PRIMA SECTION 2

D.1.2 / SIF DESCRIPTION AND GUIDELINES

(WP1 Project baseline and sustainable innovation framework design)

SUSTEMICROP PROJECT

Development of eco-sustainable systemic technologies and strategies in Mediterranean crop systems contributing to small farming socio-economic resilience

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Project details and Deliverable information

✓ Project Details

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Table of Contents

List of abbreviations and definitions

Abbreviation	Definition
TBL	Triple Bottom Line
SIF	Sustainable Innovation Framework
KPIs	Key Performance Indicators
WP	Work package
TCS	Technological Case Studies
ICM	Integrated Crop Management
IPM	Integrated Pest Management
SDGs	Sustainable Development Goals
GRI	Global Reporting Initiative
EU	European Union
PEF	Product Environmental Footprint

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Executive summary

The continuous technological advances as well as environmental pressure towards a more sustainable and responsible world is a central issue nowadays in our society. As it happens in other fields, in the agriculture context, farmers experience the pressure to produce more and higher quality food at a lower cost in an environmentally and socially sustainable manner. Thus, they are encouraged to introduce new practices and techniques in their production activity. Moreover, the climate conditions force farmers to develop more resistant variants of different crops to survive and to be competitive. Finally, although farmers need to pay more attention to their stakeholders, their main objective is to be economically autonomous and competitive in the long-term. In this sense, sustainable practices contribute to achieve the Triple Bottom Line (TBL) easily, i.e., manage to be economically, socially and environmentally sustainable.

The objective of this deliverable is to present the initial Sustainable Innovation Framework (SIF). The SIF, together with a set of tools, aims to guide farmers through the sustainable process following different stages and considering their stakeholders and relationships. This deliverable presents the following materials:

- The *initial SIF*, which provides a detailed overview of the framework as well as a description of all the steps needed to develop and implement it.
- The *measurement framework*, which provides tools to measure the economic, social and environmental performance before and after undertaking the innovation process by using Key Performance Indicators (KPIs).
- The *implementation guidelines*, which help farms in the implementation of the initial SIF and the application of the measurement framework.

The SIF proposed in this deliverable (D.1.2) is a conceptual and theoretical work that describes how farmers can implement sustainable production practices and how they can measure the TBL impact in their farms. This SIF is used in Work Package number 6 (WP6 - Evaluation and Acceptance of Agro-ecological Innovation) to be applied to different pilots and measured using a digital tool developed in WP5 (Sustainability Assessment through Novel Digital Tools).

1. Introduction

1.1. Project summary

In the past decades, the Mediterranean region has experienced unsustainable agricultural practices, low productivity, biodiversity loss and climate change that altogether represent an enormous challenge for small farming systems. The European Green Deal, launched by the European Commission, has been designed to deal with climate and environmental-related challenges, in an attempt to build a sustainable response. Among several topics, agricultural activities have been addressed. This includes measures (like the European Farm-to-Fork Strategy) dealing with the use of Plant Protection Products and fertilizers of synthetic origin, given their negative effect on air and water pollution, soil degradation, food safety, and human health. However, the accomplishment of all the established measures has become a challenge especially for small farmers, with lesser economic resources and limited training skills. There is an urgent need to address some of these threats effectively and achieve sustainable agro-ecological practices to improve small farmers' resilience and adaptation to climate change and regulation changes.

In this context emerges the SUSTEMICROP project which is a Research and Innovation project that aims to increase the resilience of Mediterranean cropping systems and the competitiveness of small farmers in a climate change-affected environment, through the development of innovative, affordable, and systemic solutions with positive economic, social, and environmental impacts. SUSTEMICROP delivers sustainable strategies, products, and tools that, when applied individually or adopted as a whole under integrated management, allow small farmers to increase their competitiveness, adopt innovations and achieve overall sustainability.

To achieve this main objective, the next specific objectives are addressed:

a) Design and validation of innovative solutions to address pests, pathogens, and adaptation to climate change in three Mediterranean crops (hop, date palm, grape vine – for both wine and table grape), by valorizing, selecting, and testing different natural resources: Bio-Control Agents (BCAs), biofertilizers based on BCA-enriched compost, biopesticides based on natural compounds, and detection of resistant varieties and breeding traits against the effects of climate change and diseases.

b) Design of a SIF to evaluate SUSTEMICROP practices/innovations applied in the selected crops by using a set of KPIs economic, social, and environmental.

c) Design of new crop management strategies to be used in Integrated Crop Management (ICM) or Integrated Pest Management (IPM) systems, by using the obtained solutions and evaluation of its replicability, utility and usability.

d) Understand the success and deterrent factors influencing adoption of innovative systemic solutions by smallholders, aligned with legislation, the Sustainable Development Goals (SDGs) proposed by the United Nations 2030 Agenda, and the European Farm-to-Fork strategy.

e) Maximize the outreach and the beneficial influence of the project results, reach the target users, and other interested stakeholders, through a communication, dissemination, and exploitation plan.

1.2. Document scope

The purpose of this document is to design a SIF to evaluate SUSTEMICROP practices/innovations applied in the selected crops, with a set of economic, social, and environmental KPIs. To achieve this main goal, in this D.1.2 we describe the state-of-the-art of the SIF that represents the core methodology developed within the SUSTEMICROP project that guide farmers to implement sustainable production practices in their farms. First, the document provides a brief background to understand the main challenges for farmers in terms of sustainable practices. It serves to introduce the key components, the objective, and the expected impact of the SIF. Secondly, we describe the literature review and the methodology used to develop the SIF. We also illustrate in this D.1.2 the relationship between this deliverable and other tasks, and/or work packages (WPs) along the project. Thirdly, we show the theoretical framework and the methodology used to develop the set of 16 KPIs. Finally, we provide a guideline for farmers to guide them in the process of implementation.

1.3. Document structure

The document is comprised of the following chapters:

Chapter 1 presents a summary of the project as well as the document scope and structure.

Chapter 2 introduces a brief review of the sustainable practices in the agricultural sector.

Chapter 3 shows the literature review and the main theories that justify the development of the SIF. Moreover, it illustrates the methodology followed in the development process of the SIF and it clarifies the relation to other activities within the project.

Chapter 4 describes the set of KPIs and the methodology used to develop them.

Chapter 5 describes the initial SIF and the guidelines for implementation.

Chapter 6 presents concluding remarks and future developments.

Chapter 7 provides the references.

Chapter 8 (appendix A) describes the KPIs included in the measurement framework.

2. Sustainability practices in the agricultural sector

The agri-food industry sector has a strict connection with sustainability issues, considering the fact that there is a common interest both from producers and consumers in environmental and health issues of food production. There is a broad scientific consensus on what is needed to achieve for a sustainable food system. Sustainable agriculture has the goal to meet the needs of present and future generations, and to achieve this by meeting sustainability goals in the three dimensions (economic, social and environmental).

The key principles of sustainability for food and agriculture are five (FAO et al., 2021):

- **Increase productivity, employment and value addition in food systems:** crop productivity needs to be increased to ensure sufficient supply of agricultural products, but at the same time safeguarding and enhancing the environment. This objective needs to be reached increasing the efficiency of technical inputs applied to crops.
- **Protect and enhance natural resources:** agricultural activities rely on natural resources, so sustainable agricultural activities need to reduce negative impacts and enhance the status of these natural resources.
- **Improve livelihoods and foster inclusive economic growth:** in order to be sustainable, agricultural activities need to provide fair employment conditions to those who practice it, in an economically and physical safe and healthy environment.
- **Enhance the resilience of people, communities and ecosystems:** policies, technologies and practices that increase producers' resilience to threats (i.e., extreme weather events, market volatility and civil strife) would also contribute to sustainability.
- **Adapt governance to new challenges:** effective and fair governance (i.e., right and enabling policy, legal and institutional context) can ensure the achievement of sustainability.

In order to achieve sustainability, it is then important to maintain agricultural yields and efficiency while decreasing the environmental burden on biodiversity, soils, water and air; reducing food loss and waste; and stimulating dietary changes towards healthier and less resource-intensive diets.

Sustainable practices to be implemented vary according to the cropping system considered, and they need to be defined by considering the particular conditions in which the farm operates. SUSTEMICROP considers Mediterranean cropping systems, and specifically grapevine (both table grape and for wine production), date palm and hops, by developing and implementing systemic eco-sustainable technologies and strategies, adapted to regional particularities. SUSTEMICROP aims to deliver more sustainable and viable agricultural solutions and techniques following a systemic approach, covering different solutions based on regenerative and circular agriculture by recycling and reusing farm waste; functional biodiversity by selecting a set of microbial species that contribute to improve plant and soil heath; new and environmentally friendly pest management by using natural crop protection products; and selection of varieties better adapted to climate change regarding water shortage, pest attacks, elevated temperatures, or CO_2 concentration.

One of the fundamental baseline ideas of SUSTEMICROP is that agricultural sustainability must be achieved with the development and implementation of integrated management strategies, adapted to each crop, region and context.

For this purpose, the research activity in this project aims to address the following main pillars: *i)* the development of functional biodiversity as crop defense by the identification of Bio-Control Agents (BCAs) and the use of crop residues enriched with BCAs; *ii)* the design and use of biopesticides and bio-fertilizers obtained from natural extracts and natural sources; *iii)* the use of novel and traditional varieties better adapted to adverse effects caused by climate change, and *iv)* agricultural practices (overall) sustainability assessment for improving decision-making process by small farmers.

All the new products developed will be used for the design of new crop management strategies for the three selected crops, to be used in current ICM or IPM systems, by using the innovative systemic solutions obtained in SUSTEMICROP and evaluate its replicability, utility and usability in Mediterranean crops.

3. The Sustainable Innovation Framework (SIF)

This chapter outlines how the SIF was built. Firstly, in section 3.1 we describe the development of the main elements and stages that make up the SIF. Secondly, in section 3.2 we describe the methodology used to build the SIF, which is the result of a mix of state-of-the art literature reviews and expert inputs. In section 3.3 we explain the methodology measurement framework, i.e., what lies behind the SIF and its potential application beyond the scope of SUSTEMICROP project. Finally, we describe the connexion between the SIF and other activities in the project grouped according to different WPs in section 3.4.

3.1. The SIF Theoretical Framework

The SIF is an iterative process, which helps agri-food actors, and in particular farmers, to assess the benefits for implementing sustainable production practices from a threefold perspective: economic, social and environmental. The SIF, along with a portfolio of tools, guides farmers through a process that starts from the identification of the baseline situation and the potential problems and moving towards developing and implementing sustainable production practices, which help them to obtain better results.

As mentioned above, a literature review was carried out in order to build the SIF. To do so, we relied upon Google Scholar, Scopus academic database as well as Science Direct where we entered key words such as “institutional theory”, “signalling theory”, “behavioural factors”, “resource-based view”, “stakeholders theory”, in combination with “sustainable practices”, “sustainability” and “agricultural sector”, “agriculture”, “agri-food sector”, and “farming”. The keywords included several variations of original keywords, for example, singular and plural variations, synonyms, and combinations of keywords; searches in different languages like English, Spanish and Italian were also carried out. Moreover, websites of leading organizations in sustainability and the link with food sector such as The United Nations Agenda and the SDGs, the Global Reporting Initiative (GRI) or the Ellen MacArthur Foundation were also checked. This literature search generated a total of 51 articles and documents which provided useful information to build the SIF.

As depicted in Figure 3.1, the SIF is composed of four main stages: *1)* definition, *2)* decision, *3)* implementation and *4)* evaluation. The next sections elaborate on these four key stages in more detail.

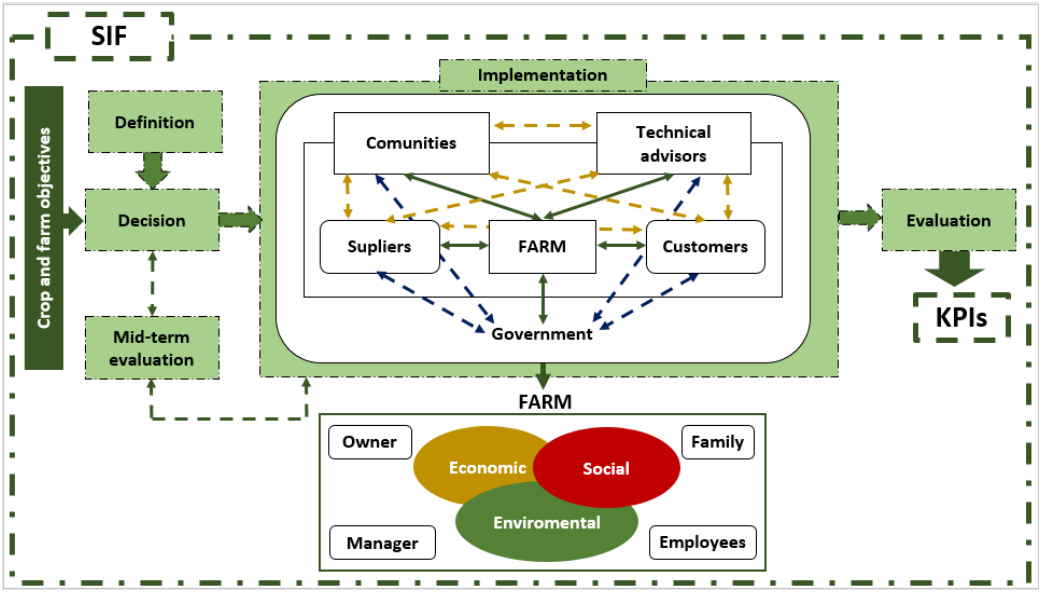

Figure 3.1. Sustainable Innovation Framework

3.1.1. Definition

This first stage refers to some key drivers that might influence farms' decision-making process when they consider developing and implementing sustainable production practices. These factors include the Institutional Context, the Signalling Theory and Farmers' Behavioural Factors.

Institutional Context

Firms operate in an institutional context that demands greater attention to sustainability criteria. According to Institutional Theory (DiMaggio & Powell, 1991), there are some kind of external pressures (social, political, economic, technological, etc.) that influence firm strategies and organizational decision-making as firms seek to adopt legitimate practices (Jennings & Zandbergen, 1995; North, 1990). International institutions, national governments, non-profit organizations, as well as publicly traded companies stress the importance of sustainability in its threefold perspective, i.e. economic, social and environmental (Van Gorp & van der Goot, 2012).

If we focus on the agri-food sector, for example, within the framework of SDGs developed by the United Nations' Agenda 2030 (United Nations, 2022), three of them are explicitly related to Sustainable Agricultural Development: SDG 2.3, SDG 2.4 and SDG 12.3 (Kusnandar et al., 2019). According to GRI, an independent, international organization that provide the world's most widely used standards for sustainability reporting, i.e., the GRI Standards (GRI, 2021), there is a specific pack (GRI 13) focused on Agriculture, Aquaculture and Fishing Sectors that covers a wide range of economic, social and environmental topics (e.g., economic inclusion, employment practices, food security and pesticide used) aligned with SDGs. Within the Circular Economy Scheme (Ellen MacArthur Foundation, 2022), both technical and biological cycles can be applied to agri-food sector. These cycles contribute to achieve more sustainable production and consumption, for example, through the the regeneration of food production or the reduction of food waste. Moreover, this influence of the institutional context on the agri-good sector and the transition of the adoption of sustainable practices have also caught the attention of the academia.

For example, the implementation of sustainable ways of production and changes along the agricultural supply chain, driven by regulatory frameworks (Higgins et al., 2010); the adoption of climate-smart agriculture driven by factors such as the climate change effects and the increasing demand of sustainable products (Mazhar, 2021) or how changes in social values, technological advancements, regulations, etc., might affect decisions regarding sustainable practices, such as green sustainable activities or environmental management (Glover et al., 2014).

Within the scope of our SIF and in order to analyse the different factors that institutional context includes and they can affect farms in their process towards the introduction of more sustainable production practices, based on PESTEL framework (see, for example, Yüksel, 2012), we identify the following factor categories:

- *Legal-political*: e.g., government policy, fair trade policy, environmental policy, trade restrictions, funding and grant opportunities, etc.
- *Economic*: e.g., interest rates, economic growth/recession investment availability, etc.
- *Socio-cultural*: e.g., health threats, lifestyle attitude, health consciousness, population growth rate, age distribution, safety emphasis, etc.
- *Technological*: relevant current and future technology innovation such as Internet of Things, Artificial Intelligence as well as copyrights and patents, General Data Protections Regulations, need for training and education, etc.
- *Environmental*: e.g., environmental policies and priorities, pollution and greenhouse gasses emissions, resources availability, global warming, extreme weather conditions and drought risks, etc.

Signalling Theory

According to Signalling Theory (Spence, 1973), which has been widely applied in describing behaviour when two individuals or groups have access to different levels of information (Connelly et al., 2011), firms' signals enable them to communicate their organizational image, intentions, behaviour and performance (Karaman et al., 2020). Signalling Theory holds a prominent position in different field of knowledge such as strategic management (Basdeo et al., 2006), corporate governance (Trevis, 2003) or human resource management (Leahey, 2007). Although it has only been in the last decade that this theory has gain relevance in the analysis of sustainability practices, there is still further research to be done in this area (Karaman et al., 2020), especially in the field of agriculture where it might help to explain what drives some farmers to adopt sustainable production practices (see, for example, Castro Campos, 2022).

As Dessart et al. (2019) states signalling motives may push farmers to adopt a particular practice or more sustainable practices in general. Thus, we include this factor within our SIF since we consider that leading farmers in implementing sustainable production practices might be lighthouses to other farms and serving as a role model that encourages them to become more sustainability oriented. Similarly, those farmers that decide to implement sustainable production practices by applying, for example, the SIF developed within SUSTEMICROP, might also serve as a reference of their commitment on sustainability to other parties (suppliers, consumers, society, etc.), which can be very well received and positively valued by them.

Moreover, this sustainable effort made by farmers might be a result of governments' legislative initiates. Specifically, regulation on sustainability in agri-food sector not only obligates firms to comply with a particular law, but also it might encourage them to take action that goes further, in order to protect themselves from possible legislative changes in the future.

Farmers' Behavioural Factors

Farmers' behavioural factors are also part of this set of key drivers that have a bearing on decision-making process towards more sustainable production practices.

