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INNOVATIVE GREENHOUSE SUPPORT SYSTEM IN THE MEDITERRANEAN REGION: EFFICIENT FERTIGATION AND PEST MANAGEMENT THROUGH IOT BASED CLIMATE CONTROL — IGUESSMED

Deliverable 4.4

Mutual learning and knowledge extchange

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Abstract

The objective of Deliverable 4.4 is to recap the methodology applied in the WP4 and to summarise the main leasson learned from the impact assessment. The deliverable presents also the main obstacles to the DSS and the key messages summarises at producers, institutional and social levels. At the individual level, growers and farmers benefit from reduced input costs and stable sale prices, which enhance decision-making and reduce uncertainties, supported by vocational education and improved ICT accessibility despite challenges like ageing populations and resistance to change.

At the institutional level, effective policies and working meso-institutions are crucial for fostering farmer cooperation, promoting sustainable innovation, and investing in digital infrastructure and education to prepare the agricultural sector for future challenges. At the societal level, new ecological labels can boost sustainable innovation, while improving food security, public health, and job opportunities for women and vulnerable groups, along with enhancing environmental and community well-being.

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ACRONYM LIST

DSS: decision support system

LCA: Life Cycle Assessment

LCC: Life Cycle Costing

LL: Living Labs

SWOT: Strengths, Weaknesses, Opportunities, and Threats

SDG: Sustainable Development Goals

1. Introduction

The iGUESS-MED project aims to develop a Decision Support System (DSS) able to effectively manage fertigation and prevent plant diseases and pests in tomato crops grown in soil and soilless in commercial greenhouses of the Mediterranean region. This innovative greenhouse DSS will be developed to (i) help greenhouse farmers to improve the management of fertigation in areas with low (saline) quality waters (ii) to reduce the use of chemicals by a sustainable and integrated pest and disease control and (iii) to improve the climatic efficiency in the existent greenhouse by low-cost climate actions. The DSS will allow obtaining healthier and higher quality productions and higher yields, while will reduce the use of water and the losses of nutrients and chemicals to the environment. iGUESS-MED will be able to manage efficient fertigation, to forecast diseases and pests, and to improve the climatic efficiency in tomato greenhouses, using only climate data acquisition and basic information on cropping system. The DSS will provide feedbacks and alerts about crop needs and real time recommendations to the farmers through friendly portable real time data visualization tools as PC, tablets or smartphones. To achieve this objective, new models for calculating crop evapotranspiration will be performed by integrating sensor data from plant, soil and climate, and forecasting models for assessing disease and pest risks will be developed by using the Integrated Pest Management.

The project consortium (research centers, SMEs and end-users of EU and non-EU countries belonging to the Mediterranean basin) will collaborate from the beginning to make the DSS marketable involving, end-users and stakeholders to validate the system in own greenhouses, reducing gaps between research, application developers and farmers. The application of DSS will benefit the workers and the consumers, providing better working conditions, crop healthiness and reduction of environmental impact.

1.1. Summary of the deliverable

The overarching objective of WP4 is to create an enabling environment for the transition towards sustainable, resilient and inclusive greenhouse cropping systems by (i) boosting stakeholders' involvement, empowering a new generation of farmers and overcoming gender barriers; (ii) providing sound evidence-based information about the socio-economic and environmental performance of the innovative solutions proposed in previous WPs, with emphasis on country-specific issues; (iii) supporting farmer investment decisions, while promoting social dialogue, gender equality and inclusion, by removing knowledge barriers. The objective of task 4.3 4 is to summarise the main lesson learned in both Living Land and participatory activities.

Deliverable 4.4 provides an overview of stakeholder engagement and lesson learned.

Table 1. Summary of deliverable from WP4.

