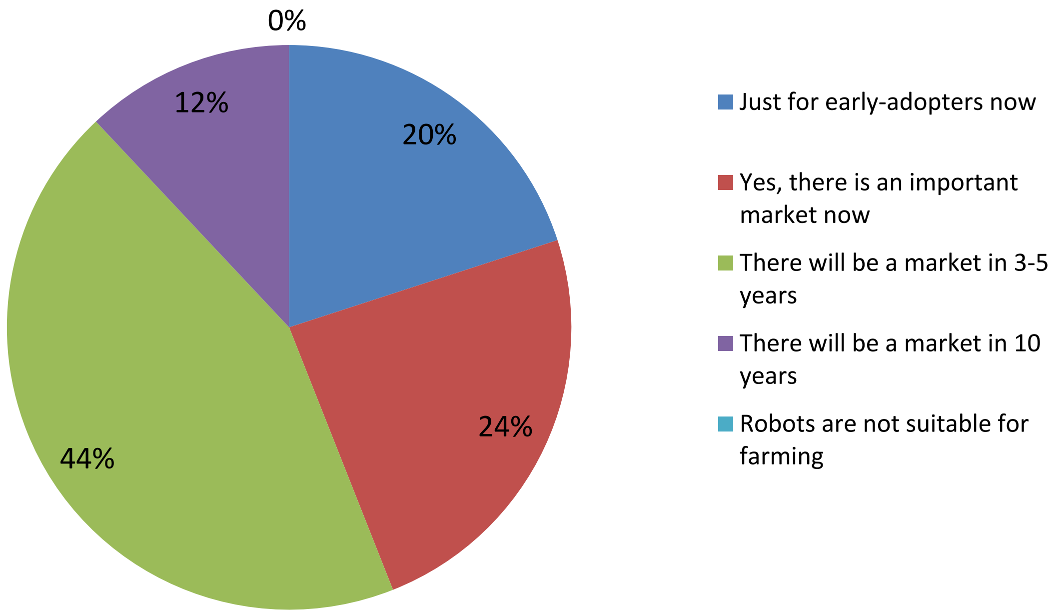
- What about tree dripline fruit keeping free of weed and grass?
- How comply with the minimum mechanical impact on the soil?

- Is the laser application also developed as stand alone? There are already several autonomous vehicles in the EU. Also to possibly develop a machine that hangs behind the tractor. This allows for faster market introduction of technology in the future.
- Have you considered the opportunity of aerial unmanned vehicles to reduce the impact on the soil?
- The question is what will be the cost of implementing this solution and its operation. It depends on the failure rate and current maintenance costs. The efficiency itself is not very big. Does the project provide for the possibility of changing the system height to work for different crops? Is this supposed to work only in crops not planted in ridges?
- Should be developed for different crops. Also for peas, carrots, potatoes, Spinach
- The sugar-beet prospect is very interesting. This would allow also easier organic sugar-beet cultivating in the organic crop rotation in our conditions. How about adding solar panels on the top and have it used alternatively with solar power? Diesel will be quite expensive and also perhaps not acceptable as sustainable. Price vs. efficiency vs. cost of using very important from farmers´ point of view.
- In Denmark we are very interested in that kind of alternatives to reduce the reduce the use of pesticides, so looking forward to follow the project.
- Every new technology is costly in the beginning: market also will make the price
- Will the laser technology also be available to apply in other autonomous platforms?
- 5 Ha in 24 hours = 70 Ha in 14 days- efficiency is very too low
- I expect in the beginning the Weeder will focus on vegetables (low surfaces), velocity for cereals (huge surfaces) will be reached by gradual adaptation
- Could we trust the technology develops during these years and the efficiency would be higher in the end of the project?
- For Sugar beets, could the AI learn to recognize weeds from growing plants?
- Maybe we have to distinguish between the efficiency ensured by the project to that ensured by the machine seller
- 10 hectares a day sounds much better. The question is what will be the cost of purchasing the machine. Even in service, such a machine will have a very limited working time during the year. So the number of services that can be provided will be very limited. This will have to be replaced by purchasing more machines.
- Will the machine be able to work in all weather conditions?
- Why the treatment speed is 2 km/h? Can it be higher in the future?
- One of the partners said that WeLASER only focus on weed in the row because between de rows we can use other machine but others said that depends on the type of crop. And the weed management in the row is most important
- How will be the accuracy of weeds detection near plant?
- Have you included false positives in your performance statistics? I mean identifying weeds from plants
- The stated efficiency is 65%. Does that account for the misleadingly positive results?Or is it just mechanical performance.
- Steketee in the Netherlands have a lot of experience in weeding machines behind the tractor. It is part of Lemken.
- This should be adaptable to various sewing machines? The process should be adapted to existing sewing machines. Absolutely to which crops and sewing machines.

I assume there are also contacts in the EU Agrobofood network?

10.1.5. Results from polls

Do you think that there is a market for autonomous farming robots?



10.2. Annex 2 – The Second WeLASER Stakeholders' Event

10.2.1. Minutes of the 2nd Stakeholder Event

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WeLASER

Eco-innovative weeding with laser

Sustainable Weed Management in Agriculture with Laser-Based Autonomous Tools

MINUTES OF THE 2ND STAKEHOLDER EVENT

May 25th, 2021

Due to the situation caused by Covid-19, a virtual event (videoconference) was organised by IETU using Zoom service. The agenda of the event is included in Annex 1. The slides of the presentations were collected and distributed to the attendees. General information on attendees is included in Annex 2. The meeting started at 9:30 a.m and ended at 13:00.

Warm up and introduction Janusz KRUPANEK	The event organizer welcomed the participants and explained:

(Event organiser/Multi-actor strategy leader) Who is present? Short presentation	❖ The aim of the event: to identify key aspects of WeLASER implementation in practice including environmental, safety, social aspects. ❖ The agenda of the event ❖ EIP-AGRI and multi-actor approach ❖ Some tips on how the event is going to work ❖ presentation of participant groups
Project and its activities - overview	
WeLASER vision and project overview Pablo GONZALEZ-DE-SANTOS (Project coordinador)	The project coordinator presented a brief overview of the project highlighting the following elements: ❖ Project main aim ❖ Project-specific objective and proposed solution ❖ Brief description of the consortium ❖ Overview of project activities EIP-AGRI and Multi-actor approach and Innovation action (and consequences) ❖ Position of the stakeholders in the project management and communication of project activities; Newsletters and Practice Abstracts
How do we want to achieve the results ? - status of project activities WP leaders: Karsten SCHOLLE (FUTONICS) - WP2 Merve WOLLWEBER (LZH) - WP3 Thomas DE SAINTIGNON (AGC), Luis EMMI (CSIC) & Guliano VITALI (UNIBO) - WP4	The leaders of technical workpackages presented project activities ❖ WP2 main system elements and technical characteristics of the laser scanner that is being developed ❖ WP3 Scanner and Perception system development: testing of system efficiency in laboratory conditions and its training using field simulation software ❖ WP4 Autonomous vehicle for laser weeding including development of key devices and system elements: ❖ Task 4.2 Adaptation of the mobile platform ❖ Task 4.3 Smart Central Controller ❖ Task 4.4 IoT and cloud computing integration and management
Expert presentations	
What do we need to put WeLASER system at work? Paul van ZOGGEL (Van Den Borne Projecten BV)	Key factors of successful implementation of WeLASER approach were presented such as trust, software integration, support solution, flexible hardware and learning experience during implementation process
How to make autonomous agricultural machines safe? Jeroen WOLTERS (Smart Agri Technology BV)	Key considerations and practical aspects of safety and security in working in the fields with agri-robots, based on current experiences were outlined. It included planning of the work, controlling of the machine, use of sensors, safety rules for workers, connection issues, standards and good practices
WeLASER – Laser-Safety Issues Michael HUSTEDT (Laser Zentrum Hannover e.V.)	The main issues of laser technology safety including relevant legal regulations, specific conditions and safety measures (closed shielding, safety circuit and sensors) proposed in WeLASER approach were presented

How to implement WeLASER technique in practice? – opportunities and drawbacks Xavier GELLYNCK (Prof, Ghent University)	The main economic aspects related to implementation of WeLASER technique were overviewed including opportunities for its application related to precision agriculture and organic farming, market conditions (competing solutions), and potential barriers such as economic feasibility or lack of knowledge
Legal challenges for WeLASER technique implementation Pamela LATTANZI (Prof, University of Macerata)	Legal issues with regard to EU legislation concerning safety and liability of producers and users were overviewed in relation to characteristics of the WeLASER invention (autonomous vehicle, Artificial Intelligence).
Break	
Panel discussion Barriers and Bridges to implementation of WeLASER technique Farmers' voices and general discussion) Panelists: Aira SEVÓN (Organic farm&NGOs Finland) Bo JM SECHER (Nordic Sugar A/S) Marcos Garcés (farmer Spain, COAG) Troels PRIOR LARSEN (farmer Denmark) Andrzej PRZEPERSKI (farmer & agrobusiness Poland) General discussion: All attendees Beata MICHALISZYN (Facilitator) Janusz KRUPANEK (WP1 Leader**)**	The facilitator divided the discussion into two different parts: ❖ Panel discussion focused on two questions: 1. Do you think that use of innovative techniques such as WeLASER could increase competitiveness of your farm? Which current issues are you facing with weeding practices that you expect WeLASER can address in order to improve your business competitiveness? 2. What kind of stimulators or barriers would be important in application of inventions such as WeLASER autonomous tools in practice? Please refer to the health and safety concerns related to the use of innovative technologies. Answering the questions panelists provided valuable insight into implementation of WeLASER based on their experiences. The detailed answers for the questionnaires is provided in annex 4 ❖ General discussion related to the main topics of the meeting was held with interventions from stakeholders and consortium members. Overview of the discussion and detailed information is provided in Annex 3
Wrap up and next steps Janusz KRUPANEK Pablo GONZALEZ-DE-SANTOS	The Multi-actor strategy WP leader summarized the main conclusions and explained the next steps of stakeholders' involvement.
Closure Janusz KRUPANEK	The event organizer thanked for the fruitful event and closed the meeting. Good evaluation is received from participants (Annex 4)