According to Dessart et al. (2019), three types of behavioural factors can be distinguished: dispositional, cognitive, and social. Dispositional factors are relatively stable and include internal variables related to a given individual, such as personality, motivations, values, beliefs, general preferences and objectives (Malle, 2011). Cognitive factors are related to learning and reasoning and include farmers' perceptions of the relative benefits, costs, and risks associated with a particular sustainable practice or whether they feel that they are skilled enough to adopt this practice. Finally, social factors are related to farmers' interactions with other individuals (e.g. other farmers or advisors) and it includes social norms and signalling motives.

Regarding social factors, two points should be taken into account. Firstly, social norms and signalling motives has been previously analysed in the current sub-section (3.1.1). as part of the Signalling Theory. Secondly, farmers´ interactions will be described under Stakeholder Theory umbrella at the implementation stage (sub-section 3.1.3). In particular, the interactions that take place between farmers and both external and internal stakeholders will be analysed. The main reason is because, although undoubtedly stakeholders are part of the set of sustainable practice key drivers in this first stage of the definition of the SIF, from our point of view, stakeholders play their main role in the implementation stage.

3.1.2. Decision

The decision stage represents how farmers, pushed by the aforementioned set of key drivers (institutional context, signals sent by leading farmers' behavioural factors) tend to be more sustainability-oriented and they are more willing to introduce sustainable practices, from a threefold perspective (economic, social and environmental) in their production activities.

At this point, farmers need to consider two key issues. First, they need to be clear about their main objectives and their stakeholders' demands to determine what kind of sustainable production practices are more suited to achieve them. Second, they must be aware of the resources and capabilities needed to be able to develop and implement such practices and manage them efficiently.

Farms' Objectives and Stakeholders' Demands

Within the SIF context, when we refer to farmer's objectives, we have not only considered objectives at strategic, competitive and functional levels (Thompson et al., 2022) but also those goals at higher levels that a farmer seeks to achieve, i.e. its mission and vision and values that are closely related to its organizational culture.

Mission can be described as how a firm defines itself and establishes the priorities of the organization (Jacopin & Fontrodona, 2009) and, if it is well-designed, it expresses the firm's primary and distinctive purpose. Vision refers to the current perception of what the firms will or should be in the future. It is the most general and long-term tool for future orientation and involves defining the strategic purpose or basic project of the firm (Hamel & Prahalad, 1989). Finally, organizational values refer to beliefs about the types of goals firm members should pursue, as well as ideas regarding standards of behaviour, organizational members should use to achieve these goals (Schein, 2010).

In addition, it should be noted that the farmers' objectives must also be aligned with the objectives or demands of their main stakeholders. This is because, as Cyert & March (1963) states, firms' objectives can be understood as the result of a process of negotiation and adjustment between the different groups involved so that all of them consider their particular objectives to be met, at least at a sufficient level.

Since the decision to adopt sustainable production practices should be considered as a tool to help farmers' to achieve their objectives, these sustainable practices must be coherent and perfectly aligned with them. As Galping et al. (2015) states, the more a farmer is oriented towards sustainability and the more sustainable the values that underpin its mission, vision and strategic objectives, the more likely the farmer will be to make the transition towards a more sustainable production process.

Farms' Resources and Capabilities

The Resource-Based View holds that the firms' sustainable development cannot be separated from strategic resources (Russo & Fouts, 1997). Considering that sustainable development should be understood in the TBL approach (Wilson, 2015), it means that firms must play a central role in achieving the goals of sustainable development strategies (Elkington, 1994) by channelling their resources and capabilities towards addressing economic, social and environmental challenges (Hart, 1995).

According to the two main assumptions of the Resource-Based View, firms are a heterogeneous combination of resources and capabilities that are not available to all firms under the same circumstances (Barney, 1991). These two founding arguments (heterogeneity and immobility) are those that can help firms to achieve a competitive advantage (Barney & Hesterly, 2012; Peteraf & Barney, 2003) and their business objectives as long as they are able to efficiently manage their resources and capabilities. Thus, if we focus on the agri-food sector, farmers must identify and assess, from a strategic perspective, which are the resources and capabilities they need that, when used efficiently and combined properly, make the likelihood of success of the development and implementation of sustainable practices further increased.

Resources are the stocks of tangible and intangible assets available (Barney & Hesterly, 2012). In particular, within the scope of this project, tangible resources refer to land, machineries, plants, distribution networks, proximity of the location to inputs and markets, financial resources, information technology infrastructure, trucks, vehicles, and raw materials, to name a few examples. These assets add economic value to the farm by facilitating the production and distribution of products in an efficient and cost-effective way (Barney et al., 2011). Intangible resources connote the non-physical resources or assets that a firm has its disposal (Barney et al., 2011). In this case, they include the knowledge, experience, motivation, commitment, etc., that workers put at the disposal of the farm and the landowner as well as the production processes and other technologies needed to manage the farm.

Capabilities are the abilities used by firms to identify and transform resources in order to achieve a particular result (Aghazadeh & Zandi, 2022). Thus, some examples of capabilities can be the abilities of farms' owners, managers, family members and employees to manage farms in a more sustainable and innovative way. It implies the ability to identify changes in the environment and deal with them as fast and flexible as possible while taking advantage of the opportunities that the environment provides (e.g., further development of sustainable production technology) and minimizing the effects of threats (e.g., water resource depletion).

The extended Resource-Based View (Barney, 2001; Lavie, 2006) states that resources might be derived from external sources, but more specifically they might come from interrelations with other firms or agents. This led us to talk about the next SIF stage (implementation) and the main theory in which it is mostly based, i.e., Stakeholders Theory. These issues will be dealt with in the following section.

3.1.3. Implementation

Stakeholders are broadly defined as "*any group or individual who can affect or is affected by the achievement of the organization's objectives*" (Freeman 1984, p. 46). Firms' interaction with stakeholders play a central role within their corporate strategy (Dentoni & Peterson, 2011) since stakeholders' engagement influences the economic, social and environmental value of a firm in the medium- and long-term (Kassinis & Vafeas, 2006; Werther & Chandler, 2011). Thus, it is important that managers consider the whole stakeholders' network in which their firms are embedded (Rowley, 1997), as they can have an influence in key aspects related to their business management such as the decision-making process, target setting or implementation strategies, among others. For that reason, many firms establish lasting alliances with their stakeholders (Dentoni & Peterson, 2011).

This firm-stakeholder relationship is found in any sector of activity and, therefore, it also takes places in the agri-food sector. The development and implementation of sustainable production practices in agri-food sector require the engagement of all farms' stakeholders (i.e. internal and external) to reap the benefits. The establishment of "common sense" (Ferraro & Beunza, 2018) will be a key issue to take into account in order to get such coordination across both internal and external farms' stakeholders, which might have different understandings and desired outcomes (Nygaard et al., 2021) and they might use different mechanisms to influence the adoption of sustainable practices (Haleem et al., 2022). Only in this way, through active communication and coordination between both parties (farmer – stakeholders), farmers will be able to develop and implement sustainable production practices that are truly mutually beneficial and more likely to succeed.

Internal stakeholders, i.e., those who are part of the farm itself (e.g., owners, managers, family members and employees), are crucial and fundamental to the development and implementation of sustainable production practices (Meixell & Luoma, 2015). It is important that owners and managers are sustainability-oriented and embrace sustainability in its TBL. Moreover, they might have the ability to manage efficiently the resources and capabilities needed to undertake these practices and the know-how to transmit, share, and pass on these values to other farm's members (family and employees) to achieve their involvement and commitment with this process (Sarkis et al., 2011). All of these internal stakeholders are undoubtedly key players in the development and implementation of sustainable production practices.

Equally important is the engagement of farm's external stakeholders (e.g., suppliers, customers, associations, technical advisors, government, local community and environment), those who are not directly part of the farm but who are in some way related to it and its activities (Delmas, 2001). These stakeholders may also play a role in the development and implementation of sustainable production practices (Delmas & Toffel, 2004). For example, this kind of processes could not be carried out without a stable, long-lasting and trusting relationship with suppliers, who provide the raw materials and other supplies needed to carry out the production process. Similarly, it would not be possible without customers who value products resulting from these sustainable production practices and they are willing to buy them. It is also important the involvement of the local community and the existence of associations and institutions that support farmers (through advice, expertise, financial resources, etc.) as well as the existence of infrastructures and other elements that make it easier for farmers to implement sustainable practices.

3.1.4. Evaluation

Once farmers have implemented the previously selected sustainable production practices, it is essential to monitor them by performing an evaluation stage. The main purpose of this stage is to assess the impact that these sustainable practices might have in the crops from a TBL (economic, social and environmental) through a set of KPIs, in this case, 16, which have been developed from the literature and adapted specifically to this project. These KPIs and the methodology used to develop them are describe in the following section (Chapter 4).

At this point, it is important to highlight two issues. Firstly, this SIF should not be considered as a rigid linear framework where the four stages mentioned above (definition, decision, implementation, and evaluation) take place consecutively and in which the evaluation is the last of them. On the contrary, it should be understood as an iterative, flexible and adaptable SIF where there is a feedback process as the information that emerges from each of these phases helps to improve and enhance the SIF as a whole. Secondly, it should be noted that the evaluation stage does not necessarily to be performed only after the implementation stage, as it can be seen in Figure 3.1. Optional, but recommended in many cases, a mid-term evaluation could be carried out during the implementation stage, which allows the farm owner/manager to be aware of how the process is going and whether it might need to be redirected.

3.2. SIF development methodology

To develop the SIF framework as a baseline of the current project, a mix of the insights from the state-of-the-art literature as well as experts' own knowledge and experiences were used. Afterwards, a general overview of the literature review carried out and the SIF development with the experts is described.

As it has been stated in sub-section 3.1 (The SIF Theoretical Framework), the overall research process began with a *state-of-the-art literature review*. In this sense, the first and most important level of search was aimed to explore theories, tools, frameworks and other insights that could be used to develop the SIF. To do so, we rely on academic databases like Scopus or Google Scholar, and on different key words and combinations of them (singular, plural, synonyms, etc.) (a more detailed description was already shown in sub-section 3.1 "The SIF Theoretical Framework"). These literature searches generated articles related to sustainability itself as well as the theories that may explain why firms are intended to incorporate sustainable practices in their strategy definition and in their day-to-day decisions.

Moreover, grey literature such as European Union (EU) deliverables on similar topics (Evans et al., 2014) and surveying websites of leading organizations in sustainability (e.g., GRI, the Agenda 2030 from the United Nations -SDGs-, United Nations Environment Programme-Society of Environmental Toxicology and Chemistry Life Cycle Initiative or the Flint EU project), sustainable practices in the food sector (e.g., FAO), innovation institutes (e.g., the Hasso Plattner Institute) as well as some PhDs directly related to the project's aim like Sánchez Fernández (2009) provided additional insights. It is necessary to mention that this literature review helps us to carry out the first two stages of our SIF framework (definition and decision). In particular, and as it has been stated before, allows us to identify the main concepts employed and the theoretical background (institutional and signaling theory and farmers' behavioral factors, among others) when explain the drives of the adoption of sustainability decisions.

Secondly, search about the KPIs, i.e., the key tool that it is going to be used in the evaluation stage of the designed framework, was also carried out. The objective of these indicators is to characterize the current state, dynamics and trends of development in the future. Thus, the analysis of these indicators should ensure decision-making system, including justifying the optimal directions of investment in sustainability practices as well as the creation of conditions for sustainable development of the farm. In particular, the literature search was focused on its concept, its main characteristics, and previous examples of indicators in specialized literature related to our topic. It follows a similar procedure relying on academic databases (e.g., Scopus) and international organisms in order to deriving a meaningful list of KPIs to be interesting for the development of the measurement framework and to capture insights on how to aggregate the different indicators. Although in section 4.2 more specific information will be provided, it is necessary to mention that three main domains were identified: economic, social and environmental. As it has been stated before, this TBL is an accounting framework that includes social, environmental and financial results as bottom lines (Elkington, 1997). Businesses, non-profit and governmental entities use TBL to evaluate their financial gains, as well as their social and environmental impact. All this information will help to develop the last stage of our SIF framework, the evaluation itself.

Both literature reviews were performance since July to October 2022, and complemented with punctual searches in 2022 year autumn.

Regarding the *involvement of experts* in the development of the general SIF, *four* different steps or *rounds* were undertaken. The study of the factors that determine the sustainable development of the enterprise is very difficult, because it is influenced by many different conditions, most of which cannot be directly quantified by a certain indicator. Therefore, in order to systematize the factors and establish their importance for sustainable development in a particular enterprise, it should use a method that allows processing the materials of the logical analysis of factors and evaluation of their mutual influence. To do this, the method of expert evaluation/recommendations is important because it allows identifying the dominant factors on which to focus (Zinina & Olentsova, 2020). Thus, along with the literature review, it is optimal to develop the initial framework by listening to experts in the field as they can provide knowledge on complex, interdisciplinary issues which involve new or future trends (Akkermans et al., 2003; Meredith et al., 1989). In fact, academic literature in similar fields also relied upon expert knowledge – see for example Sauer & Seuring (2019) who studied sustainability in the mineral value chain, Bocken et al. (2013) and Geissdoerfer et al. (2016, 2017) who studied the business model innovation process, or Prosman et al. (2022) which offers a guide to agri-food value chain actors through the innovation process.

The next sections describe each single round carried out with experts in more detail in order to build the initial SIF.

- *Round 1*

On 21-22 July 2022 a KICK-OFF MEETING was held in León as a first meeting among all the partners involved in SUSTEMICROP. The sessions took place using a hybrid format: face-to-face meeting and on streaming for partners that were not able to travel to León. Thus, that meeting allows us to be familiar with certain baseline concepts of the project and its steps. Moreover, it was a good opportunity to share information with the rest of partners about how designing our SIF and to draft a questionnaire to contact with farmers. This questionnaire aimed to collect preliminary information about our pilot farmers and to build the KPIs. Thanks to the use of an online meeting it was possible to collect information from all partners. However, it is true that a major drawback of using an online meeting with several experts connected at once may be the difficulty to express themselves correctly and the less personal contact among participants also reduces the possibility of strengthening ties.

Thus, in our study the first sub-group of supporting people considered is the 'outsider experts', that is, those from firms, universities and research institutions that attended to the KICK-OFF-MEETING. All outsider experts have developed deep knowledge of sustainability through research and policy making. As shown in Table 3.1, the experts represent various European Mediterranean countries, in particular from the University of León (ULE), the French Wine and Vine Institut (IFV), National Research Institute for Agriculture, Food and Environment (INRAE), Slovenian Institute for Hop Research and Brewing (IHPS), National Research Institute of Water, Forest and Rural Engineering – University of Carthage (INRGREF), Agrogenia Biotech S.L. (AGBIO), HORTA S.R.L. (HORTA), Mohamed I University (UMP), Mohammed VI Polytechnic University (UM6P) and Lebanese University (LU).

Based on the literature review a presentation was given about the main elements and goals of the SIF, i.e., a framework that represents all the relevant variables and dynamic innovation processes allowing the farmers to become more sustainable through control of pathologies (soil-borne fungal pathogens) - composting biofertilizers- and formulation of new biopesticies based on essential oils. Besides, this first round encompassed the reminder of the three objectives regarding the SIF framework (the framework itself, the definition of economic, social and environmental indicators and the evaluation of farmer's level of sustainability performance). Next, the project partners were asked to confirm, add, criticize the key elements of the SIF, and specially, about the initial online questionnaire to collect information about farmers, its main characteristics and stakeholders.

- ***Round 2***

With the suggestions received in the previous meeting, the framework as well as the designed initial questionnaire was improved. In particular, this last one was sent to HORTA, trying to get an even more improved version receiving the point of view of this particular expert before sending to the farmers. In addition, two online meetings were held with HORTA in the second half of July 2022 to organize the KPIs content itself and the corresponding procedure.

In addition, at the beginning of September meetings with colleagues from our own university who are familiar with corporate social responsibility issues also provided us useful ideas about the framework itself and the KPIs development.

Table 3.1. Outsiders experts involved in the SIF development

Type	Country (Institution)	Number of Experts
University	Spain (ULE)	1
Research Organization	France (IFV)	3
Research Organization	France (INRAE)	2
Research Organization	Slovenia (IHPS)	1
University	Tunisia (INRGREF)	1
Small Medium Enterprise	Spain (AGBIO)	1
Small Medium Enterprise	Italy (HORTA)	1
University	Morocco (UPM)	2
University	Morocco (UM6P)	1
University	Lebanon (LU)	1

- ***Round 3***

Another supporting subgroup is the people working in the agricultural activity (e.g., farmers, employees or technical officers) who are involved in implementing sustainability practices in their respective businesses. Thus, a field survey was conducted in this research among agricultural producers. For the successful conduction of the survey the questionnaire was sent to the coordinator of each WP and these partners collected the necessary information and sent to us. For example, issues such as farmer general information (assets, employees), type of crops and crop operation during the cropping season were asked. However, the key aspect of this questionnaire were related to the type of treatment and the timing for its application in order to design when the sustainability assessments after and before the treatment are going to be carried out in the evaluation stage. In addition, general information about the farmer's stakeholders was also asked in order to include KPIs related to all of them, especially in what concern to social indicators.

This information from people from the agricultural activity itself as well as the literature review performance may be useful to guide farmers and stakeholders in the implementation stage.

In particular, regarding the treatment applied in WP2 we received two filed questionnaires from Slovenia (hop crop), one questionnaire from Spain for each crop (hop and grape vine), and 17 questionnaires from Morocco. In addition, one filled questionnaire from France (INRAE/IFV) (grape vine) and another from Lebanon were sent to us (table grape). No information was received on the treatment applied to WP3, as this treatment will be tested in vitro instead of in commercial farms.

On the other hand, after the information shared with our university colleagues, the research team consolidated the individual contributions into a focus group to improve the overall framework used in this initial SIF.

- ***Round 4***

In this last stage, the theoretical framework was obtained and written thanks to all the literature review, the suggestions received from the project partners as well as from colleagues at our university and the general information about the pilot farmers. SIF was performed and checked in collaboration with HORTA who enriched it with her point of views, experience and knowledge, mainly in the sustainability environmental dimension. In addition, a composition of a set of indicators from economic, social, and environmental sustainability, identifying their characteristics also was established; this allows us to undertake the evaluation stage of our SIF framework.