List of WP4 outcome	Description	Deliverable date
D4.1: Conceptual and analytical framework	It will contain both conceptual and analytical frameworks to conduct the impact assessment	May 2021
D4.2: Protocol for living labs creation	It would contain the protocol for data collection and LCA	April 2024
D4.3: Feasibility and sustainability assessment document	It will be developed by integrating the intermediate LCSA outputs and by combining country-specific and socio-economic impact assessment results	May 2024
D4.4: Mutual learning and knowledge co-creation	It will include the lesson learned	May 2024

2. Living lab approach

2.1 Living lab in the literature

Living Labs (LLs) are an innovative methodology emphasising user-centred research and development, especially in real-life environments and are essential for applying the Responsible Researchs and Innovation approach (Cascone et al., 2024). Therefore, LLs have been applied in agriculture as they can offer a dynamic platform for collaborative research and the co-creation of solutions addressing complex agricultural challenges. LLs engage several stakeholder categories such as farmers/growers/primary producers, researchers, supply chain actors, policymakers, and local communities and civil society. Overall, Living Labs operate based on several four principles:

- **User-Centre:** Engaging end-users (farmers) in the innovation process to ensure solutions meet their needs.
- **Real-Life Setting:** Testing innovations in actual agricultural environments rather than in isolated experimental conditions.
- **Multi-Stakeholder Participation and Interactive Process:** Involve diverse participants to bring varied perspectives and expertise and continuously apply testing, feedback, and refinement to improve solutions.
- **Consensus-seeking: Aim for solutions that combine all participants' economic viability, environmental health, and social well-being by ensuring continuous dialogue** and plural views.

Living labs are widely used to confront new technologies' adoption or assess the impact of disruptive technologies. They can deepen stakeholders' understanding of the innovation process (Bouma, 2022), support and reduce polarisation of views through back-and-forth interaction with stakeholders, and support the sustainable transformation of the agrifood system (Bouwma et al., 2022).

Følstad (2008) particularly suggests that living labs can face several challenges regarding ICT, such as access to adequate knowledge regarding the user context, early validations of market potential, trials in contexts familiar to users, valid user feedback on state-of-the-art ICT solutions, and utilization of users as a co-creating resource.

2.2. Living lab in iGUESS-MED project

Living labs in the context of the iGUESS-MED project are built upon three main activities:

1. Identification of the country-specific focal question;
2. Identification of needs and expectations
3. Participatory impact assessment

As defined in the previous chapter, the living labs are user-centred and open innovation ecosystems that operate in real-life settings, integrating research and innovation processes within a public-private partnership. They enable a broader category of stakeholders (i.e., policy actors, researchers, advisors and extension services, farmers/growers and value chain actors) to collaborate and identify desired trajectories of change based on shared values and user/society needs. Thus, this implies a) understanding the interplay between technological innovations and the socio-ecological system within a so-called socio-technical system (STS) and b) identifying a common research question based on shared values among stakeholders (focal question). According to D4.1, we identify how innovation can drive a system transition, its effects on site-specific conditions (greenhouses/producers), and how these changes, along with external conditions (formal and informal institutions; policy, political, environmental, demographic, and social conditions) impact the territorial area where the system is located. Each living lab is then centered around a focal question that is specific to each country, representing the main scope of the living lab (see D4.1). The focal question described in the DoW was: "How to improve the competitiveness, environmental performance, and efficiency of the MED-protected horticulture sector by ensuring its social sustainability, especially by improving health-related issues, as well as gender inclusiveness and equality?" According to preliminary activities in D4.1, interviews with local experts refined the focal question in each case study area. D4.3 presents the focal questions developed in each country. Table 2 lists the stakeholders composing the living lab and involved in the activities of D4.4.

Table 2. Stakeholders involved in WP4 activities

Category	IT	ES	TN	TK
Policy actors	3	7	3	1
Researcher	25	7	6	3
Advisor	3	1	1	1
Farmer	4	6	3	6
Value chain actors	1	10	1	10
total	36	31	14	21

Both the identification of STS and the focal question support the idea of impact domains at both the test site and territorial levels. Figure 1 presents the sustainable dimensions investigated and their linkages with the SDGs.