10.2.2. Agenda of the 2nd Stakeholder Event

WeLASER
Eco-innovative weeding with laser

Sustainable Weed Management in Agriculture with Laser-Based Autonomous Tools

AGENDA OF THE 2ND STAKEHOLDER EVENT

Link to the meeting: https://us02web.zoom.us/j/84881065558?pwd=Z0ZMemFMMjVKeGhBbExFbklHR1hiQT09

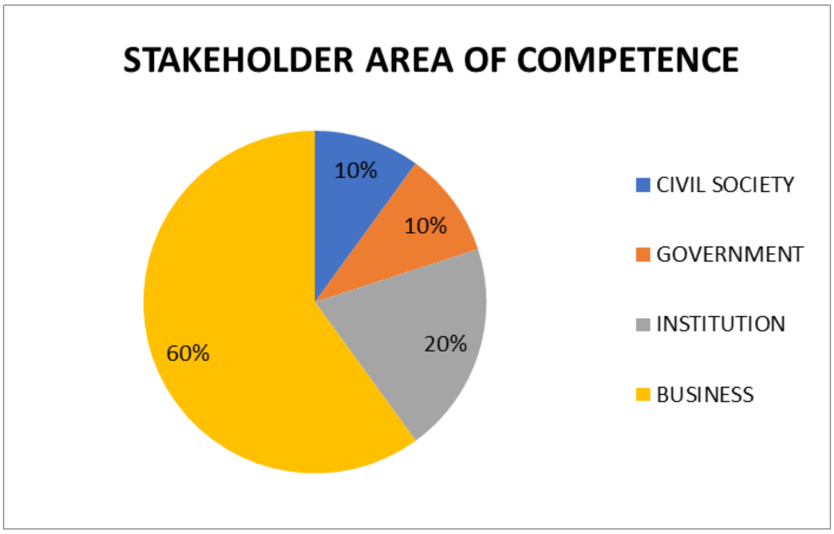
Virtual meeting

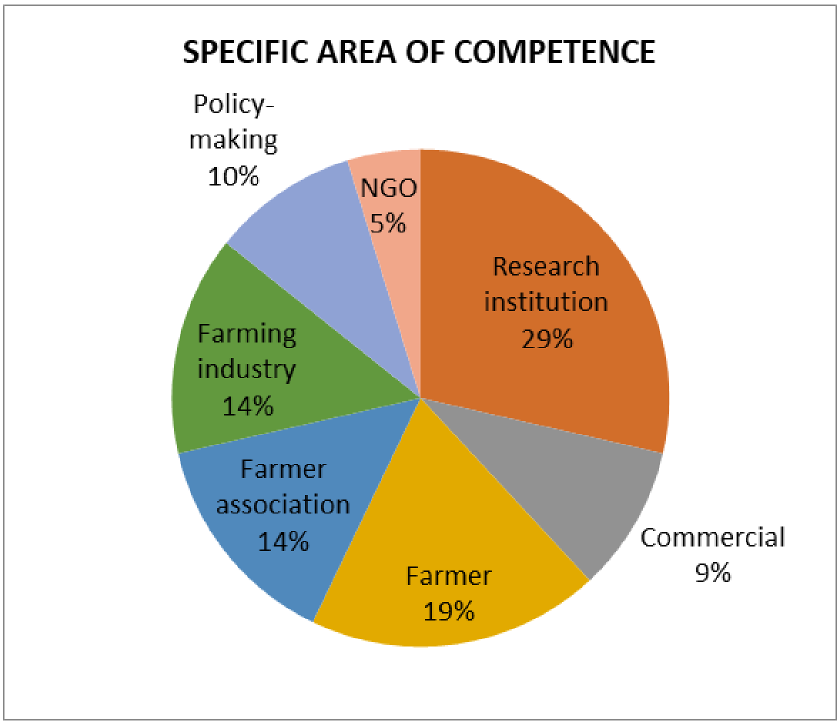
May 25th, 2021

09:30 – 9:35	**Warm up and introduction**	Janusz KRUPANEK (Event organiser/Multi-actor strategy leader)
9:35 – 9:45	**WeLASER vision and project overview**	Pablo GONZALEZ-DE-SANTOS (Project coordinador)
9:45 –10:15	**How do we want to achieve the results ? - status of project activities**	WP leaders
10:15 – 10:25	**What do we need to put WeLASER system at work?**	Paul van ZOGGEL (Van Den Borne Projecten BV)
10:25 – 10:35	**How to make autonomous agricultural machines safe?**	Jeroen WOLTERS (Smart Agri Technology BV)
10:35 – 10:40	**WeLASER – Laser-Safety Issues**	Michael HUSTEDT (Laser Zentrum Hannover e.V.)
10:40 – 10:50	**How to implement WeLASER technique in practice? – opportunities and drawbacks**	Xavier GELLYNCK (Prof, Ghent University)
10:50 – 11:00	**Legal challenges for WeLASER technique implementation**	Pamela LATTANZI (Prof, University of Macerata)
11:00 – 11:20	**Break**	
11:20 – 12:50	**Barriers and Bridges to implementation of WeLASER technique** **Farmers' voices and general discussion**	Panelists, All attendees Beata MICHALISZYN (Facilitator) Janusz KRUPANEK (WP1 Leader)

12:50 – 13:00	**Wrap up and next steps**	Janusz KRUPANEK Pablo GONZALEZ-DE-SANTOS
13:00	**Closure**	

10.2.3. Overview of attendees





10.2.4. Discussion session

Panel discussion

The short panel session was held. During the session, panelists were asked for a very brief answer to the following two questions:

1. Do you think that the use of innovative technologies, such as WeLASER, can increase the competitiveness of your farm? Please explain why. What current issues are you facing regarding

weed control practices that you think WeLASER technology can solve to improve your company's competitiveness?

2. What other stimuli or barriers could be important in implementing technologies such as WeLASER in practice? Please justify your answer briefly. Please also refer to the occupational health safety aspects.

Panelists:

1. Aira Sevón,

2. Bo JM Secher,

3. Troels Prior Larsen,

4. Marcos Garcés

5. Andrzej Przeperski (expressed his opinion by sending written statement)

Summary of panelists' statements.

Agricultural crops are associated with weed problems for example the cereal fields. Due to changes taking place in the countryside, agricultural practices are aimed at maximizing the good health and safety of plants, soil and the environment as a whole. We are very much depended on the activities of the Common Agricultural Policy and Green Deal Action Plan. It would be significant to receive investment money to gain new opportunities like this type of machines.

This [WeLASER] invention would be absolutely great for organic farming, especially perfect for sugar beet farming. Many companies, in order to limit the use of chemical agents for weed control, are looking for new solutions in this field. For example, Denmark is close to meeting its herbicide use limits: WeLASER technology could be a good solution for both conventional and organic farms in this country. For companies (example Danish) in the sugar industry, the implementation of the WeLASER technology would be a great support. The use of innovative technologies such as WeLASER can increase the competitiveness of farms, provided that the investment will pay off within a certain period of time. Currently, the costs calculations are not known and there is not possible to compare them with costs of other technologists.

The technology is very interesting. Safety aspects, which were underlined by other participants are important especially having the farm of about 20 hectares and having in mind that there are people around the farm where the robot is operating that could be in danger. But there are other, very important problems - controlling weeds. We are looking for and cannot find alternative solutions for weed removal without chemicals. In the future safety problems will be solved.

Farmers must manage the risk, know how to carry pioneer growing and benefit from professional revolution. The initial trainings and continuous trainings are needed for the implementation of new technologies – the WeLASER technology is an example of this.

The barriers indicated by the panelists were:

- Price of the new technology. Financial assistance will be needed, especially for small farms. Large farms or producer groups are the first to enter the highest technological level.
- Reliability.

- Trust in a new solution.
- There are concerns about the safety aspects of people who move around the field. For example, citizens (Finland) have free possibilities to go round the forest and fields. This would be dangerous.
- Human supervision is needed in order to provide safe, for the environment and people, operation of the technology.
- The issue of some technical matters is important: stability of the GPS system, equipment with sensors.

General discussion

We have to think about CAP and possibility of using of pandemic funds which will be just right for WeLASER technology implementation. Unfortunately, it will be coming into force in 2021. There is information that it might be delayed and it will be used in next two years 2022-2023. It might come too quickly for the project. We are hoping that it can be relevant for producers of sugar beets, vegetables and perhaps something else and hopefully also for cereal farmers, if the technology is efficient and the costs are low enough. The project management is urged to approach the EU Commission to make them see the arising opportunities and use the project's results as the possibility to affect the structure of the fund of next CAP.

There was a question of opportunities of WeLASER use for perennial weeds. Perennial weeds such like Thistle and Couch grass will be always the problem. They regrow as their root system can be very deep. They come again and again and we have to treat the field many times, but if we are looking at conventional farmers we can use different techniques for this. Danish farmers have the opportunity to use drones to map their fields and to spray crops for perennial weeds like thistles in the specific places. The combination of different methods could be useful but there still be a problem with organic agriculture and we really do not have a good solution. And it has still to be continued to avoid thistle and couch grass in the field and reduce it as much as possible and if you have a robot you will have to treat it several times as well.

This is also what we have to do today as we treat several times sugar beet in conventional and organic farms. We have to go out very early in the season to the field when the weed seedlings are very small. It will be exactly the same with the robot as there will be also regrowth of all common weeds species such like *Stelaria media* and all the other species

Another question is whether the rain affects the operation of the robot. In muddy fields it is not recommended to carry out the operations. It is rather light robots we are talking about and they do not make the same damage with the pressure as the tractor but if the crops or the weeds are wet, more energy is needed to get rid also of the water off the plants. Water protects the weeds as well. It would be much efficient to use the technique in dry conditions.

One comment is that when developing of such a platform - based on the experience of autonomous vehicles we have so far - one should not underestimate the software that has to be developed in order to control the system. The software must be easily accessible. There are examples where the developers get really confused in the end because of the troubles with operating of the system.