- ***Round 5***

It is necessary to mention that in this final version (dated to October 2024) some additional improvements were carried out in collaboration with HORTA to define and reduce the final list of KPIs after the feedback and suggestions received during the presentation and defense of the Mid-term technical report in May 2024.

3.3. Measurement framework methodology

The measurement framework proposed in this Deliverable 1.2 (D.1.2.) is designed to be used for farmers interested in the implementation of different sustainable practices. Thus, their main objective is to guide agri-food actors to rebalance their sustainable practices and enhance its sustainability (economic, environmental and social) through bio-fertilizers, bio-pesticides and more resistance plants. These sustainable practices can be complemented with other agricultural innovations. In this deliverable, not only the farmer is the focus, but also its surrounding ecosystem is taken into account in order to optimize all possible relationships and to enhance farmer's sustainable performance. Moreover, although this framework was developed for the pilot farmers included in the project, we create this SIF with the aim of capture other sustainable practices in the sector and help farmers to take sustainable decisions and oriented them in the process.

The measurement framework proposed was composed by four stages (definition, decision, implementation and evaluation [ex-post]) and one optional phase (evaluation [ex-ante]). In this project, we created this SIF following the methodology described above. As it has been stated before, this SIF was also complemented by a set of KPIs for economic, social, and environmental performance that will be described deeply in Chapter 4.

Although this study integrates the measurement framework within the SIF for the farmers that participate in SUSTEMICROP, the development of the measurement framework itself for external farmers – i.e., which KPIs should be included – should be reformulated by an expert specialized on the crop.

While the stages proposed in our SIF can be implemented immediately by other farmers outside the scope of the project, KPIs will require an adaptation as the development methodology should be different for farmers included in the project and others farmers. In particular, the first two stages of our SIF (definition and decision) are defined for pilot farmers because each of them knows the crop selected and the sustainable practices that will be implemented in their farms. However, those farmers beyond the scope of the current project that may be interested in using the SIF to evaluate their sustainable performance will have to define and decide the optimal sustainable practices for its crop and farm. The implementation stage will be very similar for pilot farmers and future pilot farmers. Nevertheless, the type of crop will be determinant to implement the KPIs developed in this project. Finally, for the evaluation stage farmers can follow the guidelines proposed in Chapter 5. However, these guidelines would need again to be reestructured according to the crop in which the treatment or sustainable practices are applied to offer a good evaluation to the farmers.

The SIF development moves from a theoretical and conceptual SIF based on current literature and current understandings (i.e., the initial SIF presented in this deliverable) towards a consolidated and validated SIF for application outside of the SUSTEMICROP project. As such, the SIF development follows two stages: the initial SIF (current deliverable D1.2: SIF description and guidelines – M6) and the final consolidated SIF (deliverable D5.3: Report on the sustainability evaluation in the TCS – M36).

The initial SIF is based upon a literature review and integrates key aspects of existing framework into a comprehensive tool validated through a review process with experts. The initial SIF also includes guidelines to support the Pilot farmers in the adoption of the framework in Chapter 5. The final consolidated SIF is built upon the initial SIF and it integrates the results of the continuous co-creation process with the KPIs and provides a very practice-oriented approach. The evidence coming from the application of the SIF and the work performed in the other WPs (especially in WP5 and WP6) are the main resources to further improve and refine the initial SIF.

In WP5 a tool that allows farmers to evaluate their sustainable performance will be designed. In a first stage, we are planning to evaluate farmers included in the project but, in the future, the idea is also to provide a tool for whoever farmer interesting in measure its own sustainable performance. At the same time, in WP6 we present the pilot farmers that will be evaluated following this framework.

3.4. Relation to other activities in the project

The SIF described in this document represents the core approach of SUSTEMICROP and it comprehensively integrates the different tools and methodologies developed within the project. Therefore, the SIF development is very closely connected with most of the activities of the project providing inputs for the continuous refinement of the SIF. Figure 3.2 depicts the connection between the different activities grouped according to WPs.

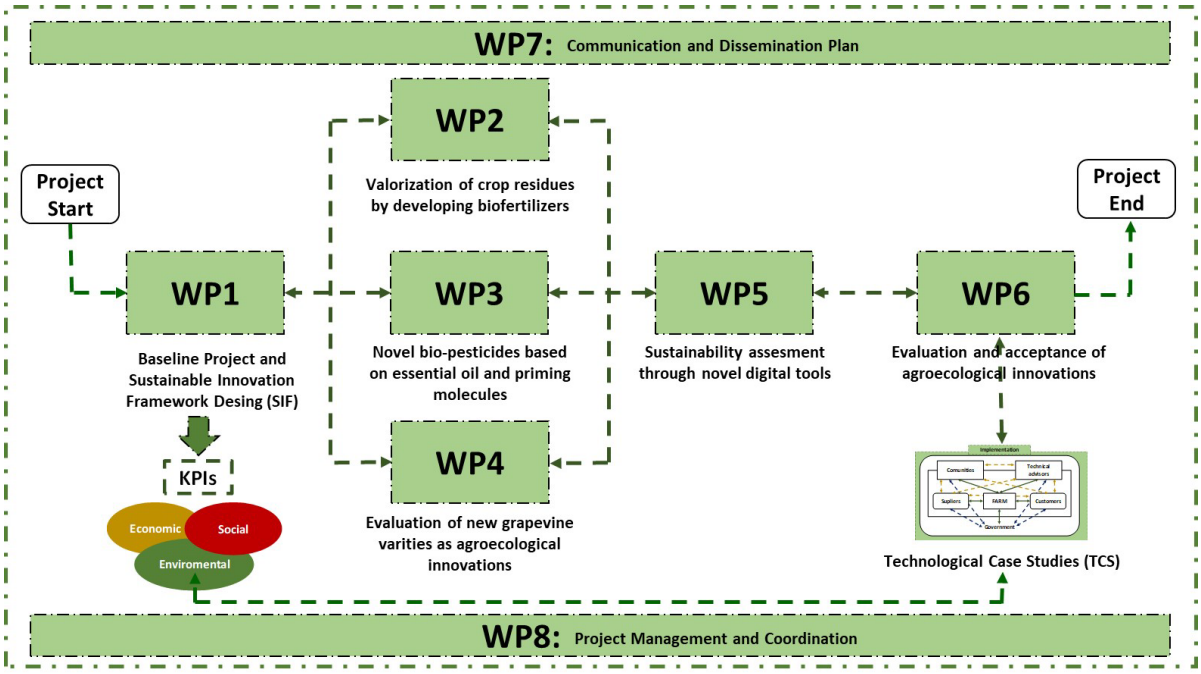

Figure 3.2. Connection between the SIF and other activities within the SUSTEMICROP project

The SIF development is performed in WP1 (Project Baseline and Sustainable Innovation Framework). Given the collaborative nature of the SIF development process, it means that a continuous coordination and alignment with the other WPs is and will be carried out. Coordination with HORTA (WP5 leaders) is especially important for the development of Tasks 1.2 (SIF Design) and Tasks 1.3 (Developing a KPI monitoring tool guideline).

Similarly, it is also important to highlight the coordination with other WPs. For example, great part of the information needed to build the initial SIF and their measurement tool – KPIs – (e.g., information regarding to the main farm's stakeholders, different phases of crops involved in the project, characteristics of the harvests, etc.), is obtained from the WP2 "Valorization of Crop Residues by Developing Biofertilizers", WP3 "Novel Bio-Pesticides Based on Essential Oil and Priming Molecules", and WP4 "Evaluation of New Grapevine Varieties as Agro-ecological Innovation".

As it was mentioned before, an intense coordination with the WP5 on Sustainability Assessment through Novel Digital Tools is also carried out. It is because this WP focuses on two main tasks: *1)* the operationalization of the KPIs (provided by WP1 through Tasks 1.2 and 1.3) by developing an online tool (Task 5.1), and *2)* the assessment on the sustainability of the project TCS (Task 5.2.)

There is also a close coordination with the WP on Evaluation and Acceptance of Agro-ecological Innovations (WP6), in which the economic, social and environmental sustainability assessment (KPIs set in WP1) of target crops and agro-ecological innovations from WP2, WP3, WP4 should be performed. This coordination task between WP1 and WP6 is carried out to ensure that the SIF effectively guides and supports the TCS.

Eventually, the suggested SIF is also promoted through the Communication and Dissemination Plan (WP7) that aims at maximizing the impact of results achieved through know-how transfer to a wider audience thus ensuring a broad adoption of the tool also beyond this project scope.

Finally, there is an obvious connection between the SIF and Project Management (WP8), which is in charge of providing the resources and managing the relevant issues (e.g. administrative, financial and legal management, scientific coordination and innovation management) needed to carry out the process successfully.

4. Key Performance Indicators (KPIs)

4.1. Concept

The measurement framework proposed in the current project consists of a set of KPIs for economic, social, and environmental performance. It is developed from the most widely used frameworks for assessing the sustainability performance (e.g., the SDGs and the GRI) with tailor-made adaption to encompass the specificities of each use case. As such, and it has been stated in the 3.1 section, the measurement framework helps both in understanding the problem as well as in evaluating sustainability practices along with the development and implementation stages.

From a conceptual point of view, a KPI is a metric, measuring how well an organization or an individual performs an operational, tactical or strategic activity that is critical for the current and future success of the organization (Kerzner, 2011). Similarly, according to the KPI Institute (2022), a KPI is a measurable expression for the achievement of a desired level of results in an area relevant to the evaluated entity's activity. It is a quantifiable measure of performance over time for a specific objective, providing targets for teams to shoot for, milestones to gauge progress, and insights that help people across the organization make better decisions. In this sense, the use of KPIs allows stakeholders to measure the progress towards a stated goal (Kerzner, 2011).

As it is stated in Dominguez et al. (2019), KPIs can be used with several purposes that can be classified in two groups taking into account whether their aim is to evaluate the performance (past or present –Pintzos et a., 2012) of a monitored system, or to predict the future behavior of a system. It must be noted that these two purposes are not exclusive, so that the same KPIs can be used for evaluation and prediction. Specifically, in the context of the current project, the use of KPIs is a method that may help to monitor the impact of farm activity in terms of sustainability (economic, social and environmental). By using KPIs, every farm owner will be aware of its positive impact on the environment or society as a whole and the damage it may cause. As a result, in the agricultural sector, KPIs may help increase productivity and profitability, help manage daily operations, contribute to informed business decisions and to improve the relationships with its stakeholders (The KPI Institute, 2022).

When analyzing KPIs, it is necessary to consider the different perspectives under which performance measures are proposed, the reasons or rationale why an indicator has to be defined must be exposed, and, finally, the scope should be taken into account in each case.

Regarding performance measurement perspectives, there is a variety of existing approaches. Among others and according to Looy & Shafagatova (2016), four criteria used for perspective definition can be mentioned: domain, focus, target groups and organizational level. The domain criterion is related with the strategic context in which performance measures are positioned (Neely et al., 1995). An example of the second criterion (focus) can be the differentiation between drivers and outcomes. The third criterion is the target group, differentiating among shareholders and top management, costumer, supplier, society, environment and employees. The fourth criterion is the organizational level in which the KPI is defined. For example, this criterion is used by Estampe et al. (2013) differentiating three perspectives: strategic, tactical or operational.

The rationale of a KPI is the description of the reasons why it is necessary to define the performance measure (Livieri et al., 2014). As far as scope is concerned, it can be understood in two different senses. A priori, it is possible to consider the definition of generic KPIs (i.e., transversal to different contexts) although it is common that they are usually defined to be used in more specific ways. On the other hand, the scope of the KPIs can also be focused only on specific areas of KPIs application (Dominguez et al., 2019).

In addition, in order to define and develop a specific KPI, there are different features that can be considered. These properties range from basic characteristics, to calculation aspects, through related human resources and relationship aspects among KPIs. Next, a general overview of these general KPI characteristics is described.

The diversity of KPI definition proposals is manifested in the few properties that can be considered *basic characteristics*, present in many approaches, such as the KPI identifier, its name, and its textual description provided in the natural language. The *features* that have to do with *calculation* are, in practice, the most important because they are the ones that really provide the indicator with its intrinsic nature. The following features can be considered (Dominguez et al., 2019):

- Hardness. The hardness of a KPI is related to its subjective or objective nature. As described in Popova & Sharpanskykh (2010), an indicator is soft whether it is not directly measurable, qualitative, e.g., customer's satisfaction, and it is hard whether it is measurable, quantitative, e.g., number of customers.

- Calculation rule. It refers to the specific formula that gives rise to the calculation (Schutz & Schrefl, 2014).

- Value type. Especially in KPIs of quantitative type, it is necessary to specify the type of data in which the KPI is expressed (integer, double, date time, etc.) (Castellanos et al., 2005), together with the unit of measure (percentage, units of weight, length, currency, etc.)

- Filter. In many cases a KPI may be accompanied by one or more conditions that play the role of filter (Diamantini et al., 2014). For example, if a KPI can be calculated following a time-line, the KPI could be filtered so that its values are obtained only for a fragment of that time-line.

- Target. Since the use of a KPI is ultimately linked to the achievement of a particular business goal, the relationship of a KPI with an associated target value is also present in many approaches (Popova & Sharpanskykh 2010; Stefanovic, 2014). This value can be presented in an absolute form or in a range form, even with the specification of a deviation range or threshold (Friedenstab et al., 2012; Pintzos et al., 2012). As stated in works such as Popova & Sharpanskykh (2010), when a KPI runs out of a value range, actions to be carried out can be specified.

- Status options. The range of values of a KPI can be divided into several intervals, so that each interval represents a status with a particular meaning (for example, in Letrache et al. (2016) three statuses are differentiated –good, acceptable and bad– represented by means of traffic lights).

- Source. The source of a KPI refers to the entities, their relationships, and data and properties that are required to compute a KPI (Matthes et al., 2012). This information can be stored in databases, repositories, files, and other sources.

- Computation. The computation of a KPI refers to the way in which it is calculated.

- Measured aspects. KPIs can also be categorized according to the concrete aspect being measured. It is often possible to indicate at this level whether it is an indicator that measures duration, frequency, fulfillment of a certain condition, object's property, resource, cost, quality, etc. (Friedenstab et al., 2012; Korherr & List, 2006).

Another aspect to take into account is that when developed KPIs, there are different people, roles or even departments within an organization involved in their development (*related human resources*). For example, the owner can be considered, that is, a stakeholder in the enterprise responsible for the achievement of a defined KPIs (Matthes et al., 2012); the responsible person, referring the one who is in charge of the indicator being calculated (Del Rio-Ortega et al., 2013); and the informed person, that is, who is interested in the KPI and should be informed of its results (Del Rio-Ortega et al., 2013). Finally, it is necessary to state that dependencies between KPIs (*relationships*) can be explicitly specified representing, for example, the components used in the computation formula (Diamantini et al., 2014). This kind of relationships among components can lead to basic KPIs, compound or derived KPIs (such as the sum or the ratio of two existing indicators) or aggregated KPIs (for example, the average of other indicators).

4.2. Methodology to build the KPIs

According to the aim of this deliverable, that is, to design a SIF to evaluate SUSTEMICROP practices and innovations applied in the key Mediterranean crops (hop, date palm, grape vine, and table vine) and their context, with aggregated indicators, KPIs belonging to the economic, social and environmental domains have been analyzed and, more specifically, those that may be more justified according to above general aim. Regarding people involved in the development of KPIs, three researchers from ULE took part in the design and development of them, in collaboration with researchers from HORTA. In addition, as it was mentioned in section 3.2, the information and feedback from other project partners were also useful in the initial stage of the design.

The following paragraphs present the methodology behind the development of the measurement framework, i.e., which KPIs should be included in the third stage of the SIF developed in order to assess the farm sustainable performance. For that, two steps are followed: *1)* Building an exhaustive set of KPIs, and *2)* Construct a summarized, structured and complete set of KPIs with detail information of each of them.

In the first step, the aim is to obtain an exhaustive overview of possible KPIs to measure sustainable performance. To do so, we critically analyzed academic and practice literature as well as internationally recognized standards and assessments focused on measuring economic, social and environmental performance. Although in this initial search we did not limit ourselves to the agricultural context, specific literature in this context took priority. Economic indicators or metrics that will formed each KPI include proxies for the organization's impact on resources mainly at the shareholder level. Social indicators or metrics deal with labour practices, human rights and broader social issues affecting a broad range of stakeholders.

Environmental indicators deal with the measurement of an organization's impact on the environment via its products and services and its activities (Hřebíček et al., 2012).

To do so, we relied upon Google Scholar, Scopus academic database as well as Science Direct where we entered keywords such as "sustainability indicators", "sustainability assessment", "sustainable performance", "economic indicators", "social indicators", "environmental indicators", "sustainable KPIs", "economic KPIs", "social KPIs", "environmental KPIs", in combination with "agricultural sector", "agriculture", and "farming". The keywords included several variations of original keywords, for example singular and plural variations, synonyms, and combinations of keywords; searches in different languages like English, Spanish and Italian were carried out. This literature searches generated articles which provided useful information about how to measure sustainable performance in the agricultural sector. Moreover, websites of leading organizations in sustainability (e.g., GRI), sustainability in the food sector (e.g., FAO) or specific PhD thesis in the field like Sánchez Fernández (2009) were also checked. This search derives in a total of 70 documents.

Each of these documents was checked in detail in order to identify different ways of measure economic, social and environmental agricultural sustainability. Thus, we first grouped the indicators under the three sustainability domains of the TBL: economic, social and environmental indicators. It is necessary to mention that although there might be overlap between indicators and the domain to each belongs, the indicators are grouped under the most direct impact. In addition, in those cases when similar indicators were shown in more than one paper we grouped them together. As a result, we derived a set of 326 potentially relevant and sustainable indicators (125 economic indicators, 162 social indicators and 39 environmental indicators).