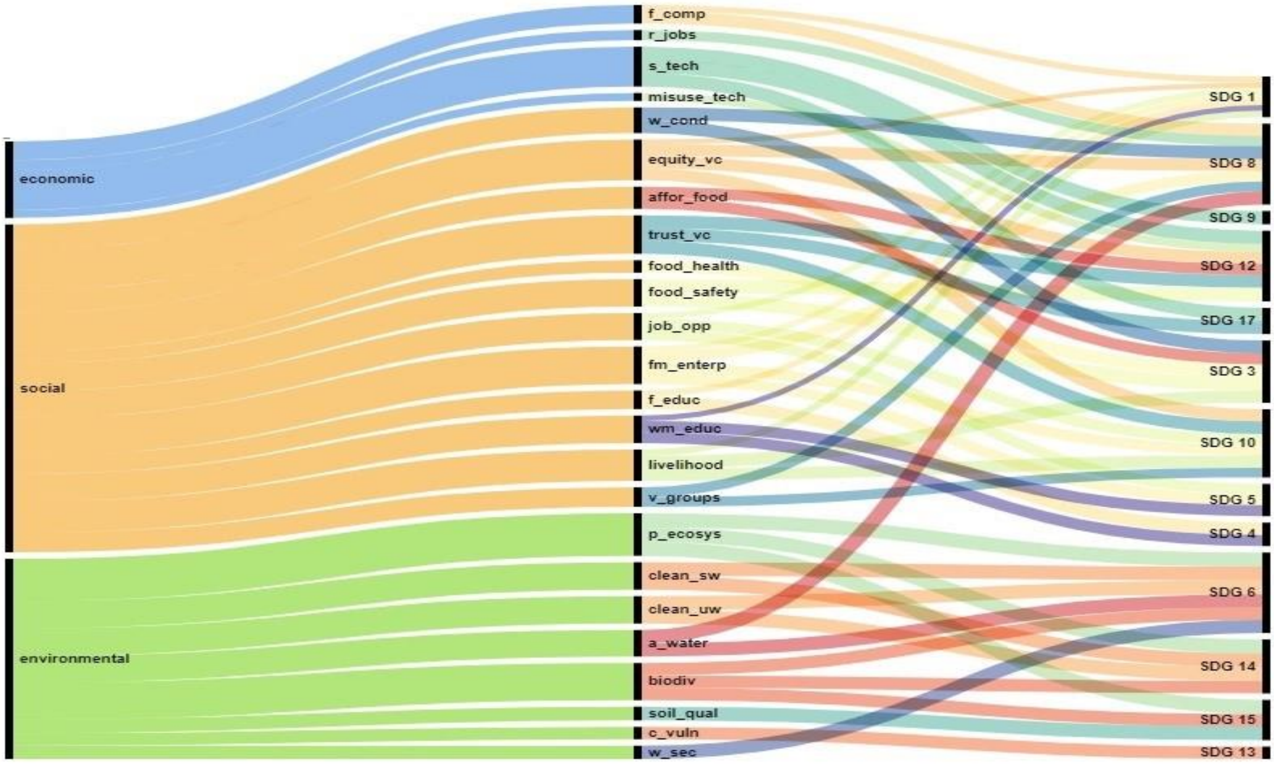

Figure 1. Impact Domains

The economic domain is disentangled into four criteria, the social one into twelve criteria, and the environmental one into eight criteria. Annex 1 provides explanations of the code used. One key component of the living lab's purpose is to understand the needs and expectations of the main actors involved. Thus, in each case study, several participatory activities were conducted to understand stakeholders' needs and expectations regarding the implementation of ICT from I-guessMED. These needs were collected by combining a contextual analysis from the SWOT and interviews with stakeholders. D4.3 presents the individual SWOT analyses. Figure 2 shows the main needs for the five stakeholder categories.

