DIGITISATION: ECONOMIC AND SOCIAL IMPACTS IN RURAL AREAS

D2.3 SOCIO-ECONOMIC SUSTAINABILITY INDICATORS (SESI) REPORT

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1 Introduction

The agri-food sector, forestry, and rural areas in Europe are experiencing a rapidly-developing digital transformation. Digitalization promises a breadth of opportunities such as improved efficiency, digital connectivity, data analysis, and environmental benefits. However, the true costs of these opportunities must be researched and understood. Digitalization creates an impact on the sustainability of all industrial sectors. The complex nature of the digital transformation within and across industrial sectors and geographical regions creates a challenge in measuring these impacts. The use of sustainability indicators can mitigate this challenge. Sustainability indicators can make sustainability tangible and comparable across spatial and temporal scales.

The DESIRA project aims to improve the capacity of society and political bodies to respond to the challenges of digitalization in rural areas, agriculture and forestry by building a knowledge and methodological base that makes it easier to assess the past, current and future socio-economic impacts of ICT-related innovation. The digital transformation of rural areas, agriculture and forestry generates intended and non-intended impacts on sustainable development and the sustainability targets such as the SDGs or national and regional goals. Not all of these impacts are supporting sustainable development since there are trade-offs between economic, environmental and social sustainability criteria. Thus some sustainability categories are winners who benefit from the change, while others are losers who are marginalized by the change. They might as well have indirect impacts by making it enhancing or making it difficult or even preventing that other technologies or approaches for sustainable development can be applied or unfold their positive or negative impacts.

Sustainable digital transformation is achieved only with a good understanding of the intended and unintended benefits, challenges and obstacles that digital technologies can bring to the local territory, its communities and the society a whole. In the DESIRA project a sustainability indicator set was developed respectively to comprehensively monitor and measure the socio-economic impacts of digitization in agriculture, forestry and rural areas. The indicator set was developed with an inter- and transdisciplinary approach to address and appraise societal needs and expectations. The participatory approach of involving stakeholders and actors was applied not only to identify, select and define relevant indicators, but also to define targets in order to conduct a distance-to-target assessment for the impact assessment. The distance-to-target method is a weighting method assessing the distance of an existing situation from a desired state (the target).

With the knowledge and insights gained within the sustainability assessment of digital transformation the capacity of rural communities, agriculture and forestry to make ICTs a driver of sustainability and wellbeing can be improved. In addition, it provides a common ground for mutual learning and exchange of knowledge among actors and across countries to empower communities and stakeholder towards sustainable digitalization. Whether digital technologies will have a positive impact on sustainable development will depend on the specific conditions of the local contexts in which they will be applied.

Within the framework of the DESIRA project, 20 DESIRA Living Labs (LLs) were created to bring stakeholders from the domains of agriculture, forestry, and rural areas into the participatory impact

assessment. These DESIRA Living Labs constituted around a focal question to co-develop ideas, scenarios, digital storytelling outputs, and socio-technical solutions related to digitalization.

1. Flevoland (NL)
2. Central Osthrobotnia (FI)
3. Rhineland-Palatinate (DE)
4. Rural Poland (PL)
5. Latvia (LV)
6. Lake of Constance (DE)
7. Austria (AT)
8. North Great Plain region (HU)
9. Switzerland (CH)
10. Central Greece (GR)
11. Trikala (EL)
12. Croatian Adriatic Region (HR)
13. Umbria (IT)
14. Tuscany (IT)
15. Andalucia (ES)
16. Aragon (ES)
17. Nouvelle Aquitaine or Occitanie (FR)
18. Nouvelle Aquitaine, Bourgogne, Bretagne, Hauts de France, Centre (FR)
19. Scotland (UK)
20. West Flanders (BE)

The impacts of digitalization were assessed ex post (past and present) using a participatory impact assessment. These impacts were qualitatively analyzed based on the perception of the respondents and participants of the LL's research activities.

The assessment is focusing on the socio-economic impacts of the digital transformation in rural areas, agriculture and forestry. Socio-Economic Sustainability Indicators. The final set of SESI presented in this report can be used to monitor and measure the impacts of digitalization in agriculture, forestry, and rural areas in other research contexts.

Socio-Economic Sustainability Indicators (SESI) These indicators operationalise the concept of sustainable development and of the Sustainable Development Goals (SDGS). The SESI indicators are identified by adapting the scientific Integrative Concept of Sustainability (ICoS). The selection of scientifically based, politically or societally discussed, and practically applicable indicators is from a variety of sources at international and national scales, including the UN SDGs, UCL INEQ-CITIES atlas[1], the OECD main economic indicator set[2], and the European Environment Agency indicators. The indicators are grouped by DESIRA domain (agriculture, forestry, and rural areas), as not all indicators are relevant for each domain.

1 https://www.ucl.ac.uk/ineq-cities/atlas
2 OECD (2019), *Main Economic Indicators, Volume 2019 Issue 10*, OECD Publishing, Paris

2 Methods

2.1 Living Labs

2.1.1 Focal Question

Each living lab in the DESIRA project proposed a focal question (FQ) (see **Table 1** in the Annex) and discussed it with the consortium during the project's kick-off meeting in September 2019. The focal question served to frame the scope of each LL, as well as clarify the specific topic, geographic area, and possible hypothesis or sub-questions. The process to finalize the focal question was iterative: during the expert interviews with a key informant, it was suggested to re-assess the FQ and adjust appropriately, if needed. The intention of the focal question for each LL was to support the assessment of both current and future impacts (WP2 and WP3). For instance, the Finnish LL poses the FQ: "How can digital systems contribute to circular economy in Central Ostrobothnia by 2030?" and the Swiss LL poses the FQ: "How to effectively and efficiently control weeds in organic farming?". An elaboration of each LL can be found in Deliverable 2.2.

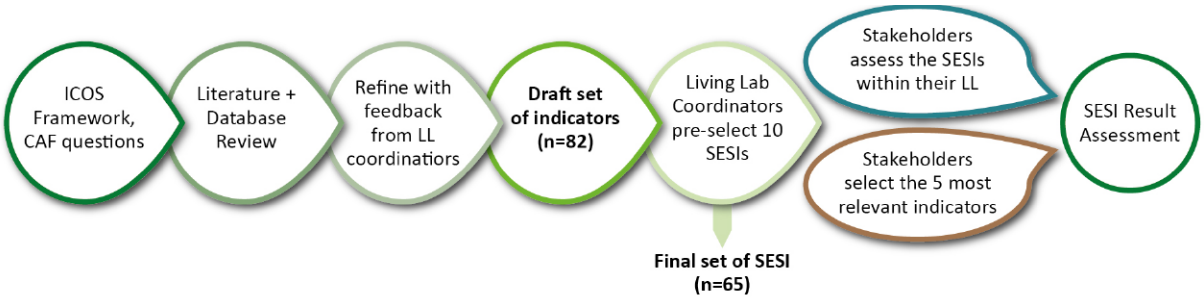
2.1.2 Stakeholders

Every LL is composed of around 20 stakeholders. Stakeholders are individuals with a personal or professional interest in the given topic; in the DESIRA project, stakeholders have a 'stake' in the digitalization of agriculture, forestry, and/or rural areas, particularly related to their LL's focal question. Some examples of stakeholders include farmers and foresters, technology developers, members of industry, policy makers, researchers, members of NGOs, and consumers.

2.2 Indicator Selection

The process of identifying, selecting, and assessing the SESIs (Figure 1) was iterative and required the active engagement of LL coordinators and LL stakeholders. This process is described in the following sections.

Fig. 1: SESI Methodology



2.2.1 Framework of the SESI

Since the idea of sustainable development is common ground in scientific and political contexts, a number of guidelines, frameworks and tools were developed to assess the sustainability of technologies, processes and systems. Since almost 30 years, several approaches to conceptualize sustainable development have been developed and applied such as the three or four pillar model or the pillar-overarching integrative approaches. The three-pillar model is dominating political and scientific practice although it is criticized for its lacking theoretical profoundness in justifying sustainable development as overall guiding principle, its systematic neglecting of interdependencies between the pillars, and an insufficient consideration of the postulate of justice and fairness.

The latest and most relevant work in this respect regards the 17 Sustainable Development Goals (SDGs) defined by the UN including 230 indicators substantiating these goals. The SDGs partly build upon the Millennium Development Goals (MDGs) that have been adopted by the UN in 2000. They are aiming at an array of issues, such as slashing poverty, hunger, diseases, and gender inequality, and improving access to fresh water and sanitation. The SDGs go much further than the MDGs by addressing the reasons for poverty and the universal need for a development that works for all people. Each SDG has specific targets to be achieved over the next 15 years.