In the second step, we tried to structure the 326 indicators into a condensed but complete set of KPIs following a three-step approach. Starting from the three sustainability domains, we then coded the themes of the KPIs to obtain further structure. As the majority of economic and environmental indicators may only have the farm itself and/or the shareholders/owner as targets, in this type of indicators the theme was considered as a first reference level of analysis. In what concerns to social indicators, stakeholders-related issues were considered, that is, in a first level several stakeholders (both internal and external) who the farm may have a relationship with were identified and then themes for each of them were coded. The literature reviewed showed that several stakeholders may be affected by the farm social commitment and practices, and for this reason social indicators were grouped in this double level (stakeholders and theme). It is also necessary to mention that in economic and social KPIs some filters were applied as some indicators were considered so general or difficult to apply to our context, keeping also those more frequently employed in previous literature. As for environmental indicators, the selection builds up on the work carried out by HORTA in the previous EU-funded projects PURE and INNOVINE. In that context, for this dimension a set of 20 sustainability indicators concerning vineyard management practices were developed, with the final purpose of assessing impacts of the grape production. The indicator system was developed based on the relevant literature, which was retrieved through a systematic literature review. Methods retrieved in the literature were analyzed and selected based on the scientific relevance and their previous use in different contexts, and they were adapted to be calculated for each vineyard as a component of the Decision Support System for sustainable viticulture; simplicity and need of few, easily to determine inputs were relevant criteria for the indicator selection. To complement this first set of indicators, European guidelines for monitoring the environmental impact of activities were reviewed, and indicators derived from the Product Environmental Footprint (PEF) guide were added to the initial set (Manfredi et al., 2012).

KPIs were created from the indicators mentioned above. These were grouped thematically and weighted according to the characteristics of each KPI. For each KPI, indicators or metrics were weighted according to previous experience and literature on this topic, calculating a numerical value for each KPI in a scale from 0 (more sustainable) to 5 (less sustainable). We created 16 KPIs that collected the economic, social and environmental effect after sustainable practices implemented. Specifically, 4 economic KPIs, 6 social KPIs, and 6 environmental KPIs were created.

To increase the internal validity of the condensed and structured set of KPIs, some of the phases were carried out in pairs and another researcher was on charge of checking the work done and solved doubts and inconsistencies. Anyway, inconsistencies between the researchers were discussed until consensus was reached. Finally, we derived a hierarchical structure (i.e., the KPIs tree) which is consistent with some notable frameworks adopted for the measurement of different types of performance dimensions (e.g., SCOR framework by the Supply Chain Council) and it is coherent with the structure of several sustainable performance frameworks (e.g., SLCA and SAFA).

For each KPI its *basic characteristics* were described (identifier, name, and its textual description). Regarding *calculation features*, in general terms, the scheme presented in section 4.1 was followed. In this sense, both hard and soft variables have been proposed as in some cases the indicator has a qualitative nature (e.g., the assessment if the inter-generational continuation of farming activity is ensured, the intensity informal network with researchers, university, etc., or the quality of working conditions) while in other cases it is a measurable and quantitative variable (e.g., farm's sales revenue as percentage of the market total sales revenues of the municipality, the number of different crops cultivated in each farm apart from the target crops every year, or the proportion of production that is produced and sold according to certification schemes). In addition, the kind of data in which the KPI is expressed and its unit of measure are provided (e.g., local currency for economic variables, tonnes for mass production, percentage, or scales for the most subjective and qualitative measures, etc.). Specific formula that gives rise to the calculation is also showed when it is needed. In some cases, there is a relationship or dependency between some KPIs or the items used to build each of them. The target value or recommendation is also presented. As it has been stated in section 3.3, the computation itself of each indicator will be carried out using the novel digital tools that will be developed in WP5 thanks to the information that is going to be collected from the pilot farmers involved in the project.

4.3. Description of the KPIs

A set of 16 of indicators was derived from the initial analysis of the existing frameworks. To structure the KPIs, we grouped the KPIs under domain. As for the ***economic domain***, we proposed a set of 4 KPIs based on the issues categories according Warhust (2002) and Zahn et al. (2008):

- *Competitiveness* which is the capability of a firm to sustainably fulfill its double purpose, i.e., meeting customer requirements and obtain profits (10 metrics, e.g., market activity, market share, certifications, gross income short term, and future existence, among others).
- *Economic independence* which refers to the capability of the farmers to economically sustain their business over time (6 metrics, e.g., crop diversity, revenues diversity, and solvency, among others).

- *Financial and economic performance* (11 metrics, e.g., cost share, cost trend, market value, and digital technologies costs, among others).
- *Resource utilization* (12 metrics related productivity –economic performance that compares the amount of goods and services produced (output) with the number of inputs used to produce those goods and services– or efficiency –how well a farm can transform things like materials, labour and capital into services and products that produce revenue–). For example, R&D investments, green economy, and labour or land productivity, among others.

In Table 4.1, it can be seen a summary of the four economic KPIs and the number of metrics and themes or issues addressed in each of them.

Table 4.1. General overview of Economic KPIs

N	KPI	Number of metrics	Themes or Issue-categories addressed
1	Competitiveness	10	Market activity; Market share; Multifunctional agriculture; Certifications; Gross income short term trend; Gross income long term trend; Net income short term trend; Net income long term; Future existence; Balanced power in food chain
2	Independence	6	Crop diversity; Revenues diversity; Debt to equity, Liquidity; Solvency; Subsidy dependency
3	Financial and economic performance	11	Cots share; Costs trend; Labour costs trend; Price oscillation; Market value; Profitability long term; Profitability short term; EBITDA; Digital technologies; Digital technologies costs; Interest expenses
4	Resource utilization	12	R&D Investment; Investment; Green economy; Green transport; Green energy; Labour productivity; Land productivity; Risky practices; Pest control with BCA; Pest control with bio pesticides; Shift to green pest control; Effects to yields by green pest control

Under the ***social domain***, a set of 6 KPIs cover the effect on different stakeholders, which are the main actors impacted by the activities carried out by the farmers. Social KPIs therefore include aspects connected to eight stakeholders (farm itself, owner, employees, suppliers, customers, associations, local community and environment) and a total of 70 metrics addressed relevant themes or issues related with this social domain (Table 4.2).

Resilience of the farm include several items like farm future, farm owner's cultural level, its resilience to bad weather, the motivation of adopting eco-friendly tendencies, information related to suppliers (diversity, autonomy, local suppliers share, degree of stability of the relationship between the farmer and suppliers, frequency of obtaining the quality parameters required by the supply chain, frequency of obtaining satisfying yields), farm's commitment with sustainable practices to promote sustainable production, farm commitment with circular economy, interest on trying to reduce waste to a minimum, or commitment of a farm with the quality of landscape elements. *Networks'* refer to the stability of the relationship between the farmer and his/her suppliers, the intensity of the relationship between consumer and producer or to the number of professional organizations in which the farmer is involved, or how farm helps to improve its community in terms of education, working conditions, quality of life, among others.

Table 4.2 General overview of Social KPIs

N	KPI	Stakeholders involved	Number of metrics	Themes or Issue-categories addressed
1	Resilience	Owner, suppliers, customers, local community, environment	14	Farm future; Cultural level; Resilience to bad weather; Eco-friendly tendencies; Diversity suppliers; Autonomy suppliers; Local suppliers share; Customer loyalty; Food quality; Food quantity; Sustainability tendencies; Circular economy; Minimizing waste; Quality landscape
2	Network	Customers, associations, local community, firm, owner	15	Relationship supply chain; Professional organizations; Environmental/social organizations; Neighbors relationship; Research relationship; Community contribution; Social Commitment; Internal network; Support; Farmers associations; Farmers market power; KM0; Farm fair trade; Food chain fair trade; Labeled products
3	Management	Owner, employees	7	Education and training; Autonomy decision making; Law compliance; Human rights; Decision makers; Capacity development; Women in decision making
4	Inclusivity	Employees, local community	10	Family working hours; Diversity (age); Female; Gender wage differentials; Local jobs; Seasonal jobs; Local seasonal workers; Labour rights; Employees diversity; Accommodation temporary workers
5	Labour	Owner, employees, local community	12	Family farm income; Health risk; New jobs recently; New jobs last 5 years; Type contract; Working hours; Working intensity; Workers satisfaction training; Workers training; Absenteeism; Turnover; Workplace accidents frequency
6	Livelihood and well-being	Employees, owner	12	Wage; Wage magnitude; Wage range; Compensation & Benefits; Workers satisfaction standard of living; Quality of work; Freedom to quit; Freedom to discuss; Freedom to associate; Safety workplace; Quality of life satisfaction; Financial satisfaction

Management includes the percentage of the owner/employee's hours spent on improving his/her training, autonomy degree in the decision-making process, who makes decisions, or employees' possibilities to capacity development. *Inclusivity* considers different items related for example to the percentage of family working hours over total work performed, share of local works, share of seasonal (local) works, or safety facilities and high-quality accommodations for temporary workers, etc. *Labour* dimension considers the health risk for employees by pesticides and chemicals, job created in the last 12 months respect to the total employees, partial vs. total contracts, the number of working hours, level satisfaction for training and/or knowledge received, or hours lost due to absenteeism. Livelihood and Well-being category refers to the level satisfaction for standard of living and personal health or satisfaction in number of holiday/weekend worked/permits, employees' freedom to quit work or raise grievances without fear, how safe and clean workplace is, income of the lowest paid employees' respect to minimum wage, to mention some examples.

It is also worth mentioning that in this social domain (in the management and inclusivity items) a possible gender bias is taking into account as women seem to be more ethical and committed with corporate social responsibility and sustainability (Bear et al., 2010; Cabeza-García et al., 2018; Post et al., 2011) and their traditional participation in agriculture activities (Sign, 2014). Specifically, the percentage of women in decision making and female presence in the farm, and gender-based wage differentials between men and women's labour are taken into account when defined the KPIs.

Finally, in the ***environmental domain*** we consider the main environmental aspects affected by agricultural practices. By means of environmental indicators, it is possible to better understand the complex issues in the field of agriculture and environment, to show developments over time, and to provide quantitative information. This kind of indicators can also be the tools to analyze productive systems' sustainability, as they allow the comparison of the effects of the crop management on the environment and on human health. Different aspects can be investigated with agro-ecological indicators, starting from the nutrients management, fossil energy use, pesticides and fertilizers use, organic matter use, pollutants emissions in the natural environment, crop rotation, arriving to biodiversity and landscape assessment. The following environmental KPIs have been identified as more relevant and examples of the corresponding 20 metrics that address the main themes or issues on this matter.

- *Human Health:* 3 KPIs are available, evaluating the impact of farming activities on human health (human tox score, dose area index, and treatment frequency index).
- *Air:* 2 KPIs related to emissions in air are considered, such as, carbon footprint and carbon sequestration.
- *Soil:* 5 KPIs are available, aiming to evaluate the impact of farm on soil (e.g., organic matter, erosion, and soil coverage, among others).
- *Biodiversity:* 2 KPIs evaluating the impact of farming on biodiversity are considered, such as, biodiversity (land used-based) and eco tox score.
- *Energy:* 3 KPIs are available, evaluating the use of fuel and waste production during crop operations, such as, fuel use, renewable fuel, and waste.
- *Water:* 5 KPIs are available to evaluate the impact of farming activities on water (e.g., water footprint, water supply, and acidification, among others).

This kind of indicators can help to transform physical and monetary data about human activities and the state of the environment into decision supporting information, allowing the selection of more sustainable practices to be implemented in the field. In Table 4.3, it can be seen a summary of the 6 environmental KPIs and the number of metrics and themes or issues addressed in each of them.

Table 4.3. General overview of Environmental KPIs

N	KPI	Number of metrics	Themes or Issue-categories addressed
1	Human Health	3	Human tox score; Dose area index; Treatment frequency index
2	Air	2	Carbon footprint; Carbon sequestration
3	Soil	5	Ecological footprint; Organic matter; Soil coverage; Erosion; Soil compaction
4	Biodiversity	2	Biodiversity (land use-based); Eco tox score
5	Energy	3	Fuel use; Renewable fuel; Waste
6	Water	5	Water footprint; Water supply; Water use technical efficiency; Acidification; Eutrophication

Figure 4.1 shows the 'hierarchical structure of the KPIs measurement framework', including the organization in three main levels in the hierarchy

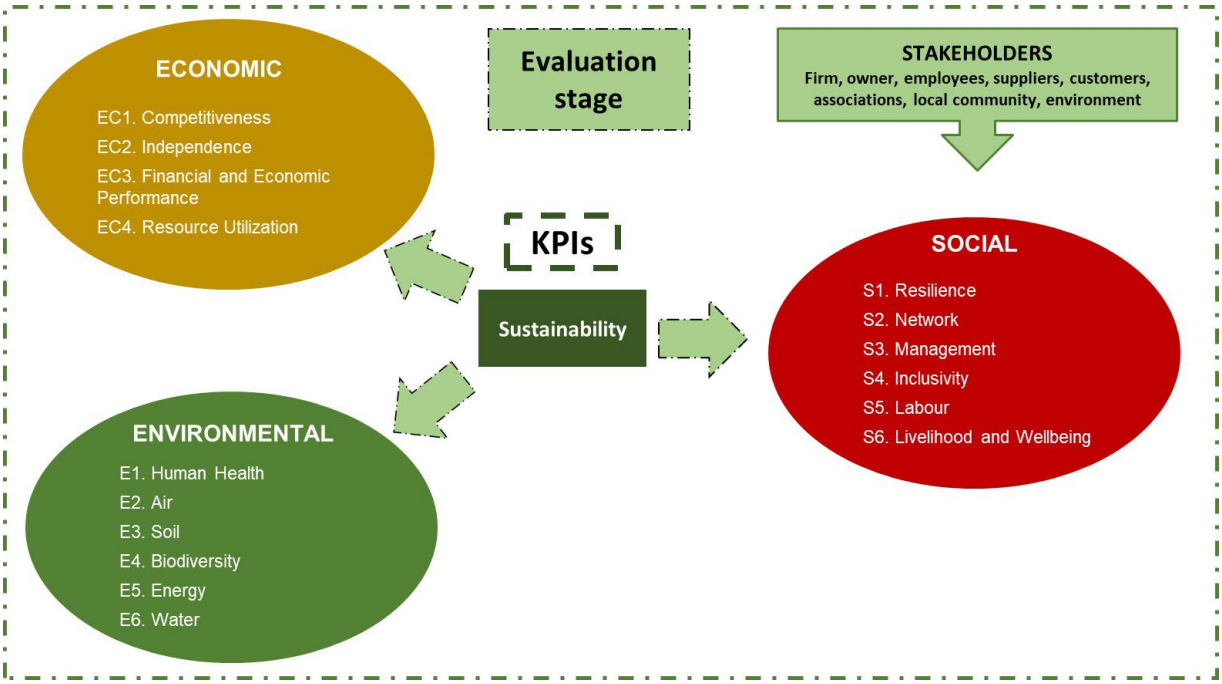

Figure 4.1. Measurement framework

In summary, Table 4.4, Table 4.5 and Table 4.6 list the KPIs belonging to each domain and metric are presented. It is enriched with the individual bibliographic sources from which we derived the metrics and the description of the KPIs. In some cases, the bibliographic references for metrics and description were refined according to the specific nature of our context where we kept in mind the goal to maintain a good balance between exhaustiveness and effort required for the measurability. The full set of economics, social and environmental KPIs including their description, goal and interpretation can be found in Appendix 1, 2 and 3, respectively. These KPIs will be used to measure the overall sustainability of the pilots considered in the project (WP6). In addition, based on these KPIs, a selection of the most suitable ones will be made to assess the sustainability of the TCS (WP5).

Table 4.4. Summary of Economic Indicators

ID	Domain	KPI	Metric	References
EC-1	Economic	Competitiveness	Market Activity	Adapted from Wrzaszcz & Zegar (2014)
EC-2	Economic	Competitiveness	Market Share	Singh et al. (2019); Wohlenberg et al. (2022)
EC-3	Economic	Competitiveness	Multifunctional Agriculture	Adapted from FAO (2014)
EC-4	Economic	Competitiveness	Certifications	Agency of Partnership for Progress (2010); BOCYL (2022); DOUE (2006); Rasmussen et al. (2017); United States Department of Agriculture (1955)
EC-5	Economic	Competitiveness	Gross Income Short Term Trend	Adapted from FAO (2014)
EC-6	Economic	Competitiveness	Gross Income Long Term Trend	Adapted from FAO (2014)
EC-7	Economic	Competitiveness	Net income Long Term Trend	Brandt & Geeson (2015); INSPIA (2022); Roy & Chan (2012); Smith & McDonald (1998); Talukder et al. (2020); Van Calker et al. (2004); Wohlenberg et al. (2022); Zhen & Routray (2003)
EC-8	Economic	Competitiveness	Net Income Short Term Trend	Brandt & Geeson (2015); INSPIA (2022); Roy & Chan (2012); Smith & McDonald (1998); Talukder et al. (2020); Van Calker et al. (2004); Wohlenberg et al. (2022); Zhen & Routray (2003)
EC-9	Economic	Competitiveness	Future Existence	Weiss (1999)
EC-10	Economic	Competitiveness	Balanced Power in Food Chain	Adapted from FAO (2014)
EC-11	Economic	Independence	Crop Diversity	Dantsis et al. (2010); Gómez-Limón & (2009); Wohlenberg et al. (2022); Zhen & Routray (2003)
EC-12	Economic	Independence	Revenues Diversity	Dos-Santos & Diz (2019); Rogelj et al. (2020); Sánchez Fernández (2009); Valkó et al. (2017); Wohlenberg et al. (2022)
EC-13	Economic	Independence	Debt to Equity	Nurmet (2011); Zawadzka et al. (2021)
EC-14	Economic	Independence	Liquidity	Business at Speed (2022)
EC-15	Economic	Independence	Solvency	Dos Santos & Ahmad (2020); Dos-Santos & Diz (2019)
EC-16	Economic	Independence	Subsidy Dependency	Sadok et al. (2009); Valkó et al. (2017)
EC-17	Economic	Financial and Economic Performance	Cost Share	Pellegrini et al. (2017); Tsolakis et al. (2018)
EC-18	Economic	Financial and Economic Performance	Costs Trend	Adapted from FAO (2014)
EC-19	Economic	Financial and Economic Performance	Labour Cost Trend	USDA (2023)
EC-20	Economic	Financial and Economic Performance	Price Oscillation	Santiago-Brown et al. (2015); Smith & McDonald (1998); Wohlenberg et al. (2022); Zhen & Routray (2003)

Table 4.4. Summary of Economic Indicators (Continued)