Question was asked whether it was tried to estimate the price tag by cost unit. The answer is: there is not enough data at this moment to estimate the cost. It is not a matter of decimal numbers but rather the range 1 thousand or 1 million. More time is needed to provide reliable figures.

The other comment regarded legislation. We have to lobby to get the approval to work with the autonomous vehicles in the fields because if we have to leave a man watching them, there will be no gain. There are common issues regarding legislation - there are no chemical compounds allowed in sugar beets for thistles. And if the farmers have to do that the compounds have to get the approval. On the other hand, we do not have to control thistle in sugar beet field if we control it in another year in another crop in rotation system. It is important that we can have a field without thistle for sugar beet.

Regarding the software, in the project consortium we do not underestimate this as we have to spend many hours and spend many resources. Regarding the price, we do not have idea about the cost of the system by now. We are going to achieve technological readiness of the level 7 and the system will be tested but not in real environment. The idea is to have 1 phase in the project and we will need additional funding for 2nd phase. It would be good to start to think about more projects and try to engage investors. Then in the second phase we will try to achieve the readiness of technology at the level of 9 what means that the system will be ready for commercialization. We have a horizon of 5.5 years from now. The system at the end of the project will be very expensive but we hope that we decrease the cost in more 3 years.

There is a bit concern that it will take 5.5 years for the consortium to start testing the solution for commercialization as there are several machines already in the US just for sale: with some examples of: EcoRobotics, Carbon robotics 2021 modifications. It is a need to be quicker. It is advisable to have the opportunity to have somehow the technique connected to the tractor. There is declaration [in Finland] to test the solution in a farm up in the north.

We are not going to reach the market at the end of WeLASER project. We are going to bring the system as close as possible to the market. Reduction of the cost is not the objective of the project. The objective is to build a technology capable to kill weeds using laser. After that we will have the chance to work to reduce the cost and develop further the technology. This is normal in technological developments.

There is discussion about the price, the speed of the machine, effectiveness and whether there should be people in the field supervising the autonomous vehicles. We should not look into the limitations in the project but rather we should look into the future. Thanks to this [WeLASER] system we can control the weeds in conventional and organic farming (in smaller crops) without using almost all chemicals. We need the project to go to the field to solve the problem if we get to that point the rest of the concerns like price and the security will be solved.

Can the cost of autonomous machinery be reduced by incorporating the technology to existing solutions (tractor) without automatization?. For the laser technology there is another project in which we are working [project partner] in implementing laser technology integrated with a tractor in a project dealing in sugar beet farming. There we try to combine hoeing in interrow weeding with laser weeding in the row. The work started in April. In the laser part we are thinking in both directions. Using of the technology with a tractor might be also the first thing to do [from Finnish perspective].

There is discussion about the price, the running speed of the machine and effectiveness. Maybe it is a good idea about using of WeLASER in cities. There is more than 20-year experience of chemical free killing weeds in the cities and at the same time carbon emission free solutions. For that purpose, there are produced electric vehicles. In the cities there are different regulations than in the agriculture. There is no need for very high speed, low speed is fine. With the first [WeLASER] machines we can go into the Cities [Netherlands] within existing networks in which a lot of research is done and find out how the innovation works in agriculture and in the middle of the cities like London and Amsterdam.

What about the solar panels, is it possible to add solar panel? The experience from other projects is that it gives very low power. It is not essential issue in WeLASER to add solar panels just to get a few Watts of energy. Another question is whether it is possible to load the machine with renewable energy.

It has to be well recognized that tractors are different than industrial machines. The rules of operation are completely different for them. In this [WeLASER] case, the agri-robot is a self-moving machine and it needs a red button to stop it immediately as it works in any industrial machine. Contrary, tractors are not autonomous vehicles. Artificial intelligence is related in this case to machines not to tractors with a man aboard.

We have to consider how the legal aspects can have an impact on agri-robots. We have to consider many legal aspects. From a legal point of view, we have to think whether we are dealing with the machinery or a tractor. According to WeLASER presentations, we can assume that we are dealing with machinery because the speed of the robot is below 6 km per hour and consequently the tractor regulation does not apply to such kind of machine. Regarding the artificial intelligence in the WeLASER system two intelligence systems can be differentiated. We have artificial intelligence for moving the machine as autonomous robot and artificial intelligence pertained to the use of laser. The proposal for regulation on artificial intelligence will be very relevant and the “new” regulation on machinery. They will be important for safety requirements and liability rules.

The law in this field is quickly evolving. [EU] Machinery regulation and the artificial intelligence regulation want to tackle legal obstacles to such innovations in several sectors, also in agriculture. New legal acts will aid manufacturer, and also users including farmers using the agriculture robots in precision agriculture. Currently, there are legal barriers even if we can find legal solutions related to liability and safety. The new regulations will be agri-robot friendly. WeLASER will have a lot of possibilities in the future.

It is also the issue of insurance. Given the information, it is assumed that the insurance cost will be a minor issue. The investment costs and operation costs will be more significant. Although, insurance will be essential. It will be critical for both the producers and users to be correctly ensured. If we are looking from cost/price perspective, for the investment, especially given the fact that technology in this domain is evolving rapidly, LiDAR it will mean that the depreciation period for the farmer has to be reduced. Because in the period of 2-3 years new revolution of technology can come to the market and considering that the hardware is not flexible and cannot be easily adapted to changes there will be a low residual value. Once it is bought immediately the value will drop dramatically, and we should try to avoid such situation in designing of the machine. Then, the cost per year and per hectare can be reduced. If this is not the case, it will be tricky for the consumer to make the investment.

In drone manned system flying safety and security is a big problem. We have a possibility to learn from this sector with regard to safety. For example, it is required to apply a parallel system to shut down the drone fly if there is a problem. The parallel system operates in other frequency than the pilot system and is commanded by another person who is the observer of the fly. You can implement a system like this in cases where it is necessary to observe the agri-robot operating in the field.

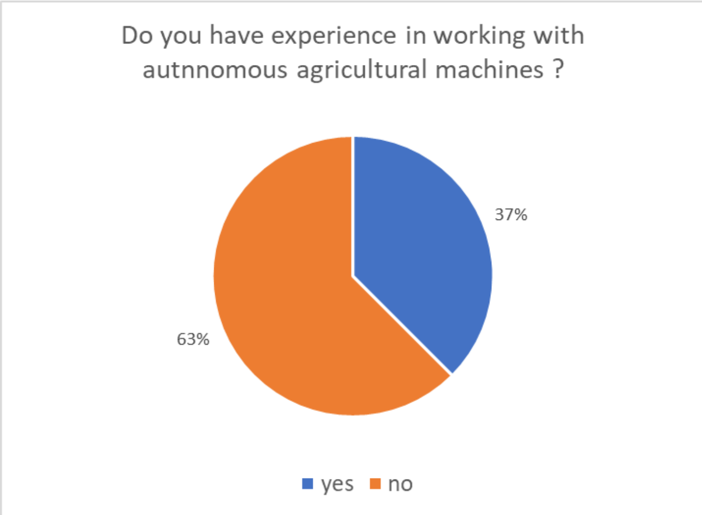
The new drones have many sensors, software and other systems. They do only what is safe and man cannot override it. The drone cannot enter the airspace which is not allowed. It is under control. As a user you also cannot do what is not allowed to do. It is European wide system but we do not know whether it can be applied for machine on the wheels. It is good for predictable emergencies. The robot can be smarter in finding out possible accidents than the humans around but it should be a possibility to shut it down by human intervention.

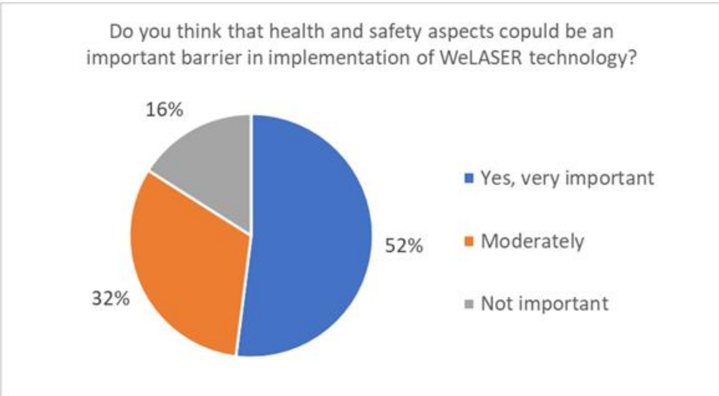
Other questions

Some other questions that have been raised in the chat:

- What are the power need from the vehicle to the laser unit?
- About the cooling system have already some experience in Southern Europe regions where the temperature could be a limit?
- we have no experience with high temp environments, but there are different chillers commercially available
- Does it separate weed such as couch grass (elymus repens) from cereals in early stage?
- Thank you for thinking of the IT-issues, it is not farmer business to constantly "discuss and adjust" with the software. But how does it learn? Into what extent farmers have to learn and adjust it to the farm/field level information?
- I am seeing just very "clean and smooth" fields, this is not the reality e.g. in Scandinavia, also Scotland might have the same issues.
- this means these are also the areas where the human work force is very expensive.
- in Poland, there are often power poles in the fields. For what the question of the collected water line?
  It often happens in the fields that a small lake forms after heavy rainfall. Will the machine enter something like this and get stuck, or will it be able to detect that something is wrong and react?
- If understand right, we need to flag around fields to stop people to come to your field? That takes time e.g. we have 20-30 hectare field, that takes quite a bit of time if the machine should save time? How about if deers or moose come near, then the machine stops?
- Damian, we got the same issues. Good questions!
- What happens if the machine reaches the edge of some, for example, an irrigation ditch crossing a field?
- Will the laser work in the air or will it detect that it is higher than it should be?
- We are additionally using a LiDAR camera to monitor the ground and plants. So this ditch would be detected.
- As a lawyer I can think of many safety issues... knowing the court cases increases the pain *LOL* and I know farmers would not probably consider as many hazards...
- will the machine be able to work in the rain? will it turn off automatically when it rains? What if the machine is struck by lightning? maybe a low probability, but still.
- Yes, surely we work the organic fields with various mechanical tools/machines throughout the year (when there is no snow ;-)), not with any chemicals though
- 1000 euro per Ha per year was/is the threshold in application. The costs per unit depends than on how many parts will be ordered at once… We need to Think Tesla ;)
- Bert van Loon makes a good point to also include city for bringing costs down in the future.
- Insurance, for Drones this is maturing. We need an EASA for autonomous machines.

10.2.5. Results from polls





10.3. Annex 3 – The Third WeLASER Stakeholders' Event

10.3.1. Minutes of the 3rd Stakeholder Event

WeLASER
Eco-innovative weeding with laser

Sustainable Weed Management in Agriculture with Laser-Based Autonomous Tools

MINUTES OF THE 3RD STAKEHOLDER EVENT

November 19th, 2021

Due to the situation caused by Covid-19, a virtual event (videoconference) was organised by IETU using Zoom service. The agenda of the event is included in Annex 1. General information on attendees is included in Annex 2. The meeting started at 9:30 a.m and ended at 12:10. The event was a new opportunity to involve stakeholders in the project activities. It was focused on key environmental requirements in relation to farmers' and societal needs and respective EU policies.

Warm up and introduction Janusz KRUPANEK (Event organiser/Multi-actor strategy leader) Who is present? Short presentation	The event organizer welcomed the participants and explained: ❖ The aim of the event present project developments and discuss environmental issues including environmental performance, key benefits and potential impacts related to the WeLASER application in practice ❖ The agenda of the event ❖ presentation of participant groups
Project and its activities - overview	
WeLASER project overview Pablo GONZALEZ-DE-SANTOS (Project coordinador)	The project coordinator presented a brief overview of the project highlighting the following elements: ❖ Project main aim ❖ Project-specific objective and proposed solution ❖ Brief description of the consortium ❖ Overview of project activities EIP-AGRI and Multi-actor approach and Innovation action (and consequences) ❖ Position of the stakeholders in the project management and communication of project activities
What we have achieved so far and what is ahead – status of WeLASER invention development WP leaders: Karsten SCHOLLE (FUTONICS) - WP2 Merve WOLLWEBER (LZH) - WP3 Suzanne BARON (AGC), Luis EMMI (CSIC) & Guliano VITALI (UNIBO) - WP4 Luis EMMI (CSIC)	The leaders of technical workpackages presented recent developments and achievements of the project ❖ WP2 – Laser-based weeding system: successful trials of laser component design operations and positive laboratory testing results of weed meristem killing ❖ WP3 – Weed-meristem perception system: further training artificial intelligence based on field and laboratory data ❖ WP4 – Autonomous vehicle for laser weeding: development of key Agri robot elements: ❖ Task 4.2 Adaptation of the mobile platform to the needs of WeLASER solution ❖ Task 4.3 Smart Central Controller: integration in the system ❖ Task 4.4 IoT and cloud computing integration and management ❖ WP5 – Industrial integration and evaluation: successful completion of the design meeting the technical requirements and stakeholders needs. and plans for its testing. Successful design of the system

Expert presentations	
EU policy related to sustainable weed control in agriculture Aira Sevón	Environmental requirements in organic farming were presented as the most demanding in agriculture in relation to EU policy. Principles of organic farming with regard to WeLASER application were reviewed and questions related to future application in the sector posed..

IFOAM - International Federation of Organic Agriculture Movements	
Sustainable weed control: benefits and challenges – organic farming perspective Aira Sevón Organic farm, Finland	There were presented key environmental considerations and practical aspects of weeding in the fields managed according to organic farming principles. Key problems of the Finnish organic farming and the feedback from Finnish farmers related to WeLASER concept were overviewed and discussed.
How can weeding with laser beams support biodiversity? Christian Andreasen University of Copenhagen	Results of WeLASER testing were presented showing high efficiency of performance for destructing weed meristems with small impact on surrounding environment (soil life). Key environmental benefits of the technique were outlined including soil life protection, safety for pollinators and beneficial animals. Lesser impact on soil compaction. was argued in comparison with mechanical and chemical weeding based on heavy machinery.
Environmental performance of WeLASER invention – project activities Janusz Krupanek Instytut Ekologii Terenów Uprzemysłowionych (IETU)	In the presentation a brief overview of WeLASER activities related to the environment, biodiversity and sustainability were outlined along with summary of key factors determining environmental performance of WeLASER technique.
Break	
General discussion: Which factors of WeLASER technique implementation should be focused on to achieve high environmental performance? Which environmental benefits would be the biggest gain ? Are there environmental risks requiring special attention ? All attendees Beata MICHALISZYN (Facilitator) Janusz KRUPANEK (WP1 Leader)	❖ During the presentations and discussion the attendees used mainly chat to express and exchange their views on the topics presented. Stakeholders comments were related not only to the environmental issues but also to general aspects of the project development. ❖ A brief discussion was held with input from stakeholders and consortium members. Stakeholders pointed at enhancing environmental and health benefits of WeLASER system application ❖ Poll related to the key topics of the meetings was carried out and the results are presented in the annex 4 ❖ Overview of the discussion and detailed information is provided in Annex 3
Wrap up and next steps Janusz KRUPANEK Pablo GONZALEZ-DE-SANTOS	The Multi-actor strategy WP leader summarized the meeting outcomes and explained the next steps of stakeholders' involvement.
Closure Janusz KRUPANEK	The event organizer thanked for the fruitful event and closed the meeting.

10.3.2. Agenda of the 3rd Stakeholders' Event

Link to the meeting: https://zoom.us/j/93229166880?pwd=a1BVbURoUWlGYnFKVmk2THR3dXJSQT09

WeLASER
Eco-innovative weeding with laser

Sustainable Weed Management in Agriculture with Laser-Based Autonomous Tools

AGENDA OF THE THIRD STAKEHOLDERS' EVENT

Virtual meeting

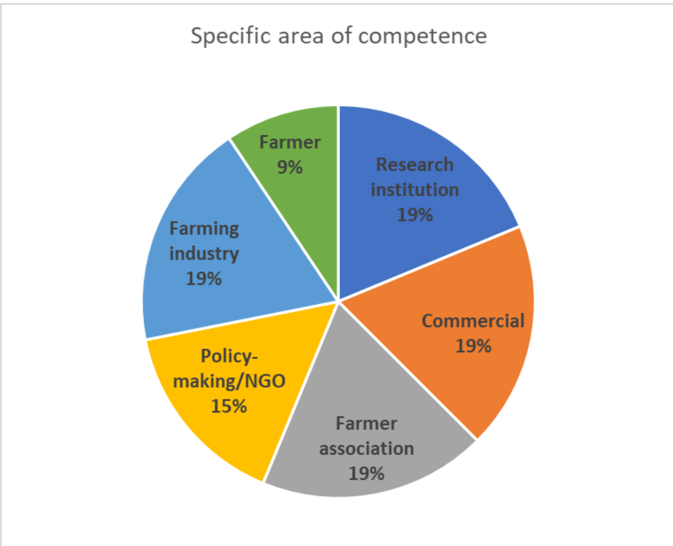
November 19th, 2021

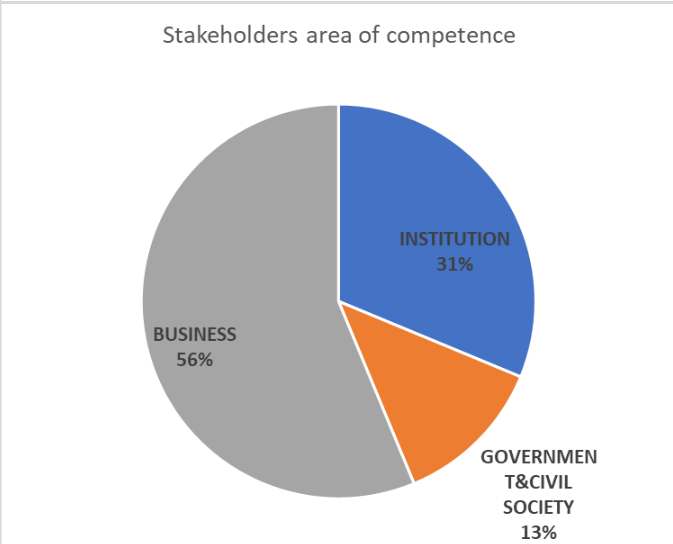
09:30 – 9:35	**Warm up and introduction**	Janusz KRUPANEK (Event organiser/Multi-actor strategy leader)
9:35 – 9:40	**WeLASER project overview**	Pablo GONZALEZ-DE-SANTOS (Project coordinador)
9:40 –10:25	**What we have achieved so far and what is ahead – status of WeLASER invention development**	WP leaders
10 min	*WP2 – Laser-based weeding system: Development and impact*	*Futonics Laser GmbH, (FUT)*
10 min	*WP3 – Weed-meristem perception system*	*Laser Zentrum Hannover (LZH)*
15 min	*WP4 – Autonomous vehicle for laser weeding*	*AGREENCULTURE (AGC), University of Bologna (UNIBO), Centre for Automation and Robotics (CSIC)*
10 min	*WP5 – Industrial integration and evaluation*	*Centre for Automation and Robotics (CSIC)*
10:25 – 10:35	**Break**	
10:35 – 10:45	**EU policy related to sustainable weed control in agriculture**	Aira Sevón IFOAM - International Federation of Organic Agriculture Movements
10:45 – 10:55	**Sustainable weed control: benefits and challenges – organic farming perspective**	Aira Sevón Organic farm, Finland

10:55–11:05	**How can weeding with laser beams support biodiversity?**	Christian Andreasen University of Copenhagen
11:05 – 11:10	**Environmental performance of WeLASER invention – project activities**	Janusz Krupanek Instytut Ekologii Terenów Uprzemysłowionych (IETU)
11:10 – 12:00	**Discussion:** **What are the benefits and what are the environmental concerns of WeLASER implementation in practice**	Janusz KRUPANEK (WP1 Leader)
12:00 – 12:10	**Wrap up and next steps**	Janusz KRUPANEK Pablo GONZALEZ-DE-SANTOS
12:10	**Closure**	

10.3.3. Overview of attendees

The Third WeLASER Stakeholders' Event gathered over 40 participants including farmers, representatives of research and agricultural institutions, policymakers, NGOs and project partners.





WeLASER Consortium	
CSIC	Pablo GONZALEZ-DE-SANTOS Roemi FERNANDEZ Luis EMMI
FUT	Karsten SCHOLLE Anja Ahrens M Kaule
LZH	Merve WOLLWEBER Michael HUSTEDT Hendrik SANDMANN
UCPH	Christian ANDREASEN
COAG	Alvaro ARETA
UNIBO	Giuliano VITALI Maurizio CANAVARI Cristiano FRAGASSA
AGC	Suzanne Baron
IETU	Janusz KRUPANED Wanda JAROSZ
UGENT	Margo Degieter Duc TRAN Joachim Schouteten
VDBP	Paul VAN ZOGGEL

10.3.4. Key results of expert feedback and the discussion

The discussion was predominantly based on experts views who presented key environmental aspects of WeLASER invention and outlined environmental and health benefits of WeLASER. A feedback from an interview of farmers in the Kymi Organic Coop in Finland related to WeLASER technique was presented. Environmental aspects were also highlighted during presentations of the work performed in particular workpackages.

Experts and stakeholders pointed at the need for enhancing environmental and health benefits in WeLASER system application. It was expressed by the participants that environmental issues in WeLASER constitute a significant aspect in further development of the invention and its practical applications. Lesser environmental contamination is viewed as the key benefit. Healthy food was also indicated as a relevant consideration.

Another question posed by the expert is whether WeLASER can be used in organic farming. The main features of the technology and its application potential has to be better explained in further project proceedings. The suitability of WeLASER technique for farms with regard to their area and scale of operations was discussed. According to farmers' views presented by the expert, the WeLASER technique can bring opportunities especially for conventional farmers. On the other hand, in large, conventional farming other opportunities for environmental improvements are also observed including those based on precision agriculture, such as the use of mechanical weeding robots and precision chemical weeding.

Use of WeLASER in organic farming would depend on particular conditions of a given farm as they are more diversified in its production scope, conditions and scale. In organic farming there is already used a wide set of environmentally friendly approaches to weed management, meeting the organic farming principles. According to the expert 90% of organic farmland has no need for plant protection products. The alternative solutions include for example: close cropping, tillage. There is also a new activity in Finland where no-till system is tested.

The issue of the impact of automation of farming work and precision agriculture on farms structure in Europe was raised as there are concerns whether smaller farms can be less competitive in Agriculture 3.0 and 4.0. The interesting question is to what extent WeLASER can raise the efficiency in applications in both types of farm structures and whether it can change the competition between them. The opportunities to serve both needs of large farms and small organic farms have to be addressed in project developments. In small organic farms it can replace the manual work and single robot can be effective and efficient.

It has to be thoroughly considered whether laser technique comply with principles of organic agriculture (principles of ecology, health and care) as well as appropriate requirements of conventional farming. From that perspective approval process has to be carried out if WeLASER has to be accepted in respective sectors. It includes verification of its efficiency, determining of Key Performance Indicators, evaluating its impacts on crops and the environment. A question arises whether existing systems for machineries, technical standards and certification of agricultural performance are sufficient to secure trust in the new technique.

It was generally agreed that WeLASER can be beneficial for biodiversity in agricultural landscapes. Lesser impact on soil compaction was argued by the expert in comparison with mechanical and chemical weeding based on heavy machinery. This can be avoided when using smaller machines. Regarding protection of soil life the tests of the laser impact are promising. The experiments of laser treatment results show that only a tiny area of soil can be affected during the laser action on plant meristems.

Moreover, ecosystem services can be potentially enhanced through operational schemes of selective weed management based on the designed agrirobot functionality, e.g., cover crops and nitrogen fixation crops have to be recognized and preserved. The autonomous robot can be more selective than the traditional techniques but it might require specific approach in the artificial intelligence program design. It was explained that the artificial intelligence is trained in the first place to recognize the crop plant and the rest of plants spotted in the treated area is removed from the field. The training is specific for a given crop. In new circumstances it has to be retrained or trained specifically to a new crop, new conditions or weeding requirements.

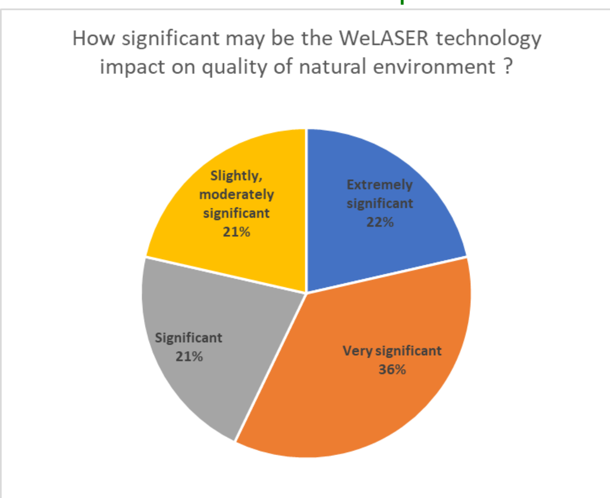
There is also the question how, where and in which situations WeLASER could be used in farming practice. The potential scenarios of usage have to be better understood. It is important to recognize the opportunities, barriers and conditions of using the WeLASER technique. These include stage of weed development, the temporal window of operation (also in relation to the velocity), cases (crop, weed and their development stages) which are excluded. It is envisaged that the technology is suitable for certain weeding scenarios. For example, in organic agriculture it is recognized that it has potential for weeding of vegetables and farming in rows, covering annuals and perennial weeds such as thistle. It can be effectively used, for example for weeding rape seed in early growth phase without harming pollinators. One of the farmers' concerns presented by the expert is the need for specific surface conditions in the field with respect to field surface characteristics. The key environmental issues for consideration in implementing WeLASER are: energy intensity, healthiness to land and crops, effects on pollinators and natural predators of certain pests and animals. From that perspective the technique can potentially address the Integrated Pest Management rules and can be favorable to biodiversity.

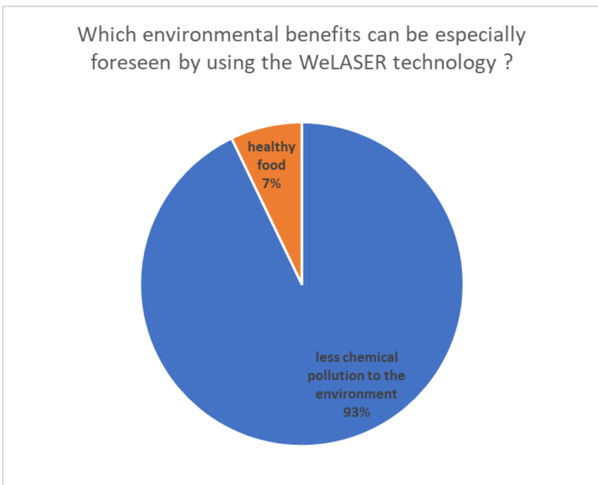
The question of efficiency of WeLASER Agri robot was discussed. One option suggested by the participants can be an extension of the implement coverage of the working area but in this case it would require higher weight. In the project a double system of four laser units is proposed in the second phase of its development after completion of the current project. In large fields to enhance weeding efficiency and environmental benefits, the opportunities for using fleets of robots can be considered. Continuous, autonomous work can play a role in this respect. In organic farming use of single robots with diversified functionalities can be of value. Flexibility of application/efficient use is one of the factors of overall and environmental efficiency: track width, operating mode on slopes, ground clearance, combination and integration of techniques (intra and inter row weeding) including chemical, mechanical and laser, flexible use of the implement in tractors or change of implements in the autonomous vehicle, addressing other plant pathogens (fungi, insects), specific needs of organic farming, crop production systems

It was explained that the project addresses environmental and health issues on technical and strategic levels. It gives a good ground for future verification of the technology and its implementation as the key points are to be clarified during the project. On technical level the specific assessment of the components is carried out e.g. impact of laser action on the soil and overall evaluation of its performance. For technical components both benefits and potential impacts on environment are taken into account. The direct and indirect impacts on the environment are addressed. Protective measures for humans and the environment researched in the project were highlighted by the expert. These include e-fence, protective curtains for laser system, very precise performance of the laser as the basic feature.

In the strategic part of the project, sustainability assessment of WeLASER application in life cycle perspective is considered including social, economic and environmental aspects. It is underlined that operational issues has to be taken into account in the research. It is agreed that the key to the success, is the overall efficiency of the robot. The benefits of WeLASER application can be fully exploited in relation to various EU policies and especially the Common Agricultural Policy. It can be envisaged that CAP reform will favor the technique if the environmental, economic, and social benefits are proven. The EU Farm to Fork strategy aims to reduce the use of herbicides and pesticides (e.g., reduce use of herbicides with 50%) and fertilizer use, reduced use of antimicrobials and increase area of organic farming to more than 25%.

10.3.5. Results from polls





10.4. Annex 4 – The Fourth WeLASER Stakeholders' Event

10.4.1. Minutes of the 4th Stakeholder Event

WeLASER
Eco-innovative weeding with laser

Sustainable Weed Management in Agriculture with Laser-Based Autonomous Tools

MINUTES OF THE 4TH STAKEHOLDERS' EVENT

November 24th, 2021

To provide an opportunity for a wide participation of stakeholders a virtual event (videoconference) was organised by IETU using Zoom service. The agenda of the event is included in Annex 1. General information on attendees is included in Annex 2. The meeting started at 9:30 a.m and ended at 13:00 p.m.. The event was a new opportunity to involve stakeholders in the project activities. It was focused on the results of the WeLASER machine integration, its testing, its key features, functionalities and efficiency as well as key factors and strategies for its successful implementation.

Warm up and introduction Janusz KRUPANEK (Event organiser/Multi-actor strategy leader) Who is present? Short presentation	The event organizer welcomed the participants and explained: ❖ The aim of the event: presentation of current results of WeLASER integration and testing and discuss its key features, functionalities, efficiency and key factors and strategies for its implementation ❖ The agenda of the event ❖ Presentation of participant groups
Project and its activities - overview	
WeLASER project overview Pablo GONZALEZ-DE-SANTOS (Project coordinador)	The project coordinator presented a brief overview of the project highlighting the following elements: ❖ Project main aim ❖ Project-specific objective and proposed solution ❖ Brief description of the consortium ❖ Overview of project activities EIP-AGRI and Multi-actor approach and Innovation action ❖ Position of the stakeholders in the project management and communication of project activities
WeLASER autonomous robot on the move – status of its development WP leaders:	The leaders of technical workpackages presented recent developments and achievements of the project ❖ WP2 – Laser-based weeding system: further modifications of the laser system aimed at higher power and energy efficiency and positive laboratory

Karsten SCHOLLE (FUTONICS) - WP2 Christian ANDREASEN (UCPH) Michael Hustedt (LZH) - WP3 Suzanne BARON (AGC), Luis EMMI (CSIC) & Guliano VITALI (UNIBO) - WP4 Luis EMMI (CSIC) - WP5	testing of laser on plants with high effects of its impact on weed (destruction) and low impact on crop seeds and living organisms ❖ WP3 – Weed-meristem perception system: opportunities for raising the efficiency, precision of performance of the weed recognition system ❖ WP4 – Autonomous vehicle for laser weeding: Confirmed functionality and successful integration of all systems ❖ Task 4.2 autonomous mobile platform: improved architecture, more powerful energy source, and better adaptation to the WeLASER robot function, ❖ Task 4.3 Smart Central Controller: integration within the system including the mobile platform and the weeding implement and it successful testing ❖ Task 4.4 IoT and cloud computing: testing of integration of the system and wide set of management opportunities ❖ WP5 – Industrial integration and evaluation: successful integration of the system (mobile platform and the implement) and its field testing and plans for further activities.
Expert presentations	
WeLASER in agriculture. Are socio-economic factors important for its implementation? Beata MICHALISZYN (IETU)	Key socio-economic aspects were presented as potential drivers or obstacles to its implementation.
The best way of WeLASER implementation in agriculture Di Minh Duc TRAN (Ghent University)	Situation in the agricultural machinery market and future trends were presented along with WeLASER potential and strategies for its implementation in practice.
Break	
Implementing WeLASER in agriculture. Vision, key functionalities and market perspectives *Do the WeLASER integration results meets your expectations?* *Which socio-economic factors would favour WeLASER implementation?* *Which implementation strategies would be the most promising?* All attendees Janusz KRUPANEK (WP1 Leader**)**	❖ During the presentations and discussion, the attendees used mainly chat to express and exchange their views on the topics presented. Stakeholders comments were related to general aspects of the project development, its effectiveness, functionalities, performance, application potential and barriers. ❖ A brief discussion was held with input from stakeholders and consortium members. Stakeholders pointed at energy efficiency and weeding performance as crucial in WeLASER system application ❖ Poll related to the key topics of the meetings was carried out and the results are presented in the annex 4 ❖ Overview of the discussion and detailed information is provided in Annex 3

Wrap up and next steps Janusz KRUPANEK Pablo GONZALEZ-DE-SANTOS	The Multi-actor strategy WP leader summarized the meeting outcomes and explained the next steps of stakeholders' involvement.
Closure Janusz KRUPANEK	The event organizer thanked for the fruitful event and closed the meeting.

10.4.2. Agenda of the 4th Stakeholder Event

Link to the meeting: https://zoom.us/j/93229166880?pwd=a1BVbURoUWlGYnFKVmk2THR3dXJSQT09

WeLASER

Eco-innovative weeding with laser

Sustainable Weed Management in Agriculture with Laser-Based Autonomous Tools

AGENDA OF THE 4 TH STAKEHOLDER EVENT

Virtual meeting

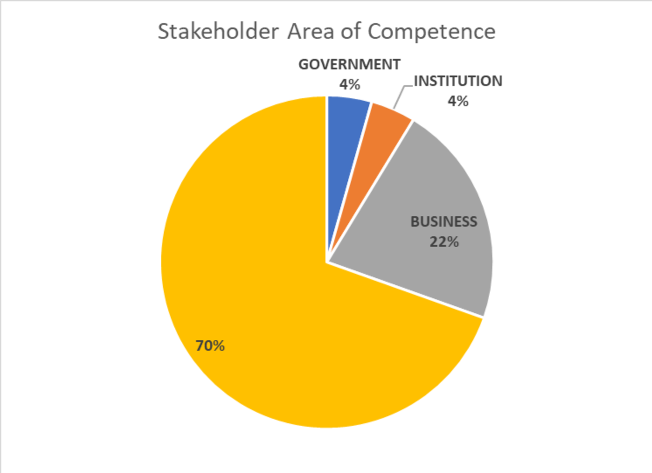
November 24th, 2022

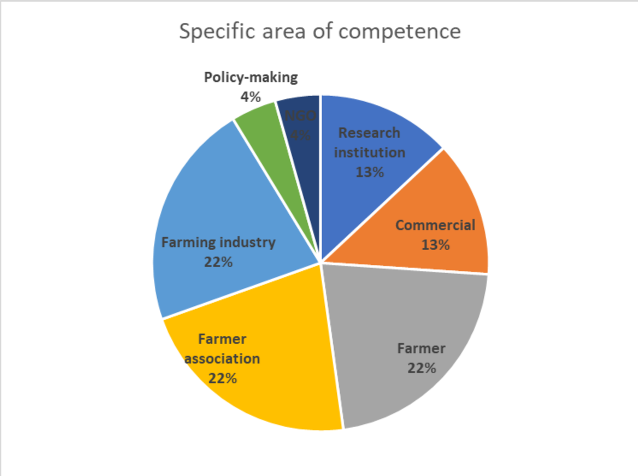
09:30 – 9:40	**Warm up and introduction**	Janusz KRUPANEK (Event organiser/Multi-actor strategy leader)
9:40 – 9:50	**WeLASER vision and project overview**	Pablo GONZALEZ-DE-SANTOS (Project coordinador)
9:50 – 11:00	**WeLASER autonomous robot on the move – status of its development**	WP leaders presentations and Q&A
9:50 – 10:15	*WP2 – Laser-based weeding system*	*FUT, UCPH*
10:15 – 10:30	*WP3 – Weed-meristem perception system*	*LZH*
10:30 –10:45	*WP4 – Autonomous vehicle for laser weeding*	*AGC, CSIC, UNIBO*
10:45 – 11:00	*WP5 – Industrial integration and evaluation*	*CSIC*
11:00 – 11:10	**WeLASER in agriculture. Are socio-economic factors important for its implementation?**	Beata MICHALISZYN (IETU)
11:10 – 11:20	**The best way of WeLASER implementation in agriculture**	Di Minh Duc TRAN (Ghent University)

11:20 – 11:35	**Break**	
11:35 – 12:45	**Implementing WeLASER in agriculture. Vision, key functionalities and market perspectives**	All attendees Moderation: Janusz KRUPANEK
12:45 – 13:00	**Wrap up and next steps**	Janusz KRUPANEK Pablo GONZALEZ-DE-SANTOS
13:00	**Closure**	

10.4.3. Overwiew of Attendees

The Fourth WeLASER Stakeholders' Event gathered over 40 participants including farmers, representatives of agricultural associations, advisers, research and agricultural institutions, policymakers, NGOs and project partners.





WeLASER Consortium	
CSIC	Pablo GONZALEZ-DE-SANTOS Roemi FERNANDEZ Luis EMMI
FUT	Karsten SCHOLLE
LZH	Michael HUSTEDT Hendrik SANDMANN
UCPH	Christian ANDREASEN
COAG	Alvaro ARETA
UNIBO	Giuliano VITALI
AGC	Suzanne Baron
IETU	Janusz KRUPANEK Wanda JAROSZ Beata MICHALISZYN
UGENT	Margo DEGIETER Duc TRAN
VDBP	Paul VAN ZOGGEL

10.4.4. Key results of expert feedback and the discussion

The discussion was in the most part based on experts' presentations from consortium who overviewed the status of development aspects of WeLASER for particular components of the invention and outlined social benefits of WeLASER application.

During LZH presentation of weed recognition system the opportunities for recognition of cover crops and other benign plants were of high interest to the stakeholders. It was explained that the recognition process is based on classification of objects where a few classes can be defined. From that point of view it is not a problem to program the system to recognize for example three classes of plants including two crops and the weeds. Moreover, it was explained that recognition of more classes would not require much more time for data processing.

In the presentation of the high-power laser by FUTONICS, the new developments oriented on lowering the energy demand and rising the efficiency of performance were presented. It was underlined that there is still essential potential for improvement of the laser system and the overall robot performance. Similarly, further developments of AGC in design of the mobile platform were carried out to provide more energy to operate the implement.

UGENT underlined in its presentation that it is crucial to be the first on the market to achieve success. The presentation rose an interest regarding the financing opportunities available for the potential customers of the machine in the market. Currently the presented opportunities are available to research funding as viable for further development of WeLASER. It was agreed that it has to be further pursued to provide farmers with support in modernization of the farming practices. The pricing of the new machine was underlined by the stakeholders as very critical factor for farmers. Currently, the strategies which are considered as the most viable by the consortium are leasing or buying. Socio-economic factors which can play a role in future implementation of WeLASER were also presented by IETU.

Effectiveness of WeLASER performance was discussed and it was underlined that the most efficient way of its application is to combine WeLASER in-row weeding with mechanical inter row weeding. In this combination WeLASER can achieve the working parameter currently set for 2 km/hour operation. Effective use of WeLASER might require also a good reconnaissance in the field with determination of field patches needing intervention. Moreover, in WeLASER development there is still a potential for further improvement of the key performance parameters – e.g lowering the energy demand per weed. Energy in case of WeLASER is viewed by the stakeholders as the most important factor determining the overall efficiency of the system.

The energy issue was one of the key concerns of stakeholders. The key features of energy generation and use were explained. The potential of using batteries was of interest for stakeholders including the time for charging the batteries, and the working time based on them in the field. It was explained that the batteries in the current version are used only as a back-up for the machine not the main source of energy which is the diesel electric system. Stakeholders underlined that using fully electric engine have certain benefits as related to noiseless work during night hours. This potential in recognizing of weeds should be considered as it was pointed out as one of the key benefits of the autonomous robot.

It was underlined by the LZH that the critical parameter is not the speed of the data processing by the weed recognition system but the energy which has to be used for killing the weeds. Basically, the speed of processing data can be further improved up to the desired level. It is possible to lower the time of laser operation sufficient to kill the meristem of the plant and through this to speed up the overall robot operation. Basically, the AI should match the efficiency of laser performance and process accordingly the data faster. Faster treatment of more weeds at the same time requires less total energy of the robot due to treatment speed. This is already optimized with scanners working in microseconds and very precise laser pulses.

The question of potential development of a series of different laser weeding robots serving various needs was also discussed. Flexibility in the opportunities of using the invention would be welcome by the farmers and other users. It was explained that, based on the basic robot construction successful implementation in WeLASER project, other solutions can be further developed including integration of the implement with common tractor. It was confirmed by the consortium that the flexibility of the solution allows to use it in other systems and combinations. This can be relatively easily done as the construction has the three-point hitch allowing at least the scanners to be mounted on the tractor. For the other components it is just the question of the housing and appropriate fixation of the housing to the specific application.

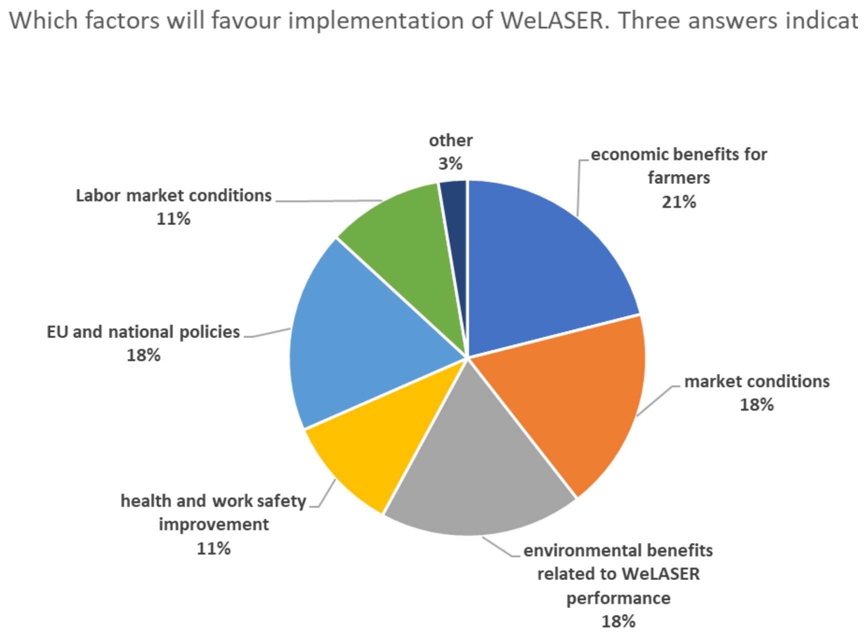
Application potential of WeLASER in weeding strategies was also discussed. Limitations of application in the field were revised by the consortium such as the stage of the growth, wetness of the soil. Although, the main crops for testing in the project are: maize, wheat, and sugar beet but the potential for laser is much greater including vineyards, potatoes for which the system can be reevaluated including the distances between and other parameters. It was underlined that WeLASER should be focused especially on high value crops. The growth stage of crop and weed can be a strong limitation. For higher growth stage more energy is needed and it can be more difficult for the recognition system to target the meristem if the plants cover each other. WeLASER is a good system for early low growth system and young crop plants where it can be used very efficiently. The farming practices can also determine the opportunities of using WeLASER. For example, for reduced tillage system where there is a lot of organic matter in the field a fire can be ignited during operation.

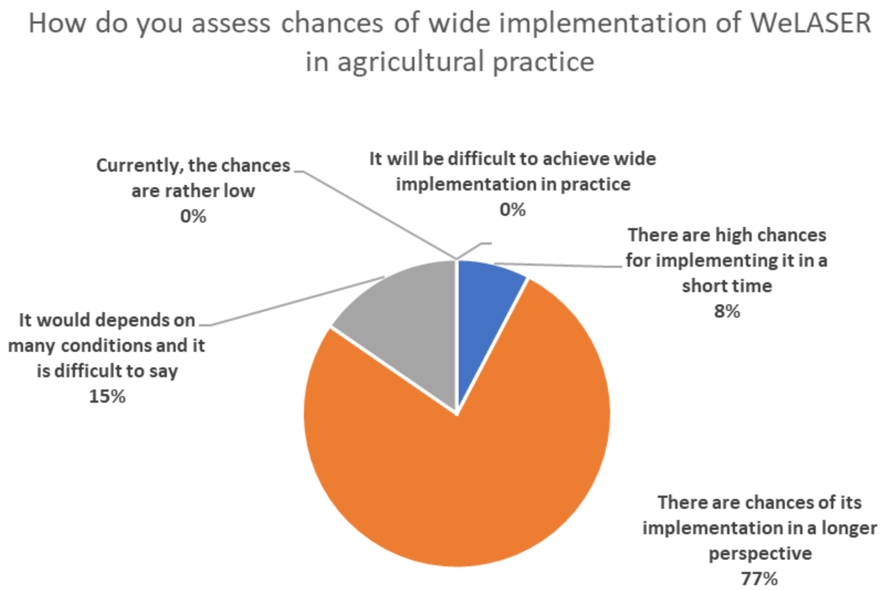
The issue of using WeLASER in the city environment was also raised. According to one of the stakeholders it is a question whether WeLASER is dedicated only to agriculture or there can be a sidestep to provide solution also for urban settings. It would be interesting to try to implement the project results to the city environment. The stakeholder underlined that the idea of WeLASER is in principle good and. for the purpose of using WeLASER in urban settings the current parameters characterizing WeLASER are fine but there are a few aspects that should be considered It is especially interesting to know how much energy of the laser is needed to kill the plant. In comparison to traditional methods where the mechanical weeding requires essential amount of petrol it potentially can be a viable option. Another issue is whether it can be used on other platforms which are more suitable for urban settings. The safety of the WeLASER in urban settings is also important. In this case specific safety issues should be required. Although, there is no possibility to carry out work within the WeLASER project it can be considered in the aftermath. Some solutions developed by the partners can be used as for example the laser units can be used as small units based on the components already available.

The sustainability of the solution was also discussed. The point of using renewable energy was raised by stakeholders. The potential of using solar energy is viewed by stakeholders as potentially important factor of future WeLASER performance. Although, the concept is interesting that in the fields the solar charges come simultaneously as the machine is working. the energy requirements of the laser are two high to be fulfilled by current technologies but this is not definitely excluded. It was reconfirmed by the developers that using of photovoltaic panels is not viable in the current stage because the area of the solar panel attached to the robot will be not sufficient to produce enough energy for the 15 kW system working in continuous mode. More plausible is to have the robot working on electric energy stored in batteries and charged from renewable sources. This issue has to be considered as the energy will be the limiting factor due to the energy crisis. Another issue is the durability of the system and possibility to reuse some of the robot parts after repair or upgrading. The fiber can be operated for very long time as is the case of medical applications. The laser has the lifetime as 10 000 working hours and it can be reused in other operational systems with the electronics for the controlling unit appropriately upgraded.

The latest development of WeLASER and the issues presented by experts were met with interest and elevated stakeholders' expectations. It was requested to have live presentation of WeLASER machine on the field during demonstrations that can be presented to farmers and potential users. The consortium promised to deliver well document materials.

10.4.5. Results from polls





10.5. Annex 5 – The Fifth WeLASER Stakeholders' Event

10.5.1. Minutes of the 5th Stakeholders' Event

WeLASER
Eco-innovative weeding with laser

Sustainable Weed Management in Agriculture with Laser-Based Autonomous Tools

MINUTES OF THE 5TH STAKEHOLDER EVENT

July 26th, 2023

The fifth Stakeholder Event was organised by COAG in the facilities of the Centre for Automation and Robotics (CAR-CSIC), Arganda del Rey (Madrid, Spain). The agenda of the event is included in Annex 1. The slides of the presentations have already been collected and distributed to the attendees. The list of attendees is included in Annex 2. The meeting started at 14:30 p.m. and finished at 17.15 p.m. Interpretation (English – Spanish – English) was provided to ensure a proper participation of Spanish attendees, specially of farmers and final users.

The main objective of this Stakeholder Event was to address the implications of the future Regulation on the sustainable use of plant protection products, as well as on future alternatives in crop protection products. Experts from European institutions, national authorities, NGOs, crop protection industry and farmers associations provided their visions. Interaction with stakeholders took place.

Regulation on the sustainable use of plant protection products – Implications for EU production	The facilitator, Manuel Linares from COAG, welcomed the participants and enhances the importance for the European production of the EU Regulation on the sustainable use of plant protection products (SUD Regulation), currently under discussion in the EU policy institutions. The main conclusions of the speakers' interventions were (more detailed conclusions are included in Annex 3): ❖ SUD proposal has helped raising awareness and achieving a more rational and sustainable use of pesticides. ❖ Transition should include real and cost-effective alternatives for farmers, like new technologies and improving the funding on R&D. ❖ Some critics were raised against the SUD proposal: excessive ambition, lack of scientific basis and agronomic balance, difficult implementation in sensitive areas, or not including socio-economic sustainability.
Plant protection products – Future and alternatives	The facilitator, Janusz Krupanek, IETU, highlights the relevance of developing alternatives for conventional and chemical plant protection products, according to the guidelines for future farming in the UE. The main conclusions of the speakers' interventions were (more detailed conclusions are included in Annex 3):

	❖ Today chemical control is the most used and cost-effective measure for a lot of farming problems. ❖ Promoting a sustainable use of herbicides and developing viable alternatives, like organic or non-chemical methods, for farmers is really important. ❖ Developing and financing public research and innovation for conventional and alternative methods is a key element for the future of farmers and of the European agriculture.
Closure Álvaro ARETA	The event organizer thanked for the fruitful event and closed the meeting.

10.5.2. Agenda of the 5th Stakeholder Event

WeLASER

Eco-innovative weeding with laser

Sustainable Weed Management in Agriculture with Laser-Based Autonomous Tools

AGENDA OF THE 5TH STAKEHOLDER EVENT

July 26th, 2023

Address: CENTRE FOR AUTOMATION AND ROBOTICS (CAR-CSIC), Ctra. De Campo Real KM 0,200 (28500) Arganda del Rey. Madrid (Spain) https://www.car.upm-csic.es/contact/

STAKEHOLDER EVENT

14:30 – 15:30 **REGULATION ON THE SUSTAINABLE USE OF PLANT PROTECTION PRODUCTS – IMPLICATIONS FOR EU PRODUCTION**

José Manuel Roche, *European Economic and Social Committee.*
Patricia de Almandoz, *COPA-COGECA.*
Carlos Romero, *Spanish Ministry of Agriculture, Fisheries and Food.*

Facilitator: Manuel Linares, COAG.

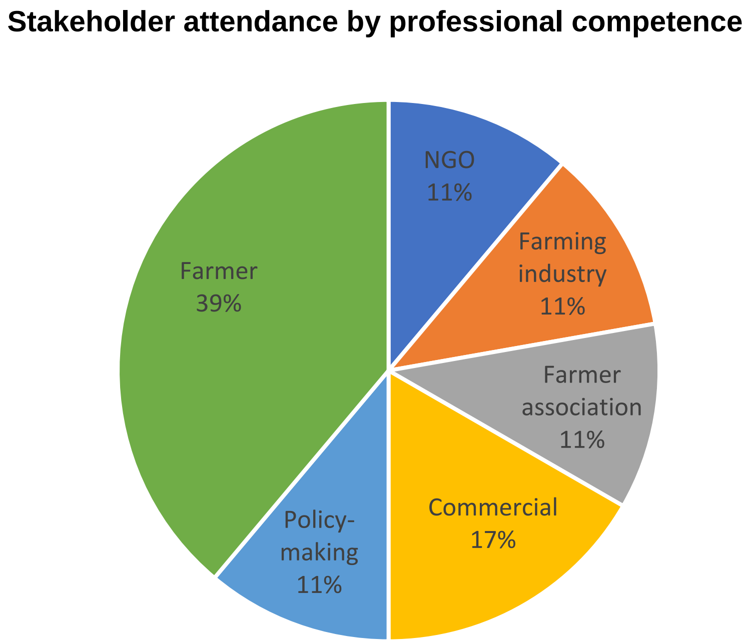
15:30 – 17:00 **PLANT PROTECTION PRODUCTS – FUTURE AND ALTERNATIVES**

Evelyne Alcázar, *IFOAM.*
Carlos Palomares, *CROPLIFE EUROPE.*
Andrés Góngora, *COAG.*

Facilitator: Janusz Krupanek, IETU

17:00 **End of meeting**

10.5.3. Overview of attendees



WeLASER Consortium

Roemi Fernández	CSIC
Luis Emmi	CSIC
Pablo Gonzalez-de-Santos	CSIC
Pedro M. Martín	CSIC
Ruth Córdova	CSIC
Eloida Cortiñas	CSIC
Manuel Linares	COAG
Mari Carmen García	COAG
Cristina Sanz	COAG
Álvaro Areta	COAG
Juan Yuri	COAG
Hendrik Sandmann	LZH
Malte Worzischek	LZH
Merve Wollweber	LZH
Janusz Krupanek	IETU
Paul Van Zoggel	VDBP
Paul Colleague	VDBP
Marco Arru	UNIBO
Matteo Golfarelli	UNIBO
Guiliano Vitali	UNIBO
Karsten Scholle	FUTONICS

10.5.4. Detailed conclusions of the round tables

The fifth stakeholders event began with the round table "Future implications of the EU Regulation on the sustainable use of products for the protection of plants". Facilitated by **Manuel Linares from COAG** and with the participation of Jose Manuel Roche, member of the European Economic and Social Committee (EESC), Patricia de Almandoz, representing the European farmers and cooperatives organization COPA-COGECA, and Carlos Romero from the Spanish Ministry of Agriculture, Fisheries and Food (MAPA).

Jose Manuel Roche (EESC) was born in Teruel, Spain. He is a professional farmer with specialized experience in environment, forestry and agriculture. He owns a family farm in Lechago (Teruel), where he manages a family cereal farm. He is General Secretary of UPA in Aragón, as well as Head of Intrernational Affairs in UPA. He is also member at the European Economic and Social Committee (EESC) where he has been actively involved for more than 10 years, participating as rapporteur of opinions related to agriculture, food security and environment.

He exposed the implications of the Regulation, commonly called the SUR Regulation. He explained that the EESC agreed on a report analysing it. It was concluded that the SUD has helped raising awareness and achieving a more rational and sustainable use of pesticides. The EESC report does not oppose the proposed regulation and its objective, however it is considered that the transition is carried out without real alternatives for farmers. Farmers need access to new alternative products. Flexibility should be given to ensure that "no one is left behind”. There is a need to improve availability and cost-effectiveness of alternatives, new technologies, and the funding on R&D. Science and innovation should be considered as a guide for moving towards a model based on reduced use of plant protection products. There are also concerns with imports from third countries if don´t comply with EU rules on plant protection. It is stated the need of promoting a fair trade and strengthen controls in the EU common market. It is also emphasized two conflicting points in the proposal: sensitive areas and the differentiation of characteristics between different countries.

Patricia de Almandoz (COPA-COGECA) is an Agricultural Engineer and Responsible of Plant Protection products in Cooperativas Agroalimentarias de España. She has been Vice-president of the COPA-COGECA Working Group of Phytosanitary Questions.

She made a complete review of the proposed SUR Regulation, stressing the implications of being a Regulation, not a Directive, and how this collided with the different rhythms in the use of phytosanitary products in European countries. Likewise, she pointed out, in reference to sensitive areas, that this concept not only cover areas within the Natura 2000 Network, but also ecologically rich areas, which comprised a large percentage of several Member States, like Spain, and even the whole territory of some countries. She also exposed other arguments against the proposal, such as: excessive ambition, lack of scientific and agronomic basis, not including socio-economic sustainability or opposition to CAP financing. Finally, she also believed that the approach should be global, not so focused on the reduction of phytosanitary products but on obtaining tools and alternatives.

Carlos Romero (MAPA) was born in Madrid, Spain. In the academic field, Carlos holds a doctorate in Agricultural Engineering, a degree in Environmental Sciences and a Master's degree in Food and Consumer Marketing, all from the Polytechnic University of Madrid. In 2007, after different positions in universities, companies and private entities, he joined the public servant force. During these years, he has held positions in different departments of the Ministry of Agriculture, and is currently the Deputy Assistant Director of the Sub-Directorate of Plant and Forestry Health and Hygiene at the Ministry of Agriculture, Fisheries and Food.

He explained that the proposal was not balanced, according to Spanish position, and this is shared by other EU member states. The intention is to find a proper balance of the regulation, to better include the agrarian perspective also. He explained that the current Spanish Presidency of the Council of the European Union wants take advantage of the opportunity to harmonize the SUR regulation. After the publication of the impact assessment report, he explained that it is possible to discuss the proposal in its entirety. Special emphasis would be placed on discussing modifications in terms of sensitive areas and reduction targets.

Finally, a round of interventions from the public was carried out: bureaucratic difficulty involved in registering phytosanitary products was exposed and how this reduces the obtaining of alternatives.

After a short debate, the round table "Plant protection products – Future and alternatives" took place. Facilitated by **Janusz Krupanek from IETU** and with the participation of Evelyne Alcázar, IFOAM (IFOAM Organics Europe is the European umbrella organisation for organic food and farming), Carlos Palomares, from CROPLIFE EUROPE, representing the Europe's crop protection industry, and Andrés Góngora, from the Spanish farmers organization, COAG.

Evelyne Alcázar (IFOAM) is an agricultural engineer graduated. She is also a technician in quality management. She has more than 20 years of experience in the Spanish organic sector, in tasks related to certification, quality management, institutional relations, projects and development of standards. She has been working for 12 years in the field of international affairs, as well as in the management of international projects on different topics related to organic production. She is currently international director at ECOVALIA and Spanish members' representative in IFOAM Organics Europe since 2013.

She stresses the importance of the farming production methods for alleviating or exacerbating the multiple challenges that we are facing, ranging from increasing hunger, climate change, and biodiversity loss to farmers and food workers not earning a decent income. Organic agriculture try foster a truly sustainable agriculture, value chains, and consumption in line with the principles of this kind of agriculture.

Carlos Palomares (CROPLIFE EUROPE) is general director at AEPLA, he is agricultural engineer from the Polytechnic University of Madrid, and in 1990 he completed an MBA at the Instituto de Empresa. He has worked in several companies involved in the phytosanitary sector, and representing it from AEPLA for the last 16 years.

He presents the objectives and works of the association he represents. He exposes that there are bureaucratic difficulties in registering new products, specially in chemical methods. Finally, he enhances innovation in plant health as the solution to provide secure and enough quantity of food for Europeans in the future.

Andrés Góngora (COAG) is professional farmer in charge of a family farm (third generation) for 20 years of 1,8 ha vegetables greenhouse (tomato, watermelon, and other products). He is member of Cooperativa Agrícola San Isidro (CASI) for 16 years where he participates in innovation programmes. He is Regional Secretary of COAG in Almería (Southeast of Spain), National Fruit and Vegetable Responsible at COAG and member of the Executive Commission of COAG, where he is in charge of phytosanitary questions.

He exposed that there are several alternative methods to chemical control: preventive methods, physical methods, cultural methods, biological methods… However, the chemical control is the most used one and it is effective for a lot of problems. As most of the phytosanitary products will disappear, promoting the sustainable use of herbicides and developing viable alternatives for farmers is really important. Regarding to this developing and financing public research and innovation for conventional and alternative methods is a key element for the future of farmers and of the European agriculture. Finally, he enhanced the importance of harmonizing the different regulations for European and imported products, regarding the use of chemical substances in order to avoid unfair competence among farmers and to improve the transparency for consumers.