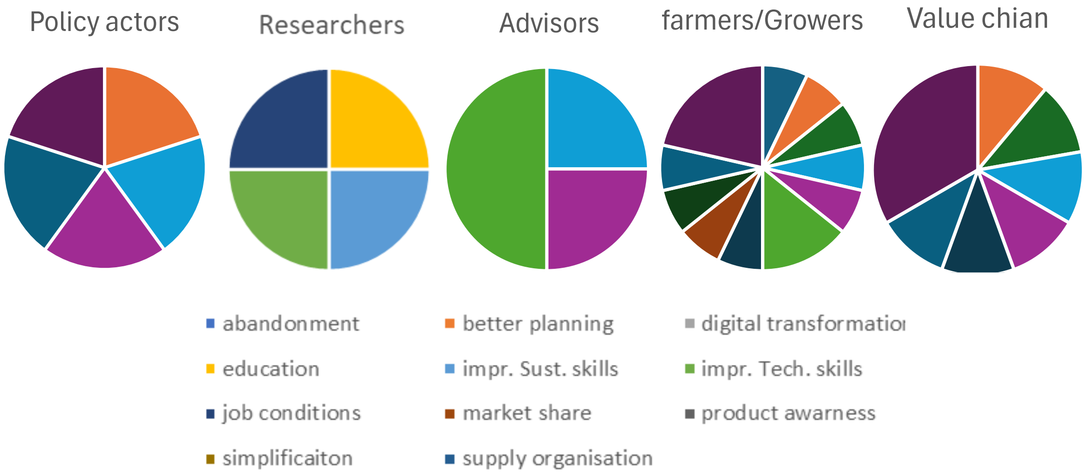

Figure 2. Main Needs

The stakeholders identified eleven different needs, covering various social concerns of greenhouses (e.g., abandonment, working conditions, and environmental awareness), market issues (e.g., increasing market share, simplification), skills (e.g., sustainability and technical skills), and overall better education. The stakeholders' needs are quite heterogeneous.

Policy actors particularly identified the needs to foster actions that improve expertise and education at the territorial level, increase planning through clear policy directionality, support the sustainable and digital transformation of greenhouses, and implement a simplification process. Researchers need to improve connections with other supply chain actors and contribute to transferring technological and sustainable skills to other actors, which is also a need for advisory services. Among all living labs, farmers and value chain networks exhibit a great variety of needs. Farmers mainly need to improve their position along the supply chain and enhance digital literacy to manage ICT technology. Conversely, supply chain actors need better cooperation and organization.

As discussed in D4.2 and D4.3, the participatory impact assessment was conducted by comparing territorial priorities with expected site-specific and territorial impacts. Table 3 provides a summary of the number of surveyed stakeholders. See D4.3 for country-specific detail of participatory impact assessment.

Table 3 Number of valid survey's responses.

Category	Priority	Socio-economic impacts
Policy expert	2	6
Researcher	13	22
Advisor	6	6
Farmer	5	17
Value chain actors	6	27
total	32	78

3. Lesson Learned

3.1 Impact at territorial level

The table 4 summarizes the impact at the territorial level, assuming that DSS will play a significant role in the territorial area in the next ten years. The table 4 presents the relative priority of each criterion, indicated by color. Green indicates low priority, while red indicates a very urgent priority. This summary exercise helps identify how DSS can address the most urgent territorial priorities. Each cell contains the causal effect of how DSS can contribute to the criteria. In addition, the table presents the level of agreement/disagreement among the stakeholders.

Table 4 Participatory impact assessment synthesis

Socio-economic parameters	IT	ES	TN	TK
Increase of farmer competitiveness	New sust. Labels (++)	Reduce use of (scarse) resources (water); better quality of prod. (++)	More yield and more incentive to invest (++)	Efficiency and reduce inputs; economic development -> more profitability (++)
Creation of rural jobs	New entrances & impr. Farm structures (++)	Unemployment rate increase (-/+)	Attractiveness for young people (++)	New business opportunity & specialisation workforces & young (++)
Improvement of working conditions	Improve sectoral reputation & less job demand (++)	Change labour skills required (++)	Less manual work demand; increase Young people (++)	Less manual work (++) better working quality (++)
Greater equity in the distribution of value added among supply chain actors	New labels and standards (+/-)	No effect (++)	No effect (++)	Better farmer position (++)
Greater affordability of food	Reduce input costs & price more stable (++)	Reduce food prices (+/-)	No effect (+/-)	Reduce food prices (+/-)
Increased trust among value chain actors	Transparency of inputs use (++)	Transparency of inputs use & better reputation of producers (++)	Improve traceability (++)	Improve connection between farmers and consumers (+/-); transparent monitoring (++)
Greater food safety	Less residues and	Less residues and better	Increase productivity and face water shortage	Increase efficiency and better quality for export