ID	Domain	KPI	Metric	References
EC-21	Economic	Financial and Economic Performance	Market Value	Santiago-Brown et al. (2015); Sarkar et al. (2021)
EC-22	Economic	Financial and Economic Performance	Profitability Long Term	Sánchez Fernández (2009); Santiago-Brown et al. (2015); Wohlenberg et al. (2022); Zhen & Routray (2003)
EC-23	Economic	Financial and Economic Performance	Profitability Short Term	Sadok et al. (2009); Wohlenberg et al. (2022)
EC-24	Economic	Financial and Economic Performance	EBITDA	Business at Speed (2022); Gómez-Limón & Riesgo (2009); Paternoster (2011)
EC-25	Economic	Financial and Economic Performance	Digital Technologies	Wolfert & Isakhanyan (2022)
EC-26	Economic	Financial and Economic Performance	Digital Technologies Costs	Pope & Sonka (2020)
EC-27	Economic	Financial and Economic Performance	Interest Expenses	Adapted from FAO (2014)
EC-28	Economic	Resource Utilization	R&D Investment	Adapted from Valkó et al. (2017)
EC-29	Economic	Resource Utilization	Investment	Gerdessen & Pascucci (2013)
EC-30	Economic	Resource Utilization	Green Economy	Aramyan et al. (2007)
EC-31	Economic	Resource Utilization	Green Transport	Lombardi & Berni (2021)
EC-32	Economic	Resource Utilization	Green Energy	Majeed et al. (2023)
EC-33	Economic	Resource Utilization	Labour Productivity	Adapted from Latruffe et al. (2016) and Valkó et al. (2017)
EC-34	Economic	Resource Utilization	Land Productivity	INSPIA (2022); Latruffe et al. (2016); Santiago-Brown et al. (2015); Sridhara et al. (2022); Talukder et al. (2020); Valkó et al. (2017)
EC-35	Economic	Resource Utilization	Risky Practices	Adapted from FAO (2014); Komarek et al. (2020)
EC-36	Economic	Resource Utilization	Pest Control with BCA	Palmieri et al. (2022)
EC-37	Economic	Resource Utilization	Pest Control with Biopesticides	Ayilara et al. (2023)
EC-38	Economic	Resource Utilization	Shift to Green Pest Control	EPRS | European Parliamentary Research Service (2021)
EC-39	Economic	Resource Utilization	Effects to Yields by Green Pest Control	Ali et al. (2019)

Table 4.5 Summary of Social Indicators

ID	Domain	Stakeholder	KPI	Metric	References
S-1	Social	General (firm)	Resilience	Farm Future	Reed & Courtney (2013); Röös et al. (2019); Van Cauwnbergh et al. (2007)
S-2	Social	Owner	Resilience	Cultural Level	Gerdessen & Pascucci (2013); Nambiar et al. (2001); Talukder et al. (2020); Van Cauwnbergh et al. (2007)
S-3	Social	General (firm)	Resilience	Resilience to Bad Weather	Diazabakana et al. (2014); Fourrié et al. (2013); Kelly et al. (2021)
S-4	Social	Owner	Resilience	Ecofriendly Tendencies	Fourrié et al. (2013); Kelly et al. (2021)
S-5	Social	Suppliers	Resilience	Diversity Suppliers	Röös et al. (2019); Talukder et al. (2020)
S-6	Social	Suppliers	Resilience	Autonomy Suppliers	Röös et al. (2019)
S-7	Social	Suppliers	Resilience	Local Supplies Share	GRI Standards (2016)
S-8	Social	Suppliers	Resilience	Customer Loyalty	Adapted from Al Shamsi et al. (2018) and Wohlenberg et al. (2022)
S-9	Social	Customers	Resilience	Food Quality	Agency of Partnership for Progress (2010); Aramyan et al. (2006); Santiago-Brown et al. (2015); United States Department of Agriculture (1955); Wohlenberg et al. (2022)
S-10	Social	Owner	Resilience	Food Quantity	Adapted from FAO (2014)
S-11	Social	Local Community	Resilience	Sustainability Tendencies	Rasmussen et al. (2017)
S-12	Social	Environment	Resilience	Circular Economy	Kelly et al. (2021); Röös et al. (2019); Zahm et al. (2008)
S-13	Social	Environment	Resilience	Minimizing Waste	Ramírez et al. (2008); Reglamento 396 (2005)
S-14	Social	Environment	Resilience	Quality of Landscape	Kelly et al. (2021); Röös et al. (2019); van Cauwenbergh et al. (2007); Zahm et al. (2008)
S-15	Social	Customers	Network	Relationship Supply Chain	Brennan et al. (2018); Ecolabel Index (2022); Kelly et al. (2021); Röös et al. (2019); Roy & Chan, (2012); Saifia & Drake (2008)
S-16	Social	Associations	Network	Professional Organizations	Diazabakana et al. (2014); Fourrié et al. (2013); Galdeano-Gómez et al. (2017); Kelly et al. (2021)
S-17	Social	Associations	Network	Environmental/ Social Organizations	Diazabakana et al. (2014); Fourrié et al. 2013; Kelly et al. (2021); Lebacq et al. (20213)
S-18	Social	Local Community	Network	Neighbors Relationships	Santiago-Brown et al. (2015)
S-19	Social	Associations	Network	Research Relationships	Diazabakana et al. (2014); Fourrié et al. (2013); Kelly et al. (2021)
S-20	Social	Local Community	Network	Community Contribution	Brennan et al. (2018); Kelly et al. (2021)

Table 4.5 Summary of Social Indicators (Continued)

ID	Domain	Stakeholder	KPI	Metric	References
S-21	Social	Local Community	Network	Social Commitment	Aparisi (n.d.); Diazabakana et al. (2014); Kelly et al. (2018); Kelly et al. (2021); Röös et al. (2019); Wohlenberg et al. (2022)
S-22	Social	General (firm)	Network	Internal Network	Röös et al. (2019)
S-23	Social	Owner	Network	Support	Fourrié et al. (2013); Kelly et al. (2018); Kelly et al. (2021); Rasmussen et al. (2017); Talukder et al. (2020)
S-24	Social	Associations	Network	Farmers Associations	Diazabakana et al. (2014); Fourrié et al. (2013); Kelly et al. (2021)
S-25	Social	Local Community	Network	Farmers Market Power	Kelly et al. (2018); Kelly et al. (2021); Reed & Courtney (2013); Wohlenberg et al. (2022); Zahm et al. (2008)
S-26	Social	Customers	Network	KM 0	Röös et al. (2019)
S-27	Social	Customers	Network	Farm Fair Trade	Röös et al. (2019)
S-28	Social	Customers/ Suppliers	Network	Food Chain Fair Trade	Brennan et al. (2018); Ecolabel Index (2022); GRI Standards (2016); Kelly et al. (2021); Röös et al. (2019); Roy & Chan (2012); Saifia & Drake (2008); Wohlenberg et al. (2022)
S-29	Social	Customers	Network	Labeled Products	Ingrassia et al. (2017)
S-30	Social	Owner	Management	Education and Training	Diazabakana et al. (2014); Fourrié et al. (2013); Kelly et al. (2018); Kelly et al. (2021); Talukder et al. (2020)
S-31	Social	Owner	Management	Autonomy Decision Making	Fourrié et al. (2013); Kelly et al. (2018); Kelly et al. (2021)
S-32	Social	Owner	Management	Law Compliance	Röös et al. (2019)
S-33	Social	Employees	Management	Human Rights	Röös et al. (2019)
S-34	Social	Owner	Management	Decision Makers	Diazabakana et al. (2014); Kelly et al. (2018); Kelly et al. (2021)
S-35	Social	Employees	Management	Capacity Development	Röös et al. (2019)
S-36	Social	Employees	Management	Women in Decision Making	Paternoster (2011); Talukder et al. (2020)
S-37	Social	Employees	Inclusivity	Family Working Hours	Dos Santos & Ahmad (2020); Dos-Santos & Diz (2019); El-Osta & Ahearn (1996)
S-38	Social	Employees	Inclusivity	Diversity (Age)	Gerdessen & Pascucci (2013)
S-39	Social	Employees	Inclusivity	Female	Paternoster (2011)
S-40	Social	Employees	Inclusivity	Gender Wage Differentials	Talukder et al. (2020)
S-41	Social	Local Community	Inclusivity	Local jobs	Fourrié et al. (2013); Kelly et al. (2021); Diazabakana et al. (2014)
S-42	Social	Local Community	Inclusivity	Seasonal jobs	Röös et al. (2019)
S-43	Social	Local Community	Inclusivity	Local Seasonal Workers	Röös et al. (2019)
S-44	Social	Employees	Inclusivity	Labour Rights	Röös et al. (2019)

Table 4.5 Summary of Social Indicators (Continued)

ID	Domain	Stakeholder	KPI	Metric	References
S-45	Social	Employees	Inclusivity	Employees Diversity	Röös et al. (2019)
S-46	Social	Employees	Inclusivity	Accommodation Temporary Workers	Röös et al. (2019)
S-47	Social	Owner	Labour	Family Farm Income	Dos Santos & Ahmad (2020); Dos-Santos & Diz (2019)
S-48	Social	Employees	Labour	Health Risk	Fourriè et al. (2013); Kelly et al. (2021)
S-49	Social	Employees	Labour	New Jobs Recently	Fourriè et al. (2013); Gómez-Limón & Riesgo (2009); Kelly et al. (2021); Mazuela (2017); Paternoster (2011); Sánchez Fernández (2009); Zahm et al. (2008)
S-50	Social	Local Community	Labour	New Jobs Last 5 years	Paternoster (2011); Röös et al. (2019)
S-51	Social	Local Community	Labour	Type Contract	Röös et al. (2019)
S-52	Social	Employees	Labour	Working Hours	Fourriè et al. (2013); Kelly et al. (2021); Lebacq et al. (2013); Röös et al. (2019)
S-53	Social	Employees	Labour	Working Intensity	Dantsis et al. (2010); Dos Santos & Ahmad (2020); Dos-Santos & Diz (2019); Eurofound (2016); Fourriè et al. (2013); Gómez-Limón & Riesgo (2009); Kelly et al. (2021); Mazuela (2017); Röös et al. (2019); Sánchez Fernández (2009); Umstätter et al. (2022); Zahm et al. (2008); Wohlenberg et al. (2022)
S-54	Social	Employees	Labour	Workers Satisfaction Training	Rasmussen et al. (2017); Wohlenberg et al. (2022)
S-55	Social	Employees	Labour	Workers Training	Diazabakana et al. (2014); Fourriè et al. (2013); Kelly et al. (2021); Röös et al. (2019); Talukder et al. (2020); Wohlenberg et al. (2022)
S-56	Social	Employees	Labour	Absenteeism	Husgafvel et al. (2015)
S-57	Social	Employees	Labour	Turnover	Bondarchuk et al. (2022)
S-58	Social	Employees	Labour	Workplace Accidents Frequency	Fourriè et al. (2013); Kelly et al. (2021)
S-59	Social	Employees	Livelihood and Well-Being	Wage	Röös et al. (2019); Zahm et al. (2008)
S-60	Social	Employees	Livelihood and Well-Being	Wage Magnitude	Briamonte et al. (2024)
S-61	Social	Employees	Livelihood and Well-Being	Wage Range	Adapted from FAO (2014); Carr (2023)
S-62	Social	Owner	Livelihood and Well-Being	Compensation & Benefits	Röös et al. (2019)

Table 4.5 Summary of Social Indicators (Continued)

ID	Domain	Stakeholder	KPI	Metric	References
S-63	Social	Employees	Livelihood and Well-Being	Workers Satisfaction and Standard of Living	Brown et al. (2021); Fourrië et al. (2013); Kelly et al. (2021); Röös et al. (2019); Santiago-Brown et al. (2015
S-64	Social	Employees	Livelihood and Well-Being	Quality of Work	Aparisi (n.d.); Business at Speed (2022); Kelly et al. (2018); Röös et al. (2019)
S-65	Social	Employees	Livelihood and Well-Being	Freedom to Quit	Röös et al. (2019)
S-66	Social	Employees	Livelihood and Well-Being	Freedom to Discuss	Röös et al. (2019)
S-67	Social	Employees	Livelihood and Well-Being	Freedom to Associate	Röös et al. (2019)
S-68	Social	Employees	Livelihood and Well-Being	Safety Workplace	Röös et al. (2019)
S-69	Social	Owner	Livelihood and Well-Being	Quality of Life Satisfaction	Brennan et al. (2018); Fourrië et al. (2013); Kelly et al. (2021); Röös et al. (2019)
S-70	Social	Owner	Livelihood and Well-Being	Financial Satisfaction	Röös et al. (2019)

Table 4.6. Summary of Environmental Indicators

ID	Domain	KPI	Metric	References
EN-1	Environmental	Health	Human Tox Score	Adam-Blondon et al. (2017)
EN-2	Environmental	Health	Dose Area Index	Adam-Blondon et al. (2017)
EN-3	Environmental	Health	Treatment Frequency Index	Adam-Blondon et al. (2017)
EN-4	Environmental	Air	Carbon Footprint	Adam-Blondon et al. (2017)
EN-5	Environmental	Air	Carbon Sequestration	Adam-Blondon et al. (2017)
EN-6	Environmental	Soil	Ecological Footprint	Adam-Blondon et al. (2017)
EN-7	Environmental	Soil	Organic Matter	Adam-Blondon et al. (2017)
EN-8	Environmental	Soil	Soil Coverage	Adam-Blondon et al. (2017)
EN-9	Environmental	Soil	Erosion	Adam-Blondon et al. (2017)
EN-10	Environmental	Soil	Soil Compaction	Adam-Blondon et al. (2017)
EN-11	Environmental	Biodiversity	Biodiversity (Land Use-Based)	Adam-Blondon et al. (2017)
EN-12	Environmental	Biodiversity	Eco Tox Score	Adam-Blondon et al. (2017)
EN-13	Environmental	Energy	Fuel Use	Adam-Blondon et al. (2017)
EN-14	Environmental	Energy	Renewable Fuel	Adam-Blondon et al. (2017)
EN-15	Environmental	Energy	Waste	Adam-Blondon et al. (2017)
EN-16	Environmental	Water	Water Footprint	Adam-Blondon et al. (2017)
EN-17	Environmental	Water	Water Supply	Adam-Blondon et al. (2017)
EN-18	Environmental	Water	Water Use Technical Efficiency	Adam-Blondon et al. (2017)
EN-19	Environmental	Water	Acidification	Adam-Blondon et al. (2017)
EN-20	Environmental	Water	Eutrophication	Adam-Blondon et al. (2017)

5. Sustainable Innovation Framework (SIF) Guideline

Figure 5.1 describes the sustainable innovation framework (SIF) presented in Chapters 3 and 4. Although this SIF will be initially implemented in the three crops analyzed in the SUSTEMICROP project, as it has been stated before, in the future it can be also implemented in other crops and farms.

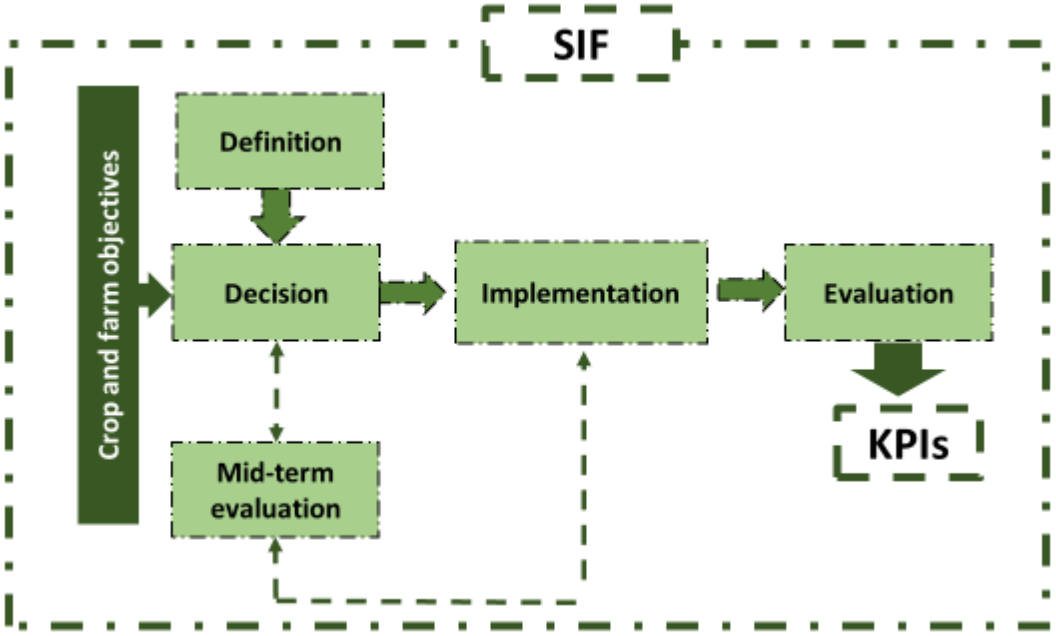

Figure 5.1. SIF stages

The SIF is composed of four main stages: definition, decision, implementation and evaluation. To implement sustainable practices into the firm it is necessary to consider previously a definition of all the sustainable practices that can be applied. From all of them, the firm would select those practices that are better aligned with farm objectives and those most relevant for the crop of the farm. In the implementation stage, two main elements should be considered. First, the firm and its internal stakeholders, that is, the family or owner of the farm, the manager/s, and the workers should be considered. In this phase, the firm should take into account its sustainability priorities (economic, social and environmental) into its decisions. Secondly, in this stage it is necessary to analyze the farm ecosystem, i.e., the relationships between the farm and their internal and external stakeholders. The relationships with the external stakeholder like suppliers and their customers are traditionally addressed in previous literature and explained in Chapter 3. Local communities and technical advisors are equally relevant for the farm but their relationship with other external stakeholders are limited because in most of the cases are unidirectional. In addition, in this implementation stage the role of government is important to carry out or not the implementation of these sustainable practices and because of its influence on other stakeholders. Finally, the KPIs allow the firm to evaluate their performance obtained through the sustainable practices implemented.

This evaluation considers the TBL perspective and measures the awareness of the farm with itself as well as with the rest of the agents from the ecosystem.

5.1. KPI Interpretation

Appendix 1, 2 and 3 show the KPI to provide guidelines to farmers directly involved or not in the project. In these charts, a specific section describes the interpretation of each indicator or at least a recommendation of the best values. However, as we previously mentioned, we provide several economic, social and environmental indicators that measured similar themes from different perspectives. To capture a valid value of each theme and to avoid biased results, we have proposed different indicators that can be joined in different KPIs and interpreted jointly.

Appendix 1 shows the economic indicators. Each economic KPIs contain the theme, description, metrics, interpretation and references. It can serve as a guideline for farmers and readers to use them.

***Competitiveness*:** In this economic KPI, we consider several proxies for the market activity, market share, total production, incomes, and the quality of the crop (certifications). The underlying justification is to assess the position of the farm in the market, its international outreach and if the farm offers high quality products. Overall, the recommendation would be that the farm should sell high quality products that allow the firm to capture the national, international market and high incomes, thus guarantying farms' future existence.

***Economic Independence*:** In this economic KPI, we analyzed some indicators such as farm diversification, or financial ratios like liquidity, solvency, or subsidy dependency. They provide information about the financial situation of the farm and its dependence (or not) from external sources of funding. In addition, we have also included a farm diversification indicator to analyze the main sources of farm incomes. In the optimal situation, farmers should obtain most of their income from agriculture activities. We also recommended focusing on one specific crop to become an expert on it, but diversification in different crops reduces risk. Moreover, the farm should not rely so much on subsidies and maintain a balance between internal and external finance.

***Financial and Economic performance*:** In this economic KPI, we analyze internal and external variables related to cost, prices and market values. All of them provide information about the profitability of the firm and the economic results of the farm. Although we consider mainly accountability indicators, farm reputation is also measured through market value and price. Overall, the recommendation would be that farms have lower production and general costs and higher income. In addition, it would be very positive for its financial situation to achieve a high market value and price because it would mean that the firm has good quality products and the people's opinion about the firm is positive.

***Resource utilization*:** This economic KPI is one of the most relevant to measure the economic situation of the farm and its level of innovation. It covers all the economic indicators associated with productivity and efficiency. Firstly, we try to capture the economic productivity of the farm in terms of land and labour. Secondly, we evaluate the capacity of the firm to produce more using fewer resources. Energy, labour, land, and assets are the resources considered to evaluate farm efficiency. Overall, the recommendation would be that farms should have greater values of productivity, which would mean that the farm is making many profits. At the same time, the farm should be efficient with its resources applied, not only because of the sustainable aspects but also because it means that the process of the farm is the right one. In addition, we analyze the capacity of the firm to explore new options in terms of new products, new processes, new organization methods, new assets, new research networks, etc. More specifically, we selected the firm investment on R&D and their investment in assets to improve processes, and the human capital investment. In the optimal situation, farms should invest large amounts (and be efficient with these

investments) in order to be at the forefront of new production methods, new machinery, new seeds, and to have agile, dynamic, and flexible human capital.

Appendix 2 provides a guideline for farmers about the social indicators. In this case, the theme is related to the stakeholder or target group. We will explain below each of them:

Resilience: Due to the complexity of the agricultural sector and the influence of macroeconomic policies because of the globalization of the sector, we consider this first social KPI. Resilience refers to the farms' ability to be able to perform its business activity both now and in the future while overcoming potential challenges, considering factors such as loss production due to bad weather or the easiness to access to inputs for cropping system. This KPI involved several relevant stakeholders such as the owner, suppliers, customers, local community and the environment. In this sense, our recommendation for the company is to be able to train one member of the family to have an heir that allows thus the continuation for farm's activity. This will allow them to continue working for the area and to develop the planned sustainable policies. In addition, a better educational prepared/qualified owner and implementing a policy that considers the fact of producing organically or sustainable production will increase the probability of firm resilience. It is also important to strengthen relationships both suppliers (for example, increasing the autonomy to choose the suppliers of local input sellers and the number of local suppliers) and customers (thorough a larger and better quality of production) as well with local community (for example, being more environmental committed reducing waste as minimum and protecting the landscape) in order to create solid networks that will allow the company to move forward stronger and safer. This will increase the farm's resilience in a sector so exposed to global changes.

Network: This social KPI captures the type and intensity of the relationship between the farm and both its internal (owner, family, employees) and external stakeholders (suppliers, customers, associations and local community). The company must be aware of the importance of establishing close relationships with agents along the whole supply chain to ensure the smooth running of its business activity. Thus, it implies proximity and cooperation with suppliers, consumers and other farmers to implement more sustainable practices, including producing by using local supplies, selling to local consumers and applying fair trade principles. In addition, farms should have and strengthen contact with technical associations and research centers because it allows introducing in the farm new developments and at the same time reinforcing the idea of group and their pressure with suppliers, governments and civil society. It is a 'cheap method' to be informed about new techniques, new seeds, etc. Moreover, farm´s commitment and contribution to local community (in terms of the improvement of education and working conditions, supporting agricultural training,...), its involvement on social activities (supporting and participating in local festivals, local farmer's markets and fair, local sport competitions, and other kind of local events) and its participation as a member of local/regional/national government is highly recommended to strengthen links, create a strong network and gain a fair position on the market to negotiate prices, quantities, etc. Finally, it is just as important for the company to establish and nurture these external relationships, as it is to create a good internal network in which the owner, family members and employees are on the wavelength with an involvement of all of them in the decision-making process. This also includes that the owner is willing to ask for and receive support and advice from the other members of the farm.

Management: The third social KPI focuses on the person in charge of managing the farm (and/or has the property) and the people who help him/her to do it. Thus, the main stakeholders involved are the owner and the employees. Some relevant issues included in this KPI address owner's personal characteristics such as its education and cultural level and its autonomy to take decisions. High levels of this characteristics are recommended, since having knowledge in agriculture, innovation and sustainability issues combine with high levels of freedom in the decision-making process that can help him/her to better achieve farms' objectives. This KPI also capture other relevant matters involve the owners and employees work conditions such as compliance with national laws in the agriculture sector, the respect of human rights conventions and agreements towards workers and the development and training opportunities for farm's employees. All these aspects must be carefully considered by the firm to ensure a good working environment that helps to improve motivation and productivity. Other important aspects to bear in mind should be the decision-making process and the person who oversees it. In this sense, we suggest that farm's decisions are made involving not only the owner and the management board, but also the workers, as this means including different points of view, some of them from people (employees) who are very connected to what happens on a day-to-day basis, which can provide more innovative solutions or ideas in terms of sustainability. We also think that it is interesting to include and/or reinforce the presence of women in the decision-making process, as they can bring different and interesting approaches and points of view.

Inclusivity: This social KPI refers to how farms take into account and manage several aspects related to age, gender, geographic origin, etc., regarding two of its main stakeholders, i.e., employees and local community. A balanced company in terms of age, which hires younger employees bringing new ideas and point of views and older employees bringing experience, can be a "good combo" to move the farm towards a good direction. Diversity should also be promoted in terms of gender equality, increasing the presence of women working on farms (a segment of population traditionally under-represented in the agricultural sector) and narrowing the wage gap between men and women performing the same job. Additionally, proactive management of the diversity of workers in terms of geographical origin and ethnicity is recommended, respecting national and international human rights treaties and laws, and facilitating their adaptation to the farm and to the new labor environment. In search of this balance in terms of origin, it is recommended that the company also hire local workers to impact positively in the local community by improving wealth and employment in the area. This mix of employees from different backgrounds can be a good breeding ground for sustainable innovation on the farm, as well are the presence of diverse kinds of employees in terms of family members or external ones.

Labour: The fifth social KPI captures relevant matters related to work environment and working conditions such as salaries, type of contracts, workers' training, absenteeism, job creation and work risk prevention. This KPI is mainly focused on these three farm stakeholders: the owner, employees and local community. Employees satisfied with their working conditions, the training courses received, and generally, with higher levels of personal wellbeing (standard of living, personal health, personal relationships, happiness, community connectedness, etc.) contribute to increase farm's productivity and to reduce the rate of absenteeism and turnover, so help farms to achieve their goals quickly. In this KPI we also analyzed the training that employees received, the total work they performed, and the wage and income they received to capture if the farm provides employees the enough knowledge to develop their work, if there is a workload and the salary conditions in comparison with regional standards.

Overall, our recommendation for the farm is to guarantee the safety and health of employees through sustainable practices that do not damage their health and provide them with enough knowledge to develop their work without any problems.

It will be advisable for farms to pay employees at least the same salary as the average regional salary and avoid workload and other illegal practices. For the owner, our recommendation is like employees'. Owners should be satisfied with their salary, personal life and working conditions. Thus, we highly recommend the participation in training courses since they contribute to be more self-confident in performing the duties of his/her job and to be up to date and apply risk regulations at work to avoid potential unnecessary risks that could cause, for example, help problems and compromise the farm management. Finally, this KPI also focuses on the importance of creating new jobs by hiring local workers with good working conditions that impacts in a positive way, in terms wealth generation and stability, in the local community and avoid negative effect such as environmental risks (pollution, etc.) or incidents/complaints of local agents.

Livelihood and well-being: The last social KPI is related to the welfare and livelihood of two farm stakeholders: the owner and employees. Thus, in the first instance, this KPI pays attention to the level of income they receive and the difference between this wage and the minimum legal and average national wage as well as the compensations and benefits provided to them. Our recommendation is that farms try to comply with high levels of these measures since they directly impact on the level of satisfaction of the financial situation and the standard of living. Owner and employee's wellbeing is also influenced by factors such as the quality of work, the safety at the workplace, and the freedom to quit, associate and to negotiate their working conditions. So high levels of these measures are also recommended if farm want to keep motivated, happy and satisfied employees, who are willing to get involved in the farm projects and contribute with new and innovative ideas on how to address sustainability challenges.

Appendix 3 provides a guideline for farmers about environmental indicators, which are grouped in six main areas, which were identified as the relevant ones for sustainability.

Human Health*:* This environmental KPI aims to explore the impact of field activities have on the human health of people working in the field. The metrics belonging to this group evaluate the chemical's hazard to humans, the exposure of individuals to chemical products and the surface treated with pesticides. The recommendation for the farmer to decrease the environmental impact of the cultivation phase is to choose Plant Protection Product taking also into consideration risk phrases and toxicity classes indicated on the label, and to minimize the number of treatments to the necessary ones.

Air*:* This environmental KPI aims to explore the impact of field activities have on the air compartment. The metrics belonging to this group are related to the measurement of the amount of greenhouse gases emitted in connection to human activities in the field, and the estimation of the amount of carbon sequestered by plant tissues during the growing season. The recommendation for the farmer to decrease the environmental impact of the cultivation phase is to choose among the available cropping techniques, the one which are less impacting on the air compartment, and to choose efficient crops, which allow for an increased carbon sequestration.

Soil*:* This environmental KPI aims to explore the impact of field activities have on the soil compartment. The metrics belonging to this group estimate the risk of soil compaction; the loss of soil due to water-caused erosion; the duration of soil coverage; the percentage of organic matter contained in the soil; evaluate land surface necessary to provide the resources.

The recommendation for the farmer to decrease the environmental impact of the cultivation phase is to choose among the available cultivation techniques, the ones that lead to a lower impact on soil or promote its health.

Biodiversity: This environmental KPI aims to explore the impact of the field activities on biodiversity. The metrics belonging to this group evaluate the farm's biodiversity, on the base of the different types of land use, and assess the chemical ecosystem hazard score related to Plant Protection Products used. The recommendation for the farmer to decrease the environmental impact of the cultivation phase is to increase the biodiversity in the farm, and to choose Plant Protection Product taking also into consideration risk phrases and toxicity classes indicated on the label.

Energy: This environmental KPI aims to explore the use of energy in the field activities. The metrics belonging to this group consider the amount of fuel used for the mechanized operations carried out in the field, the use of fuel from renewable sources, and the farm's waste management. The recommendation for the farmer to decrease the environmental impact of the cultivation phase is to choose cultivation techniques that reduce the amount of fuel used, to increase the use of energy from renewable sources, and to improve the management of all kind of wastes generated during farm activities.

Water: This environmental KPI aims to explore the impact of field activities have on the water compartment. The metrics belonging to this group assess the water footprint; evaluates the types irrigation system and water used for crop irrigation; the emissions of compounds causing acid rains and the effect of excess of nutrients on water ecosystems. The recommendation for the farmer to decrease the environmental impact of the cultivation phase is to choose among the available cultivation techniques, the ones that lead to a lower impact on water.

5.2. Implementation guidelines for the Sustainable Innovation Pilots

In the previous subsection, the SIF that can be implemented in the farms is described. Although this framework is developed to be implemented in three different crops (grapevine, hop, date palm), the idea is that other farms not directly involved in SUSTEMICROP would be able also to implement this framework. The different stages go from the very preliminary understanding of the problems and challenges to be addressed in the farm to the evaluation of the sustainable practices implemented. This framework takes into account the different contexts in which sustainable practices are developed. The next subsections describe the guidelines for the pilots on how to use the SIF.

5.2.1. Establishing the starting point

As it was previously mentioned in Chapter 3, the starting point of the SIF was established in July, 2022. However, we had some pilot farmers interested in using these sustainable practices (biopesticides and biofertilizers) in their farms before SUSTEMICROP was formally started. Thus, the contact with these farmers started a few months before July, 2022. In order to obtain conclusions that would be valid for other crops and context, we expanded our sample to different farmers from the same crops but from different regions. This stage took three months, from July to October, 2022. In the stage of '*Define'* we explored new crops and farmers to apply the treatment. This stage was related to the '*Decision'* stage to decide the most relevant sustainable practice for each farm. Both of them were developed during these initial months. Moreover, although this SIF has been elaborated for these pilot cases, the framework is available for other farmers interested in including sustainable practices in the future or for those firms that want to evaluate their sustainable performance nowadays.

The third stage of the SIF, however, represents a fundamental tool to analyze the farm ecosystem, thanks to its non-linear and iterative processes between the farm and its internal and external stakeholders. This stage was the longest phase of the framework because of its complexity and it varies widely between one farm and another. Finally, it is necessary to remark that before starting to apply the SIF, it is highly recommended to assess the starting point of each farm through KPIs, paving the way for a more thorough analysis and evaluation in the different stages of the sustainable process.

5.2.2. Using the SIF and its tools

In this Deliverable 1.2, a SIF that will be applied to different farms is described. However, as it was commented in Chapter 3, the tool itself will be developed in WP5 of the Project. In this stage of the project, the farmers that will implement the sustainable practices have been chosen and we explain the SIF to them. ULE and HORTA had organized some meetings with experts, farmers, managers, farm workers, and other farmers' stakeholders in order to guide the pilot farmers in the process. Some of these meetings have been in group and other has been bilateral meetings. During these six initial months, we have had monthly group meetings with experts, and at least one bilateral meeting with each farmer (owner, manager, or both) was organized. The aim of these initial meetings was to create a consolidate SIF, a useful framework for all the crops and countries analyzed in the current project. After this initial stage, we will develop with HORTA (leader of WP5) a digital tool which allows farmers to evaluate their sustainable performance. As we proposed in the project, we will evaluate their sustainable performance through KPI (described in Chapter 4) in three different moments: at the beginning of the project, in the middle of the project and at the end of the project. We will organize bilateral meetings with all of them to guide pilot farmers in the assessment or at least to explain the use of the online tool.

We proposed in Chapter 4 to assess firm sustainable performance through 4 economic KPIs, 6 social KPIs and 6 environmental KPIs. Besides, for environmental indicators information about the crop operations carried out in the cropping season in field is also needed. To collect information about these economic and environmental indicators we can ask directly to the owner or farmer. However, in the case of social indicators, it would be also highly recommended to contact with farm' stakeholders to be completely objective and have information from different points of view. For each phase of the SIF, the use of the applicable tools (after WP5) will be explained by the experts of the relevant WP during farmers meetings, dedicated expert meetings and, if needed, ad-hoc meetings.

5.2.3. Using the measurement framework

To reach a balanced, complete and sustainable oriented framework, 16 KPIs that cover most of the economic, social and environmental actions of the farm has been developed. However, it is necessary to remark that it is not mandatory to achieve a minimum score in each of the indicators. In addition, for many of these indicators only recommendations can be made, as it will depend on other factors. Detailed descriptions of the KPIs can be found in the appendixes. In this first stage of the project, we selected those KPI to perform the baseline assessment of each crop. In WP5, a digital tool that allows farmers to evaluate their sustainable performance will be designed. In this tool the indicators will be adapted to each crop and country characteristics. Regarding to the definition, decision and implementation stages for the pilot farmers, the partners involved in WP2, WP3, WP4 and WP6 advise pilot farmers on the most appropriate sustainable techniques for their crops, helping them to make decisions on which of these techniques to apply. Finally, between WP1 and WP6 will advise farmers on the implementation of these techniques and guide them in their relationship with stakeholders.

Those farmers not directly involved in the project can consider the sustainable practices suggested in this project, and they should analyse other sustainable practices in the market in the case of their own crops. Then, as we suggested in our SIF, they can organize meetings with experts and technical advisors to evaluate the most relevant practices for each crop and farm. Then to address the implementation part, farmers can open their management practices and work together with other stakeholders. Finally, to evaluate their sustainable performance, they can use the digital tool that will develop in WP5.

6. Conclusions

This deliverable presents the initial SIF and how it was developed. We provide a SIF made up by four main stages (definition, decision, implementation and evaluation), which together with a set of tools (economic, social, and environmental KPIs, and practical guidelines), guides farmers along the implementation process of sustainable practices. The SIF takes into account several key drives that might influence the adoption of sustainable practices such as the institutional context, farmers' objectives, farms' main stakeholders and their relationships with them, as well as the farmers' resources and capabilities.

The SIF presented in this deliverable plays an important role in the SUSTEMICROP project and great effort has to be done in order to develop it. Despite this initial SIF is still in an early development stage itself, it shapes up to be a promising useful tool for guiding farmers in the development of sustainable practices. It provides farmers technical support throughout four stages considering the main factors that might influence this kind of processes while allows them to choose the type of sustainable practice more aligned with their objectives.

The SIF is provided with a measurement tool (KPIs) and guidelines, which can be adapted according to the type of crop that allow farmers to perform an assessment of their activity from a threefold perspective. It means that farmers can focus on their main concern (be economically autonomous and competitive) while they can reach social and environmental objectives imposed by legislation, society, customers, etc.

Based on the lesson learnt in the TCS (WP5) in which the SIF is intended to be applied (WP6) and based on the knowledge developed in other WPs, the SIF will be continuously updated throughout the course of the project.

This SIF can be considered a starting point to guide farmers along the process of implementing sustainable practices. However, at the end of the 'SUSTEMICROP project' the SIF will be empirically validated and consolidated in order to support the replication of sustainable practices also in different contexts different from those addressed in this project (i.e., countries, types of crops, etc.).

Similarly, the measurement framework will be further developed. For example, a more detailed time horizon of the KPIs and how to measure them will be developed based on different contexts.

In conclusion, this deliverable provides the SUSTEMICROP project with an initial SIF which will be further improved in the remainder of the project.

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8. Appendix

Appendix 1: Economic indicators detailed description

EC-1	Market Activity
Domain	Economic
KPI	Competitiveness
Description	Geographical distribution of sales as percentage of farm total sales
Goal	>30 (% national shares) 30-50 (% international shares) <50 (% own consumption)
Interpretation	Ideal range for balanced global sales between national, international and own consumption. >30% National Shares: Preferred to ensure a substantial domestic market presence and support national economic stability. 30-50% International Shares: Ideal range for balanced global expansion without excessive dependence on foreign markets. <50% Own Consumption: Keeping self-consumption below 50% promotes resource allocation to external sales, enhancing revenue potential.
References	Adapted from Wrzaszcz & Zegar (2014)

EC-2	Market Share
Domain	Economic
KPI	Competitiveness
Description	It measures a farm's sales revenue as a percentage of the market total sales revenues of the municipality
Goal	>5 2-5 <2
Interpretation	Green values are recommended
References	Singh et al. (2019); Wohlenberg et al. (2022)

EC-3	Multifunctional Agriculture
Domain	Economic
KPI	Competitiveness
Description	It measures the proportion of net income deriving from farm education, agricultural nature management, agro tourism, child care, and services to civilians/consumers
Goal	>30 10-30 <10
Interpretation	Green values are recommended
References	Adapted from FAO (2014)

EC-4	Certifications
Domain	Economic
KPI	Competitiveness
Description	It measures the proportion of production that is produced and sold according to certification schemes
Goal	>50 5-50 <5
Interpretation	Green values are recommended
References	Agency of Partnership for Progress (2010); BOCYL (2022); DOUE (2006); Rasmussen et al. (2017); United States Department of Agriculture (1955)

EC-5	Gross Income Short Term Trend
Domain	Economic
KPI	Competitiveness
Description	Gross income of the last year available with respect to the last 5 years (gross saleable products - direct costs)
Goal	>0 0 <0
Interpretation	Green values are recommended
References	Adapted from FAO (2014)

EC-6	Gross Income Long Term Trend
Domain	Economic
KPI	Competitiveness
Description	Gross income of the last 5 years with respect to the last 20 years (gross saleable products - direct costs)
Goal	>0 0 <0
Interpretation	Green values are recommended
References	Adapted from FAO (2014)

EC-7	Net Income Short Term Trend
Domain	Economic
KPI	Competitiveness
Description	Net income of the last year available with respect to the last 5 years (gross saleable products - (direct + fixed costs)
Goal	>0 0 <0
Interpretation	Green values are recommended
References	Brandt & Geeson (2015); INSPIA (2022); Roy & Chan (2012); Smith & McDonald (1998); Talukder et al. (2020); Van Calker et al. (2004); Wohlenberg et al. (2022); Zhen & Routray (2003)

EC-8	Net Income Long Term Trend
Domain	Economic
KPI	Competitiveness
Description	Mean of net income of the last 5 years with respect to the last 20 years (gross saleable products - (direct + fixed costs)
Goal	>0 0 <0
Interpretation	Green values are recommended
References	Brandt & Geeson (2015); INSPIA (2022); Roy & Chan (2012); Smith & McDonald (1998); Talukder et al. (2020); Van Calker et al. (2004); Wohlenberg et al. (2022); Zhen & Routray (2003)

EC-9	Future Existence
Domain	Economic
KPI	Competitiveness
Description	Likelihood that the farm will exist in the next 10 years, probability %
Goal	>80 50-80 <50
Interpretation	Green values are recommended
References	Weiss (1999)

EC-10	Balanced Power in Food Chain
Domain	Economic
KPI	Competitiveness
Description	Relevant position of farmers in the food supply chain.
Goal	Increasing Stable Decreasing
Interpretation	Green values are recommended
References	Adapted from FAO (2014)

EC-11	Crop Diversity
Domain	Economic
KPI	Independence
Description	Crop diversity: the number of different crops cultivated in each farm apart from the target crops every year
Goal	>4 3-4 <3
Interpretation	Green values are recommended
References	Dantsis et al. (2010); Gómez-Limón & (2009); Wohlenberg et al. (2022); Zhen & Routray (2003)

EC-12	Revenues Diversity
Domain	Economic
KPI	Independence
Description	Farm revenues from the other gainful activities to total revenue
Goal	>25 10-25 <10
Interpretation	Green values are recommended
References	Dos-Santos & Diz (2019); Rogelj et al. (2020); Sánchez Fernández (2009); Valkó et al. (2017); Wohlenberg et al. (2022)

EC-13	Debt to Equity
Domain	Economic
KPI	Independence
Description	It measures the farmer's leverage level. Share of debt with respect to total equity (external finance/equity).
Goal	<5 5-10 <10
Interpretation	A D/E ratio lower than 1 is typically ideal, indicating conservative leverage and financial stability, especially valuable in agriculture due to the sector's exposure to risks like weather fluctuations, price volatility, and seasonal income. Ratios above 1.5 may indicate high financial risk, as they can lead to cash flow challenges during periods of low yield or revenue.
References	Nurmet (2011); Zawadzka et al. (2021)

EC-14	Liquidity
Domain	Economic
KPI	Independence
Description	Liquidity is the ability to convert assets into cash quickly and cheaply (current assets/current liabilities)
Goal	>1 0,5-1 <0,5
Interpretation	Green values are recommended
References	Business at Speed (2022)

EC-15	Solvency
Domain	Economic
KPI	Independence
Description	Solvency relates to a farm's overall ability to pay debt obligations and continue business operations (total assets/total liabilities)
Goal	>1 0,5-1 <0,5
Interpretation	Green values are recommended
References	Dos Santos & Ahmad (2020); Dos-Santos & Diz (2019)

EC-16	Subsidy Dependency
Domain	Economic
KPI	Independence
Description	It measures the farm's dependence on agricultural direct subsidies (direct subsidies/gross profit)
Goal	<0,5 0,5-0,8 >0,8
Interpretation	Green values are recommended
References	Sadok et al. (2009); Valkó et al. (2017)

EC-17	Costs Share
Domain	Economic
KPI	Financial and Economic Performance
Description	% of final price of the product corresponding to direct costs
Goal	<60 60-90 >90
Interpretation	Green values are recommended
References	Pellegrini et al. (2017); Tsolakis et al. (2018)

EC-18	Costs Trend
Domain	Economic
KPI	Financial and Economic Performance
Description	It measures if direct costs are changing faster or slower than gross saleable products
Goal	<0 0 >0
Interpretation	Green values are recommended
References	Adapted from FAO (2014)

EC-19	Labour Costs Trend
Domain	Economic
KPI	Financial and Economic Performance
Description	It measures if labour costs are changing faster or slower than gross saleable products
Goal	<10 0-10
Interpretation	Green values are recommended
References	USDA, 2023

EC-20	Price Oscillation
Domain	Economic
KPI	Financial and Economic Performance
Description	It measures the price oscillation in the market.
Goal	Low Very low Medium possibility Very high High
Interpretation	Green values are recommended
References	Santiago-Brown et al. (2015); Smith & McDonald (1998); Wohlenberg et al. (2022); Zhen & Routray (2003)

EC-21	Market Value
Domain	Economic
KPI	Financial and Economic Performance
Description	Perception of product value with respect to market price
Goal	Product value is similar to market price Product value is higher than market price Product value is significantly higher than market price
Interpretation	Green values are recommended
References	Santiago-Brown et al. (2015); Sarkar et al. (2021)

EC-22	Profitability Long Term
Domain	Economic
KPI	Financial and Economic Performance
Description	It denotes farm profitability in terms of return on assets (ROA) which indicates the effectiveness of the farm's management, i.e., the capacity of its assets to generate value (operating profits/total assets)
Goal	>0 0 <0
Interpretation	Higher values are recommended
References	Sánchez Fernández (2009); Santiago-Brown et al. (2015); Wohlenberg et al. (2022); Zhen & Routray (2003)

EC-23	Profitability Short Term
Domain	Economic
KPI	Financial and Economic Performance
Description	It denotes farm profitability as a percentage of sales revenue (ROS); this ratio helps businesses assess how efficiently a farm can convert revenue to operating profit. [Sales revenue – Operational costs]/[Sales revenue].
Goal	>0 0 <0
Interpretation	Higher values are recommended
References	Sadok et al. (2009); Wohlenberg et al. (2022)

EC-24	EBITDA
Domain	Economic
KPI	Financial and Economic Performance
Description	It denotes farm earnings before interest, taxes depreciation and amortization, that is, it is a way to measure the impact of savings on operating costs.
Goal	>10 4-10 <4
Interpretation	Green values are recommended
References	Business at Speed (2022); Gómez-Limón & Riesgo (2009); Paternoster (2011)

EC-25	Digital Technologies
Domain	Economic
KPI	Financial and Economic Performance
Description	Effect of digital solutions to optimize cropping systems
Goal	Increasing Stable Decreasing
Interpretation	Green values are recommended
References	Wolfert & Isakhanyan (2022)

EC-26	Digital Technologies Costs
Domain	Economic
KPI	Financial and Economic Performance
Description	Effect of digital solutions to total direct costs
Goal	<5 5-10 >10
Interpretation	Green values are recommended
References	Pope & Sonka (2020)

EC-27	Interest Expenses
Domain	Economic
KPI	Financial and Economic Performance
Description	Effect of interest expenses on farm budget
Goal	Low Very low Medium possibility Very high High
Interpretation	Green values are recommended
References	Adapted from FAO (2014)

EC-28	R&D Investment
Domain	Economic
KPI	Resource utilization
Description	It denotes farm investment in Research and Development (R&D), that is, it captures observable innovation inputs (resources and incentives used to finance innovation task). % of Net income used for R&D
Goal	>30 15-30 <15
Interpretation	Green values are recommended
References	Adapted from Valkó et al. (2017)

EC-29	Investment
Domain	Economic
KPI	Resource utilization
Description	It consists of resident producers' investments, deducting disposals, in fixed assets during a given period. It also includes certain additions to the value of non-produced assets realized by producers or institutional units. Property, plant, and equipment are standard fixed capital items. % of Net income used for investment.
Goal	>30 15-30 <15
Interpretation	Green values are recommended
References	Gerdessen & Pascucci (2013)

EC-30	Green Economy
Domain	Economic
KPI	Resource utilization
Description	Investments in energy saving and efficiency actions in the last 5 years
Goal	Increasing Stable Decreasing
Interpretation	Green values are recommended
References	Aramyan et al. (2007)

EC-31	Green Transport
Domain	Economic
KPI	Resource utilization
Description	Transport efficiency (use of biodiesel, electric vehicles, efficiency in intra-company travel, etc.).
Goal	Increasing Stable Decreasing
Interpretation	Green values are recommended
References	Lombardi & Berni (2021)

EC-32	Green Energy
Domain	Economic
KPI	Resource utilization
Description	Share of renewable energy respect to total used
Goal	>70 50-70 <50
Interpretation	Green values are recommended
References	Majeed et al. (2023)

EC-33	Labour Productivity
Domain	Economic
KPI	Resource utilization
Description	It measures trend of the amount of product obtained per annual work unit (AWU= average annual hours full-time) respect to the last year [Total mass production/Annual work unit]
Goal	Increasing Stable Decreasing
Interpretation	Green values are recommended
References	Adapted from Latruffe et al. (2016) and Valkó et al. (2017)

EC-34	Land Productivity
Domain	Economic
KPI	Resource utilization
Description	It measures trend of the amount of product obtained per each harvested area (i.e., utilized agricultural area [UAA]) respect to the last year [Total mass production/Utilized agricultural area]
Goal	Increasing Stable Decreasing
Interpretation	Green values are recommended
References	INSPIA (2022); Latruffe et al. (2016); Santiago-Brown et al. (2015); Sridhara et al. (2022);Talukder et al. (2020); Valkó et al. (2017)

EC-35	Risky Practices
Domain	Economic
KPI	Resource utilization
Description	Presence de risky practices (excluding pesticides).
Goal	Increasing Stable Decreasing
Interpretation	Green values are recommended
References	Adapted from FAO (2014); Komarek et al. (2020)

EC-36	**Pest Control with Bio pesticides**
Domain	Economic
KPI	Resource utilization
Description	Trend hypothesis of bio pesticides use in the farm vs. traditional pesticides in next 5-years
Goal	Increasing Stable Decreasing
Interpretation	Green values are recommended
References	Palmieri et al. (2022)

EC-37	**Pest Control with BCA**
Domain	Economic
KPI	Resource utilization
Description	Trend hypothesis of BCA (Biocontrol Agents) use in the farm vs. traditional pesticides in next 5-years
Goal	Increasing Stable Decreasing
Interpretation	Green values are recommended
References	Ayilara et al. (2023)

EC-38	**Shift to Green Pest Control**
Domain	Economic
KPI	Resource utilization
Description	Willingness to increase pest control costs of 5% using BCA and biopesticides
Goal	Very high High Medium possibility Very low Low
Interpretation	Green values are recommended
References	EPRS | European Parliamentary Research Service (2021)

EC-39	**Effects to Yields by Green Pest Control**
Domain	Economic
KPI	Resource utilization
Description	How much is expected to change yields shifting by traditional to green pest control based on BCA and bio pesticides.
Goal	> 10% 5 / 10% -5 / +5% -5 / -10% < -10%
Interpretation	Green values are recommended
References	Ali et al. (2019)

Appendix 2: Social indicators detailed description

S-1	Farm Future
Domain	Social
KPI	Resilience
Description	Inter-generational continuation
Goal	Yes, surely; Very likely; Probably; Unlikely; No
Interpretation	Recommended Goal: Yes, surely Ensures long-term sustainability and continuity of family farming
References	Reed & Courtney (2013); Röös et al. (2019); Van Cauwnbergh et al. (2007)

S-2	Cultural Level
Domain	Social
KPI	Resilience
Description	Farm owner's cultural level
Goal	PhD; University; Secondary school; Middle school; Primary school or less
Interpretation	Recommended Goal: PhD Higher education equips the farmer with advanced skills for better farm management
References	Gerdessen & Pascucci (2013); Nambiar et al. (2001); Talukder et al. (2020); Van Cauwnbergh et al. (2007)

S-3	Resilience to Bad Weather
Domain	Social
KPI	Resilience
Description	Farm resilience if experienced loss production. Tolerance in yield loss in a year without negative effects on financial stability
Goal	-100% -60% -40% -20% 0%
Interpretation	Recommended Goal: 0 Ideal resilience means no negative financial impact from production losses. So, the farm should tolerate higher loss production. Values close to -100% means that the farm has higher resilience
References	Diazabakana et al. (2014); Fourrié et al. (2013); Kelly et al. (2021)

S-4	Eco-Friendly Tendencies
Domain	Social
KPI	Resilience
Description	Motivation level to produce organically
Goal	Farm 100% organic managed; partial farm organic management; Available to shift toward organic systems in the future; Quite unwilling to shift; Not available at all
Interpretation	Recommended Goal: Farm 100% organic managed Full commitment to organic production ensures alignment with sustainability goals
References	Fourriè et al. (2013); Kelly et al. (2021)

S-5	Diversity Suppliers
Domain	Social
KPI	Resilience
Description	Easy to access to inputs for cropping system (seeds, chemicals, fertilizers, etc.)
Goal	Very high; High-Medium possibility; Low; Very low
Interpretation	Recommended Goal: Very high Easy access prevents delays and promotes consistent production
References	Röös et al. (2019); Talukder et al. (2020)

S-6	Autonomy Suppliers
Domain	Social
KPI	Resilience
Description	Autonomy to choose the suppliers of local inputs sellers
Goal	Very high; High; Medium possibility; Low; Very low
Interpretation	Recommended Goal: Very high Greater autonomy gives flexibility and control over quality and costs
References	Röös et al. (2019)

S-7	Local Suppliers Share
Domain	Social
KPI	Resilience
Description	Share of cropping system inputs by local suppliers
Goal	Very high; High; Medium possibility; Low; Very low
Interpretation	Recommended Goal: Very high Supporting local suppliers strengthens local economies and ensures quality
References	GRI Standards (2016)

S-8	Customer Loyalty
Domain	Social
KPI	Resilience
Description	Degree of stability of the relationship between the farmer and suppliers
Goal	Very high; High; Medium possibility; Low; Very low
Interpretation	Recommended Goal: Very high Stable relationships foster reliability and potential cost advantages
References	Adapted from Al Shamsi et al. (2018) and Wohlenerg et al. (2022)

S-9	Food Quality
Domain	Social
KPI	Resilience
Description	Frequency of obtaining the quality parameters required by the supply chain
Goal	Always; Frequently; Sometimes; Rarely; Never
Interpretation	Recommended Goal: Always Consistency in quality ensures market access and pricing stability
References	Agency of Partnership for Progress (2010); Aramyan et al. (2006); Santiago-Brown et al. (2015); United States Department of Agriculture (1955); Wohlenerg et al. (2022)

S-10	Food Quantity
Domain	Social
KPI	Resilience
Description	Frequency of obtaining satisfying yields
Goal	Always; Frequently; Sometimes; Rarely; Never
Interpretation	Recommended Goal: Always. Consistency in food quality ensures satisfying market demand
References	Adapted from FAO (2014)

S-11	Sustainability Tendencies
Domain	Social
KPI	Resilience
Description	Farm's commitment in sustainable practices to promote sustainable production
Goal	Very high adoption of regenerative practices with sustainable certifications; High adoption of regenerative practices; Some sustainable practices adopted; Low adoption; Only conventional cropping system, no sustainable practices
Interpretation	Recommended Goal: Very high adoption of regenerative practices with sustainable certifications It demonstrates a strong commitment to environmental sustainability and market demand
References	Rasmussen et al. (2017)

S-12	Circular Economy
Domain	Social
KPI	Resilience
Description	It measures the farm commitment with circular economy (processing of non-organic waste, avoidance of burning organic waste and sorting and reuse of organic waste on-sit)
Goal	Very high; High; Medium possibility; Low; Very low
Interpretation	Recommended Goal: Very High It demonstrates a strong commitment to achieve the "zero waste" objective and to reuse and recycle every potential waste which still has any king of value susceptible to be exploited
References	Kelly et al. (2021); Röös et al. (2019); Zahm et al. (2008)