The SDGs were developed and agreed upon by developed and developing countries, whereas transformative action is dedicated primarily to the national level. Here, more differentiated and further indicators are needed for striking a careful balance between different sustainable development issues. For the definition of additional indicators with relevance to scientific debates and societal and political decision-making, a theoretically well founded and operable conceptual approach for analyses and assessments is required. The Integrative Concept of Sustainable Development (ICOS) that was developed within the German Helmholtz Association is such a concept and is used in this work as a methodological framework to derive a coherent system of sustainability indicators (Kopfmüller et al. 2001). In contrast to other concepts structured along the economic, ecological and social dimension, ICOS is based upon three constitutive elements of sustainable development, which characterize the key documents of sustainable development like the Brundtland report, the Rio Declaration and the Agenda 21:

1. Inter- and intra-generational justice, both equally weighted, as theoretical and ethical fundament. Justice is understood as distributional justice with respect to rights and obligations, benefits and burdens.
2. A global perspective, by addressing key challenges of the global community and developing goals and strategies to achieve them. It also includes a strategic justification to translate globally defined goals into the national and regional context.
3. An enlightened anthropocentric approach including an obligation of humankind to interact cautiously with nature based on a well-understood self-interest.

These constitutive elements of ICOS are translated into three general goals and preconditions of sustainable development:

1. Securing human existence, including basic needs and the capability of human beings to shape their lives on their own.
2. Maintaining society's productive potential, which consists of natural, man-made, human and knowledge capital.
3. Preserving society's options for development and action, addressing 84 immaterial needs such as integration in cultural and social contexts, which complement material needs.

These goals are specified by substantial sustainability rules (Figure 2) forming the core element of ICOS.

Fig. 2: The Integrative Concept of Sustainable Development (Kopfmüller et al. 2001)

Substantial Rules		
Securing human existence	Maintaining society's productive potential	Preserving society's options for development and action
1. Protection of human health 2. Satisfaction of basic needs 3. Autonomous subsistence based on income from own work 4. Just distribution of opportunities to use natural resources 5. Reduction of extreme income and wealth inequality	6. Sustainable use of renewable resources 7. Sustainable use of non-renewable resources 8. Sustainable use of the environment as a sink for waste and emissions 9. Avoidance of technical risks with potentially catastrophic impacts 10. Sustainable development of man-made, human and knowledge capital	11. Equal access for all to information, education and occupation 12. Participation in societal decision-making processes 13. Conservation of cultural heritage and cultural diversity 14. Conservation of the cultural function of nature 15. Conservation of social resources
Conditions to achieve the substantial sustainability		
1. Internalization of external social and ecological costs 2. Adequate discounting 3. Limitation of public debt 4. Fair international economic framework conditions 5. Promotion of international co-operation	6. Society's ability to respond 7. Society's ability of reflexivity 8. Society's capability of government 9. Society's ability of self-organization 10. Balance of power between societal actors	

The ICOS was used to develop the SESI for the DESIRA project. Therefore, the three general goals of the substantial rules and the instrumental rules were applied. This ensured that all topics of sustainability were covered, as the substantial sustainability rules describe the minimum requirements of sustainable development for all people. In addition to the ICOS, the Conceptual Analytical Framework (CAF) of the DESIRA project was used to frame the selection of SESI. The CAF has defined and elaborated the main concepts of this project, including digital transformation, the social-cyber-physical system, and socio-economic impact, and all concepts are set in relation to digital technology use in agriculture, forestry, and rural areas (Rijswijk et al. 2020). Each concept is elaborated upon within the CAF with implications for empirical analysis and a set of questions, which link the various concepts. Such questions from the CAF that are particularly relevant for the SESI include: "How do stakeholders' needs and expectations change over time, for whom and in what way?", "How can digital technologies (potentially) change the way activities are carried out in the area? ".

2.2.2 Literature Review to Indicator selection and the Sustainable Development Goals (SDGs)

In this next step, work package leaders reviewed scientifically based, politically or societally discussed and practically applicable and measurable indicators to consider for the first draft of the SESI list. These indicators were selected from a variety of sources at international and national scales, including the United Nations Sustainable Development Goals, UCL INEQ-CITIES atlas (Ineq-cities and University College London 2022), the OECD main economic indicator set (OECD 2002), and the European Environment Agency indicators (European Environment Agency (EEA) 2014). The indicators were plugged into the ICOS sustainability rules framework, as previously described. The indicators are grouped by DESIRA domain (agriculture, forestry, and rural areas), as not all indicators are relevant for each domain. Due to the specific nature of each LL and the associated FQs, the initial set of indicators was created to cover all topics of digitalization in agriculture, forestry, and rural areas. In a separate column, the SDGs of direct relevance for each indicator were listed for later reference in the analysis. For instance, SESI #1 'share of manual workers in workforce' (as seen in **Table 1**) relates to SDGs 3 (good health and wellbeing), 8 (decent work and economic growth), and 10 (reduced inequalities). By linking each indicator with one or more SDGs, the results of the SESI analysis could be put into a familiar context and appeal to a greater audience. Specifically, analyzing the SDGs in relation to the SESI identifies implications for the sustainability of digitalization in agriculture, forestry, and rural areas in various regions across Europe within the larger, global context of the SDGs. Together, this process created a draft list of indicators.

Living Lab coordinators received the draft list of indicators around M6 (January 2020) and were requested to provide feedback. Specifically, coordinators were asked to provide a short 'yes' or 'no' answer to each indicator when considering of the indicator was relevant to their LL and FQ. Coordinators were also encouraged to provide feedback or suggestions for other indicators. From this point onward, differentiations were not made between socio-economic and environmental indicators, for instance they were not grouped into separate tables for selection or analysis. This was intentional because part of the analysis was also to see which socio-economic and/or environmental indicators were overall of more importance/value to the LL coordinators and their stakeholders.

2.2.3 Creation of DESIRA Sustainability Targets

In order to add context to the indicators and to allow stakeholders to assess the impact on sustainability using the indicators, a DESIRA Sustainability Target was created for each indicator. The targets are the positive form of the indicator; for instance, the indicator' share of manual workers in the workforce' has the DESIRA Sustainability Target of 'increased share of manual workers in the workforce'. The targets are not bound to a region or nation, but can be set as targets across all LLs in the project. It is necessary to include targets in the assessment so that the stakeholders involved in the assessment of the indicators have a common goal in mind when asked to assess the impact of digitalization per indicator towards the indicator's target.

2.2.4 Identification of Top 10 Indicators per LL

For the stakeholders to be able to assess the relevant indicators, each LL coordinator was tasked to select a maximum of 10 indicators for their LL from the draft list based on relevance to the focal question. In some cases, indicators were articulated further by the LL coordinator to create sub-indicators. For instance, the indicator' Agricultural input efficiency' was elaborated upon with a sub-indicator 'Agricultural Input Efficiency (pesticides, fungicides, insecticides, fertilizer, etc.) in Organic Agriculture', as this was particularly relevant for one LL's focal question. This method functioned to both elaborate the existing draft list by filling any gaps from the previous steps, as well as improving the relevance of the indicator list to current issues in the three DESIRA domains. Based on this selection, a final set of SESI was created (see **Table 1** in section **3.1**).

2.3 Indicator Assessment

2.3.1 Online Survey: SESI assessment by LL stakeholders

Two questions on the SESI assessment were included in the online survey developed jointly by KIT-ITAS and UNIPI (more information on the online survey and the common structure can be found in the Annex of Deliverable 2.2). The 10 sustainability targets for each of the 10 indicators selected by the LL were translated into the national language and added to the LL's online survey. For each target, respondents were prompted to answer the questions:

Two questions on the SESI assessment were included in the online survey developed jointly by KIT-ITAS and UNIPI (more information on the online survey and the common structure can be found in the Annex of Deliverable 2.2). The 10 sustainability targets for each of the 10 indicators selected by the LL were translated into the national language and added to the LL's online survey. For each target, respondents were prompted to answer the questions:

1. How would digitalization influence the progress towards the target?
2. Please identify the 5 targets you value to be the most important/critical of the 10. To identify them, please rank them from 1 to 5, with 1 being the most important.

To question 1, respondents were provided with 5 Likert-scale responses: Strongly Reduce Current Progress; Reduce Current Progress; No impact on current Progress; Improve Current Progress; Strongly Improve current Progress; and No answer. For instance, for the sustainability target "reduced risk to farmers and farm workers by dust and pesticides", respondents should consider to what extent digitalization in the context of their FQ would influence the current progress towards this target.

To question 2, respondents were provided with a ranking from 1 to 5, in order to rank the same listed targets by perceived level of importance. There was also an option for 'does not belong to top 5' so that for each target, a response should be given, even if the target was not important enough to be 1-5. Using the same target above as the example, respondents should have considered if the target "reduced risk to farmers and farm workers by dust and pesticides" was the most important of all 10 (therefore 1), important but not the most important (therefore 2,3,4, or 5) or was not important in comparison.

3 SESI Results Assessment

The qualitative assessment collects the perspectives/expectations of stakeholders on the impact of digitalization in the context of their LL Focal Question and with their five selected indicators. In this way, the assessment considers current and future impacts.

3.1 SESI Indicators

The SESIs selected by LL coordinators for their respective LL (as described in section **2.2.4**) were collected into a Microsoft Excel file. Indicators from the draft list that were not chosen by any LL were eliminated. This resulted in a set of 65 SESI that were identified as being relevant to the sustainability of digitalization in agriculture, forestry, and/or rural areas.

Tab. 1: Final Set of Socio-Economic Sustainability Indicators (n=65) Comparative Analysis of the SESI Selection Results

ICoS Rule Group	ICoS Rule	SESI	Indicator	Indicator source	SDG	Applies to Domain	DESIRA sustainability target
Securing Human Existence	Protection of human health	1	Share of manual workers in the workforce	UCL INEQ-CITIES atlas	3, 8, 10	all	increased share of manual workers in the workforce
		2	Health risks of farmers by dust and pesticides	DESIRA	3, 6	AG	Reduced risk to farmers and farm workers by dust and pesticides
		3	Health risks to the public by dust and pesticides	DESIRA	3, 6	AG	Reduced risk to the public by dust and pesticides
		4	Pollution of air and water	(DESIRA)	3, 13	all	Reduced pollution of air and water
	Satisfaction of basic needs	5	Volume of production per labour unit by classes of farming/pastoral/forestry enterprise size	SDG 2.3.1	2, 10, 8	all	Increased volume of production per labour unit by classes of farming/pastoral/forestry enterprise size
		6	Household expenditure changes for digitalization (ie. Is the cost of living reduced via digitalization)	(DESIRA)	9, 10	RA	Decreased household expenditure
		7	Proportion of medium and high-tech industry value added in total value-added	SDG 9.b.1	9	all	Increased proportion of medium- and high-tech industry value added in total value-added
		8	Value-added to end-product via digitalization	Kruse et al., 2009	8, 9	all	Added value to end-product
		9	Proportion of small-scale industries in total industrial value-added	SDG 9.3.1	8, 9, 10	all	Increased proportion of small-scale industries in total industrial value-added
		10	Share of production from small-scale industries within total industrial value-added	DESIRA (Inno'vin)	9, 10	all	Increased share of production from small-scale industries within total industrial value-added

ICoS Rule Group	ICoS Rule	SESI	Indicator	Indicator source	SDG	Applies to Domain	DESIRA sustainability target
Securing Human Existence	Satisfaction of basic needs	11	Proportion of material needs that can be sourced locally	DESIRA (Cultivate LL)	7, 8, 9, 11. 12	RA	Increased proportion of material needs that can be sourced locally
	Autonomous subsistence based on income from own work	12	Unit labour cost	OECD 31	8	all	Reduced unit labour cost
		13	Total employment	OECD 33	8	all	Increased total employment
		14	Locally-based employment	DESIRA (Cultivate LL)	8, 9, 10, 11	RA	Increased locally-based employment
		15	Dependence on seasonal migrant workers	DESIRA	8	AG	Decreased dependence on seasonal migrant workers
		16	Employment of women in agriculture and forestry	(DESIRA)	5, 8	AG, FO	Increased employment of women in ag and forestry
		17	Average income of small-scale food producers, by sex and indigenous status	SDG 2.3.2	2, 5, 8	AG	Increased average income of small-scale food producers by sex and indigenous status
		18	contribution to income (of new technology)	adapted from Kruse et al. 2009	8, 9	all	New technology has a positive contribution to income
		19	Online sale of the product	DESIRA (Inno'vin)	9	all	Increase share of online sales
	Just distribution of opportunities to use natural resources	20	Ownership and disclosure of collected data	DESIRA	10, 12	all	Increased protection of ownership and disclosure of collected data
		21	Ability of actors to collect data	DESIRA (Inno'vin)	10, 12	all	Increased ability of actors to collect data
		22	Availability of data collected (by the farmer or land manager to the landowner or lessor)	DESIRA	10, 12	all	Increased availability of data collected (by the farmer or land manager, the landowner or lessor)

ICoS Rule Group	ICoS Rule	SESI	Indicator	Indicator source	SDG	Applies to Domain	DESIRA sustainability target
Securing Human Existence	Just distribution of opportunities to use natural resources	23	Accessibility of public data with business-related interfaces (farmers)	DESIRA	10, 12	AG	Increased accessibility of public data
Maintaining Society's Productive Potential	Sustainable use of renewable resources	24	Freshwater Use Efficiency	DESIRA	6, 13, 14	all	Improved freshwater use efficiency
		25	Agricultural Input Efficiency (pesticides, fungicides, insecticides, fertilizer, etc.)	DESIRA	2, 12, 13, 14, 15	AG	Improved agricultural input efficiency
		26	Agricultural Input Efficiency (pesticides, fungicides, insecticides, fertilizer, etc.) in Organic Agriculture	DESIRA (KIT LL)	2, 12, 13, 14, 15	AG	Improved agricultural input efficiency in organic agriculture
		27	Land Use efficiency	DESIRA	13, 15	all	Increased land use efficiency
		28	Digitized land area	DESIRA (Inno'vin)	9, 15	all	Increase in the number of hectares digitized, mapped and remotely detected
		29	Energy Use efficiency	DESIRA	7, 13	all	Increased energy use efficiency
		30	Area under organic farming	Eurostat_ sdg_02_40	2, 13, 15	AG	Increased area under organic farming
		31	Agriculture: area under management practices potentially supporting biodiversity	EEA_SEBI020	2, 13, 15	AG	Increased area under biodiversity practices
		32	Diversification of emerging farming models using digital and the number of new farms using digital from the start	DESIRA (Inno'vin)	9	AG	Diversification of emerging farming models using digital and increase in the number of new farms using digital from the start
		33	Livestock genetic diversity	EEA_SEBI006	15	AG	Increased livestock genetic diversity

ICoS Rule Group	ICoS Rule	SESI	Indicator	Indicator source	SDG	Applies to Domain	DESIRA sustainability target
Maintaining Society's Productive Potential		34	Soil erosion - area affected by severe erosion rate	source: JRC Eurostat_ sdg_15_50	6, 15	AG, FO	Reduced area affected by severe rates of erosion
		35	Progress towards sustainable forest management	SDG 15.2.1	15	FO	Increased progress towards sustainable forest management
		36	Forest fires	EEA_CLIM035	15	FO	Reduced number of forest fires
		37	Forest: growing stock, increment and fellings	EEA_SEBI017	15	FO	Increased growing stock, increment, and fellings
	Sustainable use of non-renewable resources	38	Non-renewable resource efficiency (fossil fuels, phosphate)	DESIRA	7, 12, 13, 14, 15	all	Improved efficiency of fossil fuel use efficiency
	Sustainable use of the environment as a sink for waste and emissions	39	Greenhouse gas emissions total	DESIRA	7, 12, 13, 14, 15	all	Reduced greenhouse gas emissions
		40	Greenhouse gas emissions from travel for work purposes	DESIRA (Cultivate LL)	11, 12, 13	RA	Reduced greenhouse gas emissions from travel for work purposes
		41	Greenhouse gas emissions from the length of supply chains	DESIRA (Cultivate LL)	9, 11, 12, 13	RA	Reduced greenhouse gas emissions through shortened supply chains
		42	CO2 emissions per unit of value-added (infrastructure and industries)	SDG 9.4.1	9, 13	all	Reduced CO2 emissions per unit of value-added (infrastructure and
		43	Generation of waste by waste category	Eurostat_ ten00018	9, 13	all	Reduced waste generation

ICoS Rule Group	ICoS Rule	SESI	Indicator	Indicator source	SDG	Applies to Domain	DESIRA sustainability target
Maintaining Society's Productive Potential	Sustainable use of the environment as a sink for waste and emissions	44	Final energy consumption by agriculture/forestry per hectare of utilized agricultural area (renewable and fossil energy)	Eurostat_tai04	7, 13, 15	AG, FO	Reduced final energy consumption by agriculture/forestry per hectare of utilized agricultural area (renewable and fossil energy)
		45	Share of fossil fuel and renewable energy consumption per hectare of farming area	DESIRA (Inno'vin)	7, 12, 13, 15	AG	Reduced share of fossil fuels and increased consumption of renewable energy's share per hectares of the farmed area
		46	Proportion of time spent on unpaid domestic and care work, by sex, age, and location	SDG 5.4.1	4, 5	all	Decreased proportion of time spent on unpaid domestic and care work by women
		47	Unemployment rate by sex, age, and persons with disabilities	SDG 8.5.2	5, 8	all	Decreased unemployment rate by sex, age, and persons with disabilities
		48	Person hours of production	Kruse et al., 2009	5, 10	all	Reduced person hours of production
	Participation in societal decision-making processes	49	Public awareness of a subject	EEA	4, 10, 16	all	Increased public awareness
		50	Public awareness of local producers/products/ services via digitalization	DESIRA (Cultivate LL)	8, 9, 10, 11, 12	RA	Increased public awareness of local producers/ products/services via digitalization
		51	Public education about digital tools	DESIRA (Inno'vin)	4, 10, 16	all	better education about digital tools (e.g. cost reduction possibilities, improvement of equipment use)
		52	Public image of a subject or product	DESIRA	4, 10, 16	all	Improved image of a subject or product
		53	Public image of sustainable, value-based practices	DESIRA (Cultivate LL)	4, 10, 16	all	Improved public image of sustainable, value-based practices/improved public image of sustainable values and lifestyles

ICoS Rule Group	ICoS Rule	SESI	Indicator	Indicator source	SDG	Applies to Domain	DESIRA sustainability target
Maintaining Society's Productive Potential	Participation in societal decision-making processes	54	Marketing of a product	DESIRA	4, 10, 16	all	Improved marketing of a product
	Conservation of social resources	55	Tourism direct GDP as a proportion of total GDP and in growth rate	SDG 8.9.1	8, 15	all	Increased tourism direct GDP
		56	Proportion of jobs in sustainable tourism industries out of total tourism jobs	SDG 8.9.2	8, 15	all	Increased proportion of jobs in sustainable tourism
		57	Number of sustainable tourism strategies or policies and implemented action plans with agreed monitoring and evaluation tools	SDG 12.b.1	12, 15, 16	all	Increased number of sustainable tourism strategies or policies and implemented action plans with agreed monitoring and evaluation tools
		58	Cooperation between different institutions and citizens	DESIRA (AMIGO LL)	16, 17	r.a.	Increased cooperation between different institutions and citizens
		59	Collaboration between non-governmental organizations, community groups, and local initiatives	DESIRA (Cultivate LL)	16, 17		Increased collaboration between NGOs, community groups, local initiatives
Conditions to achieve the substantial sustainability	Society's ability of reflexivity	60	Climate-related economic losses by type of event	Eurostat_ sdg_13_40, source: EEA	10, 13	all	Reduced economic losses from climate-related types of events

ICoS Rule Group	ICoS Rule	SESI	Indicator	Indicator source	SDG	Applies to Domain	DESIRA sustainability target
Conditions to achieve the substantial sustainability	Society's ability of reflexivity	61	official development assistance and public expenditure on conservation and sustainable use of biodiversity and ecosystems	SDG 15.a.1	11, 15, 16	AG, FO	Increased official development assistance and public expenditure on conservation and sustainable use of biodiversity and ecosystems
		62	Gross value added of the forestry industry, at basic prices	Eurostat_ tag00058	8, 9, 15	FO	Increased gross value added to the industry
		63	Regional Connectivity	DESIRA (Oosterwold LL)	11, 12, 16, 17	all	Increased regional connectivity
	Balance of power between societal actors	64	Application of digital technology in small and medium-sized enterprises	DESIRA	8, 9, 10	all	Increased application of digital technology in small and medium-sized enterprises
		65	Interdependency in food	DESIRA (Oosterwold LL)	2, 11, 12	all	Increased interdependency in food

3.2 Comparative Analysis of the SESI Selection Results

As a first round of analysis, the indicators chosen most frequently among the various LL's top 10 were identified across all LLs and domains.

Table 2 shows the ten indicators most often assessed by the LLs. The overall most selected indicator is number 64: 'Application of digital technology', for which 65% of all living labs found to be relevant for assessing the sustainability of digitalization. Two other indicators were selected by more than half of the LLs, namely SESI #8 'Value added to end-product via digitalization' (57%) and SESI #18 'contribution to income (of new technology)' (48%). The Top 10 list is concluded by two indicators, 'Marketing of a product' and 'Energy use efficiency', selected by only a fourth of all LLs. Of these 10 indicators, 8 are socio-economic and 2 are environmental indicators. This implies that at the time of the participatory sustainability assessment within the DESIRA project, socio-economic challenges related to digitalization are more prevalent among living labs than environmental challenges.

Unfortunately, indicators related to women (indicators n. 16, 46 and 47) were not taken into consideration by Living Labs. DESIRA has carried out a data collection apart to address gender issues.

Tab. 2: Top 10 most selected indicators in all domains (rural, agricultural and forestry) by the stakeholder of the 20 Living Labs of the DESIRA project

Top 10 most selected Indicators in all domains (rural, agricultural and forestry)			
	SESI	**Indicator**	**% of LL who chose this indicator**
1	64	Application of digital technology in small and medium sized enterprises	65
2	8	value added to end-product via digitalization	57
3	18	contribution to income (of new technology)	48
4	52	public image of a subject or product	48
5	49	public awareness of a subject	43
6	27	Land Use efficiency	39
7	20	Ownership and disclosure of collected data	35
8	5	volume of production per labour unit by classes of farming/pastoral/ forestry enterprise size	35
9	54	marketing of a product	26
10	29	Energy Use efficiency	26

Table 3 shows that most of the selected indicators belong to the ICOS Rule Group' Securing Human Existence' (40%). This specifies that LL coordinators saw the need to measure essential sustainability targets to secure human existence, such as the satisfaction of basic needs or autonomous subsistence based on income from own work, over less essential topics when researching digitalization in the LLs. On the other hand, 'Conditions to achieve substantial sustainability' is the group with the smallest share of examined indicators (10%). Of the 'Securing Human Existence' group, around two thirds of the indicators belong to the ICOS Rules' Satisfaction of basic needs' (38%) and 'Autonomous subsistence' (29%). The 'Maintaining society's productive potential' group consists mainly of indicators belonging to the ICOS Rule' Sustainable use of renewable resources' (72%). Most of the indicators that fit into the 'Preserving society's options for development and action' group are part of the ICOS Rule' Participation in societal decision making processes' (63%), while only 14% of the group's indicators belong to 'Equal access for all to information, education, and occupation'. Finally, the smallest ICOS Rule Group' Conditions to achieve the substantial sustainability' is primarily made up of indicators belonging to the 'Balance of power between social actors' ICOS Rule (76%).

Tab. 3: Most selected ICOS Rule Groups/Rules s in all domains (rural, agricultural and forestry) by the stakeholder of the 20 Living Labs of the DESIRA project

Most selected ICOS Rule Groups/Rules				
	ICOS Rule Group	**% of chosen indicators of rule group from total chosen indicators**	**ICOS Rules**	**% of chosen indicators for each within ICOS rule group**
1	Securing Human Existence	40	Protection of human health	13
			Satisfaction of basic needs	38
			Autonomous subsistence based on income from own work	29
			Just distribution of opportunities to use natural resources	21
2	Maintaining Society's Productive Potential	28	Sustainable use of renewable resources	72
			Sustainable use of non-renewable resources	0
			Sustainable use of the environment as a sink for waste and emissions	28
3	Preserving Society's Options for Development and Action	22	Equal access for all to information, education, and occupation	14
			Participation in societal decision making processes	63
			Conservation of social resources	22
4	Conditions to achieve the substantial sustainability	10	Society's ability of reflexivity	43
			Balance of power between societal actors	76

While only in the third place overall, the most selected indicator of the LLs in the Agricultural domain is 'Contribution to income (of new technology)' (69%), as can be seen in Table 4. It is followed by 'Application of digital technology in small and medium sized enterprises' (54%) and 'Value added to end-product via digitalization' (46%). Furthermore, there are two indicators specific to the Top 10 of the 'Agricultural' domain, namely 'Person hours of production' (38%) and 'Agricultural input efficiency' (Agricultural input efficiency (pesticides, fungicides, insecticides, fertilizer, etc.)' (31%). Similar to the top 10 indicators selected across all domains (**Table 2**), only two of the top ten indicators chosen in the agricultural domain are environmental indicators, suggesting socio-economic challenges are most pressing at the time of this research.

Tab. 4: Top 10 most selected indicators by the stakeholders of the DESIRA LL in the Agriculture domain

Top 10 most selected indicators of the DESIRA LL stakeholder in the Agriculture domain			
	Indicator No	**Indicator**	**% of LLs who chose indicator**
1	18	Contribution to income (of new technology)	69
2	64	Application of digital technology in small and medium-sized enterprises	54
3	8	Value-added to end-product via digitalization	46
4	5	Volume of production per labour unit	46
5	20	Ownership and disclosure of collected data	38
6	48	Person hours of production	38
7	52	Public image of a subject or product	38
8	25	Agricultural Input Efficiency (pesticides, fungicides, insecticides, fertilizer, etc.)	31
9	29	Energy Use efficiency	31
10	54	Marketing of a product	31

As seen in Table 5, all the LLs in the 'Forestry' domain chose 'Value added to end-product via digitalization' as one of their studied indicators. This demonstrates a unanimous agreement among LL coordinators that digitalization in forestry will impact the value added to end-products, and that this indicator must be assessed to understand the influence of digitalization on the sustainability of forestry. Besides that, four of the most selected indicators can only be found in the Top 10 of the 'Forestry' domain: 'Progress towards sustainable forest management' (75%), 'Soil erosion - area affected by severe erosion rate' (75%), 'Forest: growing stock, increment and fellings' (50%) and 'Forest fires' (50%). Compared to the other DESIRA domains, forestry places more importance on environmental indicators, which can be seen in the higher number of environmental indicators (5 of 10).

Tab. 5: Top 10 most selected indicators by the stakeholders of the DESIRA LL in the Forestry domain

Top 10 most selected indicators in the Forestry domain			
	Indicator No	**Indicator**	**% of LLs who chose indicator**
1	8	Value-added to end-product via digitalization	100
2	22	Availability of data collected (by the farmer or land manager or the land owner or lessor)	75
3	35	Progress towards sustainable forest management	75
4	34	Soil erosion - area affected by severe erosion rate	75
5	64	Application of digital technology in small and medium sized enterprises	75
6	27	Land Use efficiency	50
7	37	Forest: growing stock, increment and fellings	50
8	36	Forest fires	50
9	48	Public awareness of a subject via digitalization	50
10	54	Marketing of a product	50

Table 6 shows the most selected indicators of the LLs in the 'Rural Areas' domain. Their main interest appears to be public perception. Three fourths of the LLs chose 'Public awareness of a subject via digitization' and 63% chose 'Public image of a subject or product' as one of their indicators for assessment. Additionally, almost 40% of the LLs in the domain assess indicators connected to the tourism industry: 'Proportion of jobs in sustainable tourism industries out of total tourism jobs' (38%) and 'Number of sustainable tourism strategies or policies and implemented action plans with agreed monitoring and evaluation tools' (38%). While in second place overall, 'Value added to end-product via digitalization' is assessed by only one fourth of the 'Rural Areas' LLs. Socio-economic indicators constitute 8 of the top 10 indicators while environmental indicators appear less often (n=2) among the top 10.

Tab. 6: Top 10 most selected indicators by the stakeholders of the DESIRA LL in the Rural areas domain

Top 10 most selected indicators in Rural Areas domain			
	Indicator No	**Indicator**	**% of LLs who chose indicator**
1	49	Public awareness of a subject via digitalization	75
2	52	Public image of a subject or product	63
3	9	Proportion of small-scale industries in total industrial value added	50
4	43	Generation of waste	50
5	64	Application of digital technology in small and medium sized enterprises	50
6	27	Land Use efficiency	38
7	56	Proportion of jobs in sustainable tourism industries out of total tourism jobs	38
8	57	Number of sustainable tourism strategies or policies and implemented action plans with agreed monitoring and evaluation tools	38
9	6	Household expenditure (limited to household, not including farm or connected enterprise)	25
10	8	Value added to end-product via digitalization	25

3.3 Analysis of the Participatory SESI Assessment Results

As described in section **2.3.1**, stakeholders of the LLs participated in the assessment of the ten SESI for their respective LLs via an online survey. Participation rates varied across the LLs, as seen in **Table 12** in the Annex. Some LLs were challenged to involve stakeholders in the online survey due to limitations such as insufficient internet access in their region at the time of the survey or inadequate stakeholder engagement. On average, 11 participants per LL participated in the online survey and therefore the participatory SESI assessment.

Raw online survey results from the various LLs were exported and then organized into the master excel file spreadsheet. Furthermore, the answers to the questions regarding those 'Top 10 indicators' were compared between the LLs. Accordingly, it was possible to check which of the 'Top 10 indicators' were chosen most often to increase or decrease the progress towards the individual goals of the LLs. On top of that, the indicators rated as 'most important' and 'least important' by the survey participants were assessed. The abbreviations for the LLs used in the following tables are elaborated in **Table 11** in the Annex.

Table 7 shows the LLs that had the majority (50% or more) of their respondents specify that digitalization either 'moderately' or 'strongly' increases the chances of reaching the DESIRA sustainability target per top 10 indicator. All LLs who assessed the two most selected indicators ('application of digital technology in small and medium sized enterprises' and 'value added to end-product via digitalization') perceived digitalization to positively impact the respective sustainability targets. The remaining indicators were assessed by the majority of the LLs as increasing progress towards the targets, although one or two LLs per indicator either negatively or neutrally assessed these targets. When these results are compared with the results below in **Table 8**, it is clear that the LLs overall perceive digitalization to increase rather than decrease progress towards the sustainability targets.

Tab. 7: Response rates for the Top 10 Indicators chosen to increase progress towards the sustainability goal

Indicators chosen most often to increase the progress towards the goal						
	Indicator No	**Indicator**	**DESIRA Sustainability Target**	**LLs who positively assessed these targets**	**LL Domain**	**Response % for 'strongly' and 'moderately' increase progress towards the target**
1	64	Application of digital technology in small and medium sized enterprises	Increased application of digital technology in small and medium sized enterprises	ZSA BSC	Agricultural	53
				ILVO	Agricultural	100
				Fraunhofer	Agricultural	54
				AgrOnov	Agricultural	75
				UCO	Forestry	86
				PEFC	Forestry	84
				WR and WU	Agricultural/ Rural Areas	88
				AMIGO	Rural Areas	75
				JYU	Rural Areas	92
				UL	Rural Areas	84
				FiBL	Agricultural	77
				AFS	Rural Areas	100
				SISTEMA	Forestry	60
2	8	Value-added to end-product via digitalization	Added-value to end-product	ZSA_BSC	Agricultural	53
				Fraunhofer	Agricultural	77
				Inno'vin	Agricultural	83
				AgrOnov	Agricultural	83
				UCO	Forestry	86
				PEFC	Forestry	79
				SARGA	Forestry/Rural Areas	100
				JYU	Rural Areas	83
				AFS	Rural Areas	84

Indicators chosen most often to increase the progress towards the goal						
	Indicator No	**Indicator**	**DESIRA Sustainability Target**	**LLs who positively assessed these targets**	**LL Domain**	**Response % for 'strongly' and 'moderately' increase progress towards the target**
3	18	Contribution to income (of new technology)	New technology has a positive contribution to income	ZSA BSC	Agricultural	53
				Fraunhofer	Agricultural	54
				Inno'vin	Agricultural	50
				AgrOnov	Agricultural	69
				Hutton	Agricultural/ Rural Areas	100
				FiBL	Agricultural	62
				AFS	Rural Areas	100
4	52	Public image of a subject or product	Improved image of a subject or product	KIT	Agricultural	54
				ZSA BSC	Agricultural	69
				ILVO	Agricultural	100
				Fraunhofer	Agricultural	85
				PEFC	Forestry	79
				WR and WU	Agricultural/ Rural Areas	75
				AMIGO	Rural Areas	81
				JYU	Rural Areas	83
				Hutton	Agricultural/ Rural Areas	50

Indicators chosen most often to increase the progress towards the goal						
	Indicator No	**Indicator**	**DESIRA Sustainability Target**	**LLs who positively assessed these targets**	**LL Domain**	**Response % for 'strongly' and 'moderately' increase progress towards the target**
5	49	Public awareness of a subject	Increased public awareness	ZSA_BSC	Agricultural	74
				Fraunhofer	Agricultural	92
				SARGA	Forestry/Rural Areas	100
				WR and WU	Agricultural/ Rural Areas	100
				Hutton	Agricultural/ Rural Areas	100
				AMIGO	Rural Areas	87
				JYU	Rural Areas	92
				UL	Rural Areas	74
				SISTEMA	Forestry	80
6	27	Land Use efficiency	Increased land use efficiency	ZSA BSC	Agricultural	59
				UCO	Forestry	86
				SARGA	Forestry/Rural Areas	100
				WR and WU	Agricultural/ Rural Areas	88
				Hutton	Agricultural/ Rural Areas	50
				AMIGO	Rural Areas	69
				AFS	Rural Areas	100
7	20	Ownership and disclosure of collected data	Increased protection of ownership and disclosure of collected data	Fraunhofer	Agricultural	61
				SISTEMA	Forestry	60
				UL	Rural Areas	90
				AFS	Rural Areas	88
				Cultivate	Rural Areas	63

Indicators chosen most often to increase the progress towards the goal						
	Indicator No	**Indicator**	**DESIRA Sustainability Target**	**LLs who positively assessed these targets**	**LL Domain**	**Response % for 'strongly' and 'moderately' increase progress towards the target**
8	5	Volume of production per labour unit by classes of farming/ pastoral/forestry enterprise size	Increased volume of production per labour unit by classes of farming/ pastoral/forestry enterprise size	KIT	Agricultural	61
				Fraunhofer	Agricultural	62
				Végépolys	Agricultural	54
				WR and WU	Agricultural/ Rural Areas	76
				Hutton	Agricultural/ Rural Areas	50
				FiBL	Agricultural	92
9	54	Marketing of a product	Improved marketing of a product	ZSA BSC	Agricultural	69
				SISTEMA	Forestry	80
				WR and WU	Agricultural/ Rural Areas	88
				Fraunhofer	Agricultural	77
				PEFC	Forestry	89
				Hutton	Agricultural/ Rural Areas	100
10	29	Energy Use efficiency	Increased energy use efficiency	KIT	Agricultural	77
				Végépolys	Agricultural	82
				JYU	Rural Areas	100
				Cultivate	Rural Areas	81
				FiBL	Agricultural	39

Table 8 displays the indicators that were assessed by LLs as perceiving digitalization to either 'moderately' or 'strongly' decrease the progress towards their respective goals. Unlike in **Table 7**, this table does not display only the responses of the majority (50% or more) of their respondents, because the participating stakeholders assessed only few indicators. There is only one LL (KIT), referring to a singular indicator (ownership and disclosure of collected data), where a majority of respondents (61%) believes that digitalization will decrease the progress towards the goal; all other negative assessments were conducted by the minority of stakeholders within particular LLs, such as the Latvian (ZSA_BSC) LL. It can be seen that the stakeholders within this LL were more often critical of digitalization's impact on the progress towards sustainability targets than other LLs. This LL focused on the question 'How have digital tools for quality recognition, traceability, and direct selling of beef meat improved market conditions for producers?'. SESI #5 (volume of production per labour unit by classes of farming/ pastoral/forestry enterprise size) was not assessed to have a negative impact on the progress towards the sustainability target by any LL.

Tab. 8: Response rates of the 'Top 10 indicators' chosen to decrease progress towards the sustainability goal

Indicators chosen most often to decrease the progress towards the goal						
	Indicator No.	**Indicator**	**DESIRA Sustainability Target**	**LLs who negatively assessed these targets**	**LL Domain**	**response % for 'strongly' and 'moderately' decrease progress towards the target**
1	64	Application of digital technology in small and medium sized enterprises	Increased application of digital technology in small and medium sized enterprises	ZSA BSC	Agricultural	21
2	8	Value-added to end-product via digitalization	Added-value to end-product	ZSA BSC	Agricultural	21
3	18	Contribution to income (of new technology)	New technology has a positive contribution to income	ZSA BSC	Agricultural	21
4	52	Public image of a subject or product	Improved image of a subject or product	ZSA BSC	Agricultural	21
5	49	Public awareness of a subject	Increased public awareness	ZSA BSC	Agricultural	21
6	27	Land Use efficiency	Increased land use efficiency	ZSA BSC	Agricultural	21

Indicators chosen most often to decrease the progress towards the goal						
	Indicator No.	**Indicator**	**DESIRA Sustainability Target**	**LLs who negatively assessed these targets**	**LL Domain**	**response % for 'strongly' and 'moderately' decrease progress towards the target**
7	20	Ownership and disclosure of collected data	Increased protection of ownership and disclosure of collected data	KIT	Agricultural	61
8	5	Volume of production per labour unit by classes of farming/ pastoral/forestry enterprise size	Increased volume of production per labour unit by classes of farming/ pastoral/forestry enterprise size	ZSA BSC	Agricultural-	21
9	54	Marketing of a product	Improved marketing of a product	ZSA BSC	Agricultural	21
10	29	Energy Use efficiency	Increased energy use efficiency	Inno'vin	Agricultural	33

Table 9 depicts the indicators assessed by LLs where a majority of the respondents stated that an indicator is the most important of the indicators. It is important to highlight here (as explained in section **2.3.1**) that the stakeholders within each LL were provided with only 10 indicators, not the final set of 65. Therefore, the stakeholders were identifying which of the 10 indicators for their LL they perceived as most important and (as seen in **Table 10**) as least important. In this regard, the indicator' contribution to income' is assessed to be the most important indicator by the most LLs. This implies that stakeholders feel this indicator is the most important to measure regarding digitalization in the domains of the DESIRA project.

Tab. 9: LLs that identified 'Top 10 indicators' as most important

Top 10 indicators LLs and domains identified the indicators as the most important (majority of responses within LL are 'most important')				
Indicator No	Indicator	DESIRA Sustainability Target	LL	LL Domain
64	Application of digital technology in small and medium sized enterprises	Increased application of digital technology in small and medium sized enterprises	Amigo	Rural Areas
8	Value added to end-product via digitalization	Added-value to end-product	Inno'vin	Agricultural
			PEFC	Forestry
18	Contribution to income (of new technology)	New technology has a positive contribution to income	Inno'vin	Agricultural
			AgrOnov	Agricultural
			Végépolys	Agricultural
			Hutton	Agricultural/Rural Areas
			FiBL	Agricultural
52	Public image of a subject or product	Improved image of a subject or product	ILVO	Agricultural
			PEFC	Forestry
			Hutton	Agricultural/Rural Areas
49	Public awareness of a subject	Increased public awareness	Hutton	Agricultural/Rural Areas
27	Land Use efficiency	Increased land use efficiency	ZSA BSC	Agricultural
			Trilofos	Rural Areas
20	Ownership and disclosure of collected data	Increased protection of ownership and disclosure of collected data	SISTEMA	Forestry

Top 10 indicators LLs and domains identified the indicators as the most important (majority of responses within LL are 'most important')				
Indicator No	Indicator	DESIRA Sustainability Target	LL	LL Domain
5	Volume of production per labour unit by classes of farming/pastoral/forestry enterprise size	Increased volume of production per labour unit by classes of farming/pastoral/ forestry enterprise size	FiBL	Agricultural
54	Marketing of a product	Improved marketing of a product	Hutton	Agricultural/Rural Areas
29	Energy Use efficiency	Increased energy use efficiency	Cultivate	Rural Areas

Table 10 shows the indicators assessed by LLs where a majority of the respondents stated that an indicator is the least important of the indicators. This implies that the stakeholders disagree with the LL coordinator's decision to measure these indicators in relation to their FQ. Further, these results indicate which indicators are perceived by stakeholders to be unimportant in measuring the impact of digitalization on the socio-economic and/or environmental sustainability in the DESIRA domains. Two LLs, and thus most, rank 'Application of digital technology in small and medium sized enterprises' as the least important indicator. This contradicts the choices of the majority of the LLs, as this indicator was chosen most frequently among all LLs. Several of the Top 10 indicators were not selected to be least important by any of the LLs. Another important result to highlight is that neither of the environmental indicators were identified by the majority of LL stakeholders to be the least important.

Tab. 10: LLs that identified 'Top 10 indicators' as least important

Top 10 indicators LLs and domains identified the indicators as least important (majority of responses within LL are 'least important')				
Indicator No	**Indicator**	**DESIRA Sustainability Target**	**LL**	**LL Domain**
64	Application of digital technology in small and medium sized enterprises	Increased application of digital technology in small and medium sized enterprises	PEFC	Forestry
			JYU	Rural Areas
8	Value added to end-product via digitalization	Added value to end-product	-	-
18	Contribution to income (of new technology)	New technology has a positive contribution to income	-	-
52	Public image of a subject or product	Improved image of a subject or product	Cultivate	Rural Areas
49	Public awareness of a subject	Increased public awareness	Cultivate	Rural Areas
27	Land use efficiency	Increased land use efficiency	-	-
20	Ownership and disclosure of collected data	Increased protection of ownership and disclosure of collected data	ILVO	Agricultural
			Cultivate	Rural Areas
5	Volume of production per labour unit by classes of farming/pastoral/forestry enterprise size	Increased volume of production per labour unit by classes of farming/pastoral/forestry enterprise size	-	-
54	Marketing of a product	Improved marketing of a product	PEFC	Forestry
29	Energy Use efficiency	Increased energy use efficiency	-	-

3.4 SESI Results related to the Sustainable Development Goals

Fig. 3: United Nation's Sustainable Development Goals (UN 2019)

Some of the SDGs (Figure 3) were included as indicators in the SESI (SESI #s 5, 7, 9, 17, 35, 42, 46, 47, 55, 56, 57, 61) based on the requirements identified by LL coordinators, while others were omitted. As described in section **2.2.1**, each SESI relates to one or more SDGs, which are listed in **Table 1**. The following tables provide an analysis of the SGDs related to the selected and assessed SESIs.

Fig. 4: Sustainable Development Goals (SDGs) related to all SESI indicators

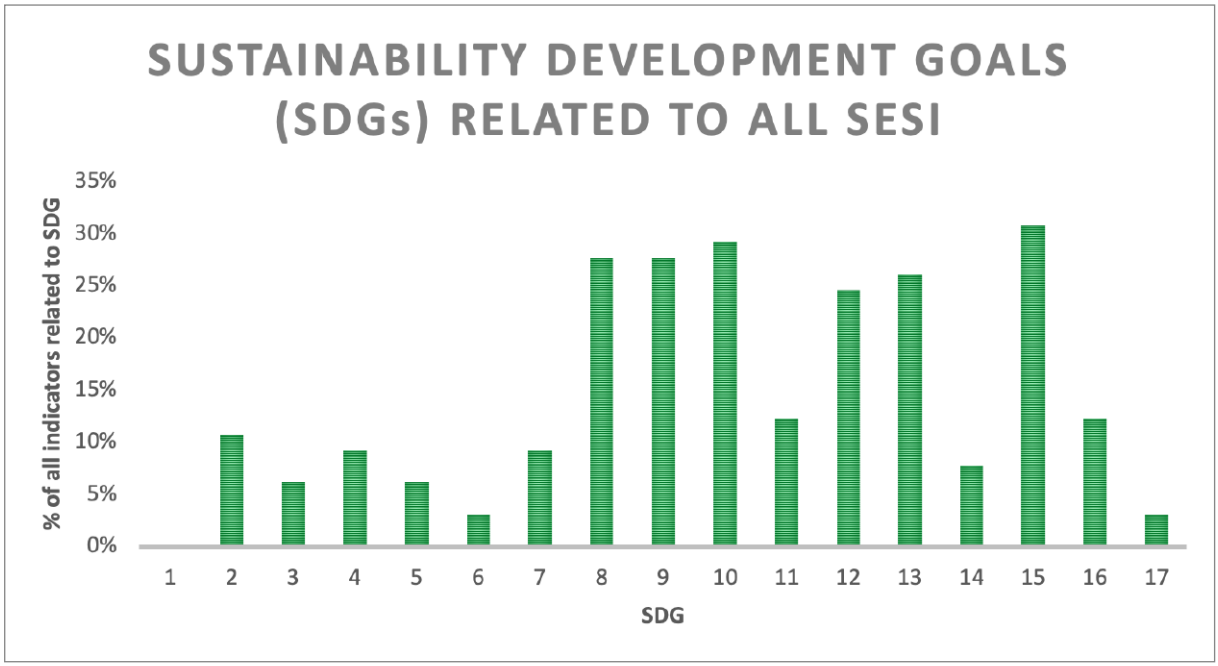
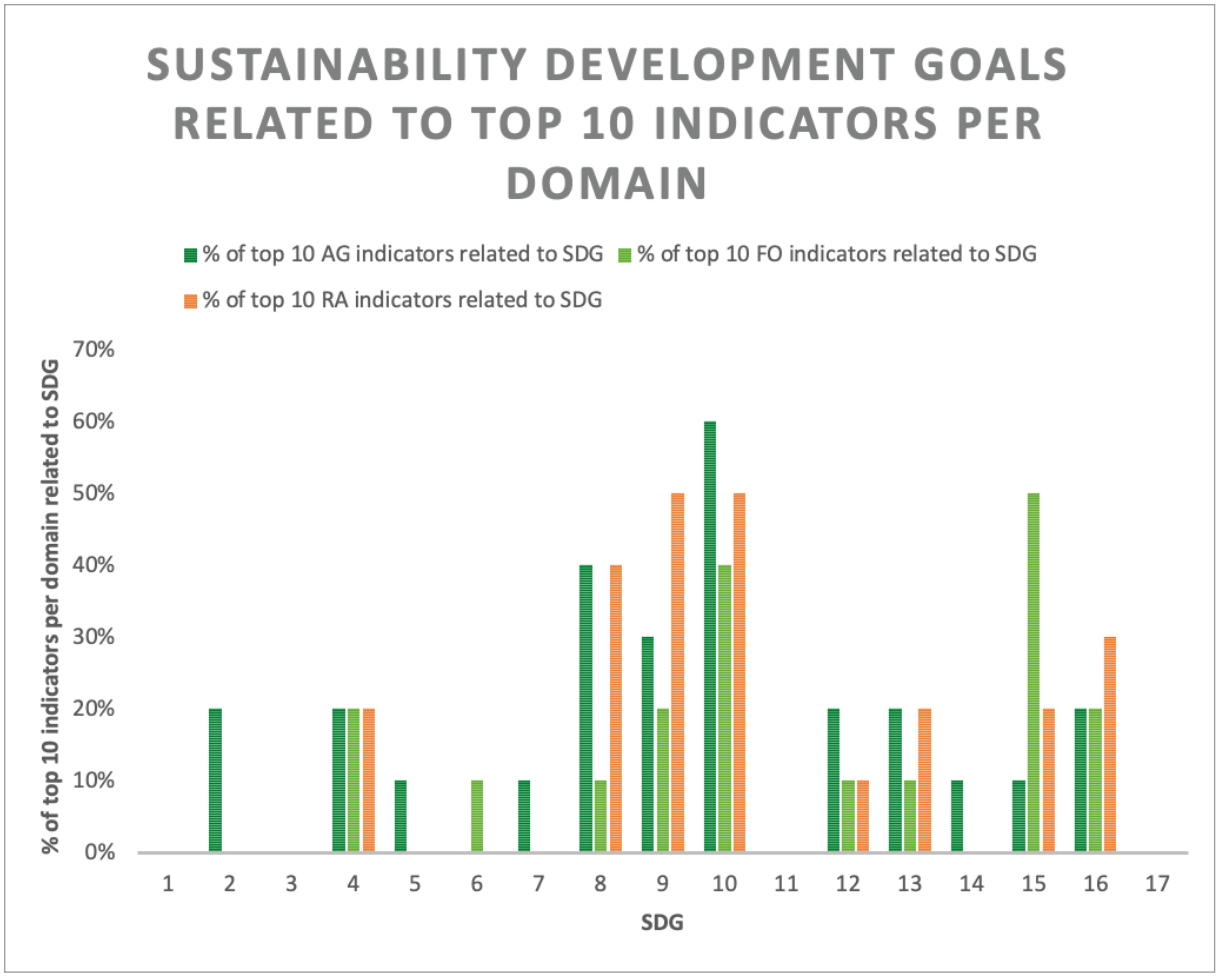


Figure 4 depicts the percentage of all SESI (n=65) that are related to the 17 SDGs. The SDGs related to the most SESI include SDG 15 (life on land); SDG 10 (reduced inequalities); SDG 9 (industry, innovation, and infrastructure); SDG 8 (decent work and economic growth); SDG 16 (peace, justice, and strong institutions); SDG 12 (responsible consumption and production); and SDG 13 (climate action). These results suggest that digitalization in agriculture, forestry, and rural areas have the greatest impact on impact these SDGs, according to LL coordinators and their focal questions. Implications of these results include a purposeful focus on these sustainability goals in research, development, and policy related to digitalization.

Of these SDGs related to the most SESI, SDG 15 and SDG 13 could be considered direct environmental indicators while the others are distinctly more socio-economic.

Fig. 5: Sustainable Development Goals (SDGs) related to the top 10 SESI indicators per domain



As seen in Figure 5, the SDGs relates to the top 10 SESI per domain were analyzed. In the agriculture domain, SDGs 10 (reduced inequalities), 8 (decent work and economic growth), 4 (quality education), and 2 (zero hunger) relate most often to the top 10 selected indicators. Similarly, for the rural area domain, SDGs 10, 9 (industry, innovation, and infrastructure), 8, and 16 (peace, justice, and strong institutions) relate most often to the top 10 selected indicators. And finally, SDGs 15 (life on land),

10, 9 (industry, innovation, and infrastructure), 16, and 4 relate most often to the top 10 selected indicators in the forestry domain. Certain SDGs relate only to SESI in one domain. For instance, SDG 2 relates to approximately 20% of the top 10 agriculture domain SESIs, but not the forestry or rural area SESIs. Similarly, SDG 5 (gender equality), SDG 7 (affordable and clean energy), and SDG 14 (life below water) relate to around 10% of the top 10 agriculture SESIs respectively, while SDG 6 (clean water and sanitation) relates only to 10% of the top 10 forestry SESI. As also indicated in the previous figure, SDGs 4, 8, 9, 10, 12, 13, 15, and 16 relate to top 10 indicators across all three domains, suggesting that sustainable digitalization is the most important regarding these goals. As an example, digitalization is perceived to have a greater impact on quality education (SDG 4) than no poverty (SDG 1).

SDGs that were not among the top 10 indicators of any domain include 1 (no poverty), 3 (good health and well-being), 11 (sustainable cities and communities), and 17 (partnerships for the goals). While this result does not indicate that these SDGs are irrelevant for sustainable digitalization in the DESIRA domains, it does suggest that these SDGs are of less relevance and that focus on progression towards the more frequently related SDGs should be a priority.

4 Discussion

The main objective of the participative sustainability research was to operationalize the Integrative Concept of Sustainability in different digitalization contexts and European regions. Therefore, Living Lab (LL) stakeholders from the domains agriculture, forestry, and rural areas identified relevant sustainability assessment indicators from the non-academic perspective. The results show that the LL stakeholders selected and ranked indicators differently due to various values, interests and cultural contexts. The method applied is considered a practical approach to monitoring, evaluating, and communicating the complex technological development of digitalization. The stakeholders assessed the perceived and expected associated socio-economic impacts, making the Integrative Concept of Sustainability operational and increasing transparency and supporting decision-making.

The limitation of the research is the relatively small number of respondents. The reluctant participation, low rate of LL stakeholders' respondents, and the gaps between the proposed indicator and stakeholders' perceptions could point to a weakness of the method applied. Although teaching was performed for the assessment task more than once and offered individually for LL coordinators, some stakeholders might have been poorly guided and thus overwhelmed by the complex task. Besides, due to Corona restrictions, the sustainability assessment task had to be performed together with the survey of D 2.2. Initially, only a survey was scheduled for the sustainability assessment. However, not to approach the LL stakeholders with two surveys, it was decided to conduct only one survey with the sustainability assessment questions placed at the end. Since the questionnaire was quite long with many questions from the D 2.2, stakeholders were probably tired due to the lengthy questionnaire. Another reason for the reluctance to use participatory assessment was the decision to conduct a qualitative evaluation of the indicators based on qualitative targets. This decision was necessary because the database for a qualitative evaluation was not available in sufficient quality and differentiation in the Living Labs. However, the results would not be representative even with a significantly higher feedback rate since the LL stakeholders are not representative in their number and composition.

Measuring the sustainability impact of digitalization is difficult when dealing with qualitative data and determining the most relevant indicators for their measurement as defined by various stakeholders. The issue of judgment and interpretation remains challenging as it encompasses subjectivity and differing stakeholders' perceptions in assessment. Nevertheless, the results are novel and exciting because most of the research on stakeholder participation associated with sustainability assessment focuses on the involvement in indicator selection and the design and development of indicator systems. They display the self-assessment of sustainability indicators conducted by different LL stakeholders and how digitalization relates to sustainability targets. The analysis focuses on relevant indicators perceived and expected to be relevant to achieving sustainable development by the LL stakeholders. Different response patterns were identified among stakeholders from other domains and Living Labs. It was also possible to determine which indicators are assumed to be improved or worsened by digitalization. Our findings support the notion that stakeholders' evaluation of the sustainability performance of digitalisation can be used as an indirect way of evaluating the strengths and weaknesses of digitalization and concluding its overall utility and societal value in the domains of agriculture, forestry, and rural areas.

5 Conclusions

Through an iterative, participatory process, a final set of 65 Socio-Economic Sustainability Indicators to assess the impact of digitalization in agriculture, forestry, and rural areas have been created. These indicators were then used in the context of the DESIRA project to qualitatively measure the impact of digitalization across 21 Living Labs towards the DESIRA sustainability targets. For example, during the first review meeting, the evaluators asked about the representativeness of our sample in relation to D2.2. We answered that the sample cannot be representative, as the respondents are Living Lab stakeholders, and that we give more emphasis to stakeholders' participation. But if you have better arguments they are welcome.

The final set of SESI presented in this report can be used to monitor and measure the impacts of digitalization in agriculture, forestry, and rural areas in other research contexts. This assessment provides a snapshot into the current and near-future impacts of digitalization in the DESIRA domains. Furthermore, these results can be compared across spatial and temporal contexts.

Most indicators chosen by LL coordinators for the final set of SESI and therefore most indicators chosen by stakeholders during the assessment were socio-economic. In particular, the impact of digitalization on the use of digital technologies in small and medium-sized enterprises, value-added to products through digitalization, data ownership, public image and public acceptance of subjects or products were identified as the most important indicators to assess across the DESIRA LLs. This implies that LL coordinators and stakeholders expect digitalization to impact socio-economic challenges, such as the public image of a subject or contribution to income, more than environmental challenges. Furthermore, that these socio-economic challenges are currently of more importance to stakeholders than environmental. In the participatory SESI assessment, most LLs assessed digitalization to increase progress towards the sustainability targets for the SESIs. This is a promising outlook for digitalization in agriculture, forestry, and rural areas.

6 Annex

Tab. 11: Focal Questions of the 21 Living Labs

	Living Lab	DESIRA Partner Abbreviation	Focal Question
1	Austria	SISTEMA	How can digitalization support and enforce the adoption of the European Timber Regulation (EUTR) concerning imported round wood in Austria?
2	West Flanders, Belgium	ILVO	What is the impact of individual farm based airborne monitoring of emissions of ammonia, particulate matter, and odour, in the intensive livestock sector for agriculture, policy, and society in Flanders?
3	Switzerland	FiBL	How to control weeds effectively and efficiently in Swiss organic vegetable farming?
4	Lake of Constance, Germany	KIT	How can digitalization contribute to the sustainability of fruit production in the Lake of Constance region?
5	Rheinland-Palatinate, Germany	Fraunhofer	How the local administration can cope with internal and external challenges of the digital transformation and integrate citizens as well as other local actors into this process?
6	Northern Greece	AFS	How to develop new digital services and functionalities for rural communities based on utilization of existing agricultural / data infrastructures and tools. How can these infrastructures be used to further support the economy and farmers' / citizens' income in rural communities?'
7	Trikala, Greece	ATHENA	How to better manage water resources for the benefit of both, farming purposes and the everyday needs of the citizens?
8	Andalucia, Spain	UCO	How can digitalization contribute to reduce the damage caused by wildfires and to make more effective firefighting and degraded land restoration by 2030?
9	Aragon, Spain	SARGA	How can digitalization contribute to enhance the global attractiveness of the territory of Maestrazgo and Gúdar-Javalambre?
10	Central Osthrobotnia, Finland	JYU	How can digital systems contribute to advancing bioeconomy and circular economy in Central Ostrobothnia in 2030?
11	New Aquitaine, France	Inno'vin	What is the current state of the level of digitalization within the wine sector's value chain and how these technologies can help achieve the agro-ecological transition of the wine sector while strengthening its competitiveness?
12	Burgundy-Franche-Comté, France	AgrOnov	How does digital technology contribute to the emergence of innovations in favour of agro-ecological transition in agriculture?

	Living Lab	DESIRA Partner Abbreviation	Focal Question
13	Végépolys Valley, France	Végépolys	How can digital technology enable horticultural companies to increase their productivity and reduce costs, while reducing their environmental impact? How can digital technology enable horticultural companies to have a better knowledge of the offer, to better appreciate the market and the real needs of end consumers, but also to diversify the sales methods?
14	Croatian Adriatic Region, Croatia	Ministry of Agriculture	How can digitization contribute to availability of local products, recognition, flexibility and standardization of local traditional small-scale products and services? How can digitization contribute to strengthening the connections between farmers and tourists, and create a better position of the small family farms in the value chain?
15	Cloughjordan, Ireland	Cultivate	How can digitalization support local livelihoods that contribute to rural regeneration and assist in the transition to a low carbon society?
16	Tuscany Nord, Italy	AMIGO	How can a better communication among citizens, farmers, public administration and other stakeholders make ordinary land management in marginal rural areas more effective? And how can digitalization facilitate the information flows between actors/tools involved in this process?
17	Apennine Region, Italy	PEFC	How to strengthen the adoption of digital tools to support the wood-energy traceability over the whole supply chain in conformity to the compulsory EU Timber Regulation (995/2010) in Italian forests
18	Latvia	ZSA BSC	To develop an innovative support system with the use of digitals tools for the recognition and traceability of beef cattle meat in order to improve and extend markets (e.g. digital marketing strategy aimed at communicating the characteristics of Latvia's beef to consumers and farmers).
19	Flevoland, the Netherlands	WR and WU	How can digital systems/platforms contribute to the exchange of knowledge of short food supply chains?
20	Rural Poland	UL	How to enhance participation in rural planning? And how can digitalization improve the involvement of local communities in spatial planning processes?
21	Scotland	Hutton	How can digital technologies promote opportunities for crofting communities in Wester Ross?

Tab. 12: Stakeholder participation in the online survey per LL

	LL	# of survey responses
1	Austria	5
2	West Flanders, Belgium	1
3	Switzerland	13
4	Lake of Constance, Germany	13
5	Rheinland-Palatinate, Germany	13
6	Northern Greece	6
7	Trikala, Greece	7
8	Andalucia, Spain	14
9	Aragon, Spain	1
10	Central Osthrobotnia, Finland	12
11	New Aquitaine, France	6
12	Burgundy-Franche-Comté, France	29
13	Végépolys Valley, France	11
14	Croatian Adriatic Region, Croatia	0
15	Cloughjordan, Ireland	16
16	Tuscany Nord, Italy	16
17	Apennine Region, Italy	19
18	Latvia	19
19	Flevoland, the Netherlands	8
20	Rural Poland	19
21	Scotland	4
Total number of stakeholder		232
Average number of stakeholder per LL		11