	better quality (++)	quality (++)	(++)	(++)
Improvement of farmer health	More heath and better quality of life (++)	More health and better quality of life (++)	More health due to less exposed to chemical products (++)	More health due to less exposition to chemical products (++)
Greater job opportunities for women	Specialised profile (+/-)	No effect	Increasing woman graduated (+/-)	No effect (++)
Increase of female entrepreneurship in agriculture	Sustainability attractive for female (+/-)	No effect	Smart farming can attract women (+/-)	Traceability and monitoring interest for women (+/-)
Improved farmer education	Create a new course on ICT & ag. 4.0 (++)	Innovation in the supply chain (+/-)	Farmers are more aware of pesticide risks (++) & learn sust. Production (++)	Participation of young (+/-); standardisation of sust. production (++)
Improved women education (especially in farming)	No impact (++)	Females more attracted by new technology (+/-)	No effect	New job opportunity due to more interest in innovation studies(+/-)
Improved farmer livelihood	Reduction of farm abandonment (+/-)	Increase living standard & better quality (++)	Less stress and more free time (+/-)	Regional development due to farmers having more productive time (++)
Condition for vulnerable groups (i.e. minority & migrants)	Improve working conditions (++)	Immigrants not trained to use DSS (+/-)-> less impact	No effect	Reduce the demand for "less qualified" work (+/-)

(++)agreement among stakeholders; (+/-) disgreement

The increasing of farmers competitiveness is pericied relevant in all four case studies, and stakeholder agrees tha DSS can improve its current level. For example in the spain and Italy the DSS benefit can determine a possibility to improve resource efficiency and better communicate to the consumers. In fact, Implementing new sustainable labels can be obtained by reduce the use of water, or reduce pesticides While in Tunisa and Turkey the DSS can increase the competitiveness mainly through eduction of production costs or increasing the yield through a better pest management. The DSS is perceived also a tool to improve the rural job as can be increase the new entrance and new investment in the sector. DSS also enhance efficiency and reduce input costs, driving economic development and making the sector more attractive to young people and new entrants, as sustainable business model, can be able to improve the sectoral reputation improves. DSS can also shift changes the labor skills required, decreasing the demand for manual labor and improving overall working conditions. Additionally, increased transparency in input use and better reputation management improve traceability and foster stronger connections between farmers and consumers, while stabilizing food prices and input costs. The DSS addresses particularly relevant concerns (working condition and distribution of value added along the supply chian) in Turkey.

The DSS can improve the affordability of food by reducing input costs and stabilizing prices to both local and international markets. In addition, the better trust among value chain actors can be achieved through enhanced transparency of input use, and better traceability or fostering a stronger connection between farmers and consumers with transparent monitoring. This is one of the mian promises of DSS as well as the possibility to develop a blockchain can contribute to that. In addition, expert indicate quite strong benefit in terms of food safety. DSS can ensure fewer residues and higher quality produce, which allow to enter in high quality makert. This was perceived relevant for Tunisia, which the production are mainly for export.

DSS also contribute to the improvement of farmer health by reducing exposure to chemical products, leading to better overall health and quality of life.

Greater job opportunities for women arise, although the specialized profiles required may have a mixed impact, while increasing female graduation rates can have a positive effect. Female entrepreneurship in agriculture can be encouraged by the sustainability and smart farming aspects of DSS, attracting more women into the sector through traceability and monitoring interests.

Improved farmer education is another significant impact, but it also demand new skills on ICT and Agriculture 4.0. Women's education in farming can improve, especially with the appeal of new technology and innovation studies, leading to new job opportunities. DSS also enhance farmer livelihoods by reducing farm abandonment, increasing living standards, providing more free time, and contributing to regional development. Finally, DSS can improve conditions for vulnerable groups, such as minorities and migrants, by enhancing working conditions and reducing the demand for less qualified work, although the lack of training for immigrants can present challenges.