S-13	Minimizing Waste
Domain	Social
KPI	Resilience
Description	Interest on trying to reduce waste to a minimum
Goal	Very high; High; Medium availability; Low; Very low
Interpretation	Recommended Goal: Very high Minimizing waste contributes to cost efficiency and environmental responsibility
References	Ramírez et al. (2008); Regulation 396 (2005)

S-14	Quality Landscape
Domain	Social
KPI	Resilience
Description	Farm commitment with the quality of landscape elements, e.g., hedges and trees, including the maintenance of old buildings and the architectural quality of new buildings to maintain rural heritage
Goal	Very high; High; Medium possibility; Low; Very low
Interpretation	Recommended Goal: Very high High commitment ensures the preservation of natural and cultural landscapes, adding value to the farm
References	Kelly et al. (2021); Röös et al. (2019); van Cauwenbergh et al. (2007); Zahm et al. (2008)

S-15	Relationship Supply Chain
Domain	Social
KPI	Network
Description	Intensity relationship between consumer and producers
Goal	Very high; High; Medium possibility; Low; Very low
Interpretation	Recommended Goal: Very high Strong consumer relationships can lead to loyalty and premium pricing
References	Brennan et al. (2018); Ecolabel Index (2022); Kelly et al. (2021); Röös et al. (2019); Roy & Chan, (2012); Saifia & Drake (2008)

S-16	Professional Organizations
Domain	Social
KPI	Network
Description	Intensity commitment with professional associations
Goal	Very high; High; Medium possibility; Low; Very low
Interpretation	Recommended Goal: Very high Active engagement in associations promotes knowledge exchange and advocacy
References	Diazabakana et al. (2014); Fourriè et al. (2013); Galdeano-Gómez et al. (2017); Kelly et al. (2021)

S-17	Environmental/Social Organizations
Domain	Social
KPI	Network
Description	Intensity commitment with sporting, religious, nature conservation, environmental civil and voluntary associations
Goal	Very high; High; Medium possibility; Low; Very low
Interpretation	Recommended Goal: Very high High commitment with environmental and social organizations demonstrates the farm willingness to involve in the community and can help to a positive share of information and collaboration
References	Diazabakana et al. (2014); Fourrië et al. 2013; Kelly et al. (2021); Lebacq et al. (20213)

S-18	Neighbours Relationship
Domain	Social
KPI	Network
Description	Intensity informal network through farmers in the same area
Goal	Very high; High; Medium possibility; Low; Very low
Interpretation	Recommended Goal: Very high To share knowledge, cooperate and collaborate with other people in your area is recommended
References	Santiago-Brown et al. (2015)

S-19	Research Relationship
Domain	Social
KPI	Network
Description	Intensity informal network with researchers, university, etc.
Goal	Very high; High; Medium possibility; Low; Very low
Interpretation	Recommended Goal: Very high Collaboration with researchers drives innovation and best practices
References	Diazabakana et al. (2014); Fourrië et al. (2013); Kelly et al. (2021)

S-20	Community Contribution
Domain	Social
KPI	Network
Description	How farm helps to improve its community in terms of education, working conditions and quality of life
Goal	Very high; High; Medium possibility; Low; Very low
Interpretation	Recommended Goal: Very high A farm actively involved in its community can improve local living standards and build goodwill
References	Brennan et al. (2018); Kelly et al. (2021)

S-21	Social Commitment
Domain	Social
KPI	Network
Description	It measures if the family farm takes part in some kind of local activities: 1 = Participation in local festivals; 2 = Participation in local farmers' markets; 3 = Participation in local farming fairs; 4 = Participation in local nature conservation; 5 = Participation in local competitions; 6 = Hosting open day events in the farm, e.g., harvest festivals, themed seasonal events, etc.; 7 = Allowing public visit in the farm, e.g. farm walks, trails or self-guided walks, etc.; 8 = Giving apprenticeships
Goal	>4 of the list 3 of the list 2 of the list 1 of the list None activity
Interpretation	Recommended Goal: >4 of the list Active participation in many activities builds community ties and promotes the farm
References	Aparisi (n.d.); Diazabakana et al. (2014); Kelly et al. (2018); Kelly et al. (2021); Röös et al. (2019); Wohlenberg et al. (2022)

S-22	Internal Network
Domain	Social
KPI	Network
Description	Internal networking intensity (Family firms, directors, employees, …)
Goal	Very high and efficient; High; Moderate with some inefficiency; Some inefficiency; Insufficient and chaotic activities
Interpretation	Recommended Goal: Very high and efficient Strong internal networks enhance collaboration, decision-making, and efficiency
References	Röös et al. (2019)

S-23	Support
Domain	Social
KPI	Network
Description	Frequency of farmers taking into account suggestions and advice (from internal and external agents)
Goal	Always; Frequently; Sometimes; Rarely; Never
Interpretation	Recommended Goal: Always A willingness to consider advice improves adaptability and decision quality
References	Fourriè et al. (2013); Kelly et al. (2018); Kelly et al. (2021); Rasmussen et al. (2017); Talukder et al. (2020)

S-24	Farmers Associations
Domain	Social
KPI	Network
Description	Freedom to build up new farmers associations
Goal	Very high; High; Medium possibility; Low; Very low
Interpretation	Recommended Goal: Very High It can bring new perspectives and new ways of collaborations
References	Diazabakana et al. (2014); Fourrië et al. (2013); Kelly et al. (2021)

S-25	Farmers Market Power
Domain	Social
KPI	Network
Description	Farmers bargaining power (to decide prices, quantities, and power on markets customers, competitors, etc.)
Goal	Very high; High; Medium possibility; Low; Very low
Interpretation	Recommended Goal: Very high Strong bargaining power allows the farmer to secure better prices and terms in the market
References	Kelly et al. (2018); Kelly et al. (2021); Reed & Courtney (2013); Wohlenberg et al. (2022); Zahm et al. (2008)

S-26	KM 0
Domain	Social
KPI	Network
Description	Short trade with local and direct sales, share of farm production
Goal	>45% 30-45% 15-30% 1-15% 0%
Interpretation	Recommended Goal: >45% A high percentage of direct local sales supports the local economy and can improve farm profitability
References	Röös et al. (2019)

S-27	Farm Fair Trade
Domain	Social
KPI	Network
Description	Farm sensibility to fair trade, fair price
Goal	Very high; High; Medium possibility; Low; Very low
Interpretation	Recommended Goal: Very high High sensitivity to fair trade practices ensures ethical production and market advantages
References	Röös et al. (2019)

S-28	Food Chain Fair Trade
Domain	Social
KPI	Network
Description	Food chain actors' sensibility to fair trade and fair price
Goal	Very high; High; Medium possibility; Low; Very low
Interpretation	Recommended Goal: Very high Alignment with fair trade practices across the food chain supports sustainability and social responsibility
References	Brennan et al. (2018); Ecolabel Index (2022); GRI Standards (2016); Kelly et al. (2021); Röös et al. (2019); Roy & Chan (2012); Saifia & Drake (2008), Wohlenberg et al. (2022)

S-29	Labeled Products
Domain	Social
KPI	Network
Description	Availability to provide additional information for food labels, sustainability certifications, etc., respect to mandatory data
Goal	Very high; High; Medium possibility; Low; Very low
Interpretation	Recommended Goal: Very high Transparency in labeling and certifications attracts consumers and meets regulatory standards
References	Ingrassia et al. (2017)

S-30	Education and Training
Domain	Social
KPI	Management
Description	Percentage of owner hours spent on improving his or her training
Goal	>20% 15-20% 10-15% 5-10% <5%
Interpretation	Recommended Goal: >20% Regular training and education improve the owner's knowledge and farm management skills
References	Diazabakana et al. (2014); Fourrié et al. (2013); Kelly et al. (2018); Kelly et al. (2021); Talukder et al. (2020)

S-31	Autonomy Decision Making
Domain	Social
KPI	Management
Description	Autonomy degree in the decision-making process
Goal	Complete autonomy; High autonomy but not in all decisions; Partial autonomy; Frequent support needed; Complete dependence on advisors
Interpretation	Recommended Goal: Complete autonomy Full autonomy in decision-making allows flexibility and independence in operations
References	Fourriè et al. (2013); Kelly et al. (2018); Kelly et al. (2021)

S-32	Law Compliance
Domain	Social
KPI	Management
Description	Subjective perception of respect of national law in agriculture sector
Goal	100% Nearly 100% 80-90% 70-80% 70%
Interpretation	Recommended Goal: 100% High compliance with national laws ensures legal security and sustainable practices
References	Röös et al. (2019)

S-33	Human Rights
Domain	Social
KPI	Management
Description	Subjective perception of respect of human rights conventions and agreements towards workers
Goal	100% Nearly 100% 80-90% 70-80% <70%
Interpretation	Recommended Goal: 100% Respecting human rights ensures ethical treatment of workers and aligns with international standards
References	Röös et al. (2019)

S-34	Decision Makers
Domain	Social
KPI	Management
Description	Who makes decisions
Goal	Jointly with the management board and consultants; Jointly with the management board; Jointly with family members; Frequently only the owner; Always the owner alone
Interpretation	Recommended Goal: Jointly with the management board and consultants Collaborative the decision-making process improves the quality and effectiveness of farm strategies
References	Diazabakana et al. (2014); Kelly et al. (2018); Kelly et al. (2021)

S-35	Capacity Development
Domain	Social
KPI	Management
Description	Employees possibilities to capacity development
Goal	Very high; High; Medium possibility; Low; Very low
Interpretation	Recommended Goal: Very high Promoting employees' development ensures better performance and talent retention
References	Röös et al. (2019)

S-36	Women in Decision Making
Domain	Social
KPI	Management
Description	Women in decision making about agricultural activities
Goal	100% 75-100% 50-75% 25-50% >25%
Interpretation	Recommended Goal: 100% High inclusion of women in the decision-making process promotes equality and diverse perspectives
References	Paternoster (2011); Talukder et al. (2020)

S-37	Family Working Hours
Domain	Social
KPI	Inclusivity
Description	Percentage of family working hours over total work performed
Goal	>75% 50-75% 25-50% 10-25% <10%
Interpretation	Recommended Goal: >50% High family involvement suggests greater commitment and sustainability of the farm
References	Dos Santos & Ahmad (2020); Dos-Santos & Diz (2019); El-Osta & Ahearn (1996)

S-38	Diversity (Age)
Domain	Social
KPI	Inclusivity
Description	Diversity in age
Goal	Young and middle aged employees; Only middle-age employees + apprentices; Only middle-age employees; Only young employees; Only elderly employees
Interpretation	Recommended Goal: Young and middle-aged employees A balanced age distribution ensures continuity and dynamic workforce capabilities
References	Gerdessen & Pascucci (2013)

S-39	Female
Domain	Social
KPI	Inclusivity
Description	Female presence in the farm
Goal	>60% 40-60% 20-40% 5-20% <5%
Interpretation	Recommended Goal: >60% employees A high percentage of female workers promotes gender equality and brings new contributions (perspectives)
References	Paternoster (2011)

S-40	Gender Wage Differentials
Domain	Social
KPI	Inclusivity
Description	Gender-based wage differentials between men and women's labour
Goal	0% 1-5% 5-15% 15-30% >30%
Interpretation	Recommended Goal: 0% Minimal wage differences ensure fair and equitable compensation across genders
References	Talukder et al. (2020)

S-41	Local Works
Domain	Social
KPI	Inclusivity
Description	Share of local works
Goal	>80% employees 60-80% employees 40-60% employees 20-40% employees <20% employees
Interpretation	Recommended Goal: >80% employees Employing a large proportion of local workers supports the local economy and strengthens community ties
References	Fourrié et al. (2013); Kelly et al. (2021); Diazabakana et al. (2014)

S-42	Seasonal Works
Domain	Social
KPI	Inclusivity
Description	Share of seasonal works
Goal	<20% employees 20-40% employees 40-60% employees 60-80% employees >80% employees
Interpretation	Recommended Goal: <20% employees Reducing seasonal work ensures job stability and long-term employees' commitment
References	Röös et al. (2019)

S-43	Local Seasonal Works
Domain	Social
KPI	Inclusivity
Description	Share of local seasonal works
Goal	>80% employees 60-80% employees 40-60% employees 20-40% employees <20% employees
Interpretation	Recommended Goal: >80% employees Hiring local seasonal workers supports the local community and reduces labor disruptions
References	Röös et al. (2019)

S-44	Labour Rights
Domain	Social
KPI	Inclusivity
Description	The farm is commitment with labour rights (national and international labour treaties)
Goal	100% 90-100% 80-90% 70-80% <70%
Interpretation	Recommended Goal: 100% High adherence to labour rights ensures ethical treatment of all workers
References	Röös et al. (2019)

S-45	Employees' Diversity
Domain	Social
KPI	Inclusivity
Description	Respect of employees' diversity (no discriminations, sexual identity, job allocation, promotions and firing, support disabled, support young, and aged workers)
Goal	Very high; High; Medium possibility; Low; Very low
Interpretation	Recommended Goal: Very high Ensuring no discrimination based on gender, age, or ability promotes inclusivity and respect
References	Röös et al. (2019)

S-46	Accommodation Temporary Workers
Domain	Social
KPI	Inclusivity
Description	Safety facilities and high-quality accommodations for temporary workers
Goal	Very high; High; Medium possibility; Low; Very low
Interpretation	Recommended Goal: Very high Safe and comfortable conditions for temporary workers ensure compliance and ethical standards
References	Röös et al. (2019)

S-47	Family Farm Income
Domain	Social
KPI	Labour
Description	Percentage of family farm income over total income
Goal	>75% 50-75% 25-50% 10-25% <10%
Interpretation	Recommended Goal: Very high High reliance on family farm income indicates greater independence and sustainability
References	Dos Santos & Ahmad (2020); Dos-Santos & Diz (2019)

S-48	Health Risk
Domain	Social
KPI	Labour
Description	Health risk for employees by pesticides and chemicals
Goal	Very low; Low; Medium possibility; High; Very high
Interpretation	Recommended Goal: Very low Minimizing health risks protects workers and reduces the potential for accidents or illness
References	Fourriè et al. (2013); Kelly et al. (2021)

S-49	New Jobs Recently
Domain	Social
KPI	Labour
Description	Job created in the last 12 months respect to the total employees
Goal	Gained >30% employees; Gained 1-30% employees; Stable number of employees; Lost 1-30% employees; Lost >30% employees
Interpretation	Recommended Goal: Gained >30% employees Significant job creation reflects growth and farm sustainable development
References	Fourriè et al. (2013); Gómez-Limón & Riesgo (2009); Kelly et al. (2021); Mazuela (2017); Paternoster (2011); Sánchez Fernández (2009); Zahm et al. (2008)

S-50	New Jobs Last 5 Years
Domain	Social
KPI	Labour
Description	Job created in the last 5 years respect to the total employees
Goal	Gained >30% employees; Gained 1-30% employees; Stable number of employees; Lost 1-30% employees; Lost >30% employees
Interpretation	Recommended Goal: Gained >30% employees A steady increase in employees over a longer period indicates continued success and expansion
References	Paternoster (2011); Röös et al. (2019)

S-51	Type contract
Domain	Social
KPI	Labour
Description	Partial versus total contracts
Goal	All employees with total contracts as required by them; All with total contracts; Mainly total contracts with some with partial contracts; Mainly as partial contracts; All partial contracts but not required by employees
Interpretation	Recommended Goal: All employees with total contracts as required by them Ensuring full-time contracts aligns with employees' needs and promotes job stability
References	Röös et al. (2019)

S-52	Working Hours
Domain	Social
KPI	Labour
Description	Number of working hours
Goal	Employees work right hours (according to the contract) Employees work +5% hours than they should do Employees work +5-10% hours than they should do Employees work +10-30% hours than they should do Employees work +30% hours than they should do
Interpretation	Recommended Goal: Employees work right hours (according to the contract) Maintaining standard working hours ensures compliance and prevents worker´s burnout
References	Fourriè et al. (2013); Kelly et al. (2021); Lebacq et al. (2013); Röös et al. (2019)

S-53	Working Intensity
Domain	Social
KPI	Labour
Description	Number of hours/year
Goal	<1500 1500-1800 1800-2100 2100-2400 >2400
Interpretation	Recommended Goal: <1500 Lower working hours per year contribute to work-life balance and well-being of employees
References	Dantsis et al. (2010); Dos Santos & Ahmad (2020); Dos-Santos & Diz (2019); Eurofound (2016); Fourriè et al. (2013); Gómez-Limón & Riesgo (2009); Kelly et al. (2021); Mazuela (2017); Röös et al. (2019); Sánchez Fernández (2009); Umstätter et al. (2022); Zahm et al. (2008); Wohlenberg et al. (2022)

S-54	Workers' Satisfaction Training
Domain	Social
KPI	Labour
Description	Level satisfaction for training and/or knowledge received
Goal	Very high; High; Medium possibility; Low; Very low
Interpretation	Recommended Goal: Very high High satisfaction with training indicates effective development programs and employee's engagement.
References	Rasmussen et al. (2017); Wohlenberg et al. (2022)

S-55	Workers' Training
Domain	Social
KPI	Labour
Description	Percentage of hours spent (hours of work) on improving employees' knowledge (training)
Goal	>20% 15-20% 10-15% 5-10% <5%
Interpretation	Recommended Goal: >20% Significant time spent on training reflects the farm's commitment to employee growth
References	Diazabakana et al. (2014); Fourrié et al. (2013); Kelly et al. (2021); Röös et al. (2019); Talukder et al. (2020); Wohlenberg et al. (2022)

S-56	Absenteeism
Domain	Social
KPI	Labour
Description	Hours lost due to absenteeism, % (month)
Goal	<4% 4-6% 6-8% 8-10% >10%
Interpretation	Recommended Goal: <4% Minimizing absenteeism ensures consistent productivity and employees´ satisfaction
References	Husgafvel et al. (2015)

S-57	Turnover
Domain	Social
KPI	Labour
Description	Employees changed in the last 5 years, %
Goal	<10% 10-20% 20-30% 0-40% >40%
Interpretation	Recommended Goal: <10% Low employees' turnover reflects stability and a