3.2 Barriers

The barriers to using DSS in agriculture and other sectors are multifaceted and are grouped into political, environmental, societal, technological, and economic challenges (PESTLE).

Political, there is often a lack of a shared vision and directionality failures, which hinder cohesive policy-making. Additionally, there are insufficient specific measures to support investment in ICT, slowing down progress.

Environmental, remote locations and the digital divide present significant obstacles due to poor digital infrastructure.

Societal, ageing populations struggle to adapt to new technologies, and there is a low skill in innovation managers equipped with the necessary knowledge, vocational training, and soft skills. Furthermore, many secondary school programs are outdated and do not adequately prepare students for a digital future.

Technological, mianly refer to the lack of digital instractucture in rural areas where access to the internet remains a critical issue, especially in remote areas.

Economical, high investment costs, the cost of educating staff, and the expenses associated with using the internet and other technologies present significant barriers.

These combined factors create a challenging environment for the widespread adoption and effective use of ICT in various sectors.

3.3 Key takeaway messages

Below the main conclusion for invidual, institutional and territorial levels.

At the individual level, growers and farmers can benefit from reducing input costs and stabilizing sale prices, which helps mitigate uncertainties and enhances decision-making capacities for risk-averse farms. To support these efforts, vocational education and training are crucial, focusing on developing digital skills, bridging the digital divide, and improving accessibility to ICT. However, challenges such as ageing populations and resistance to (technolgcal) change may reduce adoption of ICT. However the ICT can contribute to mitigate some concerns about working conditions like temperature, residues, and pesticide exposure.

At the institutional level, policies and meso-institutions play a crucial role in fostering cooperation among farmers to afford investments and concentrate supply, which both ca contribute to improve the farmers position alog the supply chian (i.e. strength farmers bargaining power). Implementing policies for sustainable innovation in agriculture is essential to ensure long-term viability and environmental stewardship. However policy directionality seems lack of effective policies tools to strhengt investments in digital and Agriculture 4.0 and sustainability. Beside to that meso-insitution should focus also on education to prepare the farmers, advisory and supply chain actor for future challenges. Significant investment in digital infrastructure is also necessary to support these initiatives and ensure widespread accessibility and effectiveness of promising ICT tools.

At the societal level, introducing new ecological labels can add value to sustainable innovations, fostering trust and transparency among consumers. Enhancing food security by increasing resilience to pests and ensuring food safety with fewer residues and pesticides is crucial for public health. Promoting job opportunities for female entrepreneurship and vulnerable groups can contribute to social equity and economic growth. Additionally, improving health conditions in greenhouse areas and reducing groundwater pollution are essential for maintaining environmental and community well-being.

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ANNEX 1 considered criteria

Categories	criteria	code
Economic	Increase of farmer competitiveness	f_comp
	Creation of rural jobs	r_jobs
	Greater availability of sustainable technology for greenhouses	s_tech
	Risk of misuse of technology	misuse_tech
Social	Improvement of working conditions	w_cond
	Greater equity in the distribution of value added along supply chian actors	equity_vc
	Greater affordability of food	affor_food
	Increased trust among value chain actors	trust_vc
	Improvement of farmer health	food_health
	Greater food safety	food_safety
	Greater job opportunities for women	job_opp
	Increase of female entrepreneurship in agriculture	fm_enterp
	Improved farmer education	f_educ
	Improved women education (especially in farming)	wm_educ
	Improved farmer livelihood	livelihood
	Condition for vulnerable groups (i.e. minority & migrants)	v_groups
Environmental	Increased protection of ecosystems	p_ecosys
	Cleaner surface water bodies	clean_sw
	Cleaner underground water	clean_uw
	Increased availability of water for agricultural uses	a_water
	Increased biodiversity	biodiv
	Increased soil quality	soil_qual
	Reduced climate vulnerability	c_vuln
	Increased water security	w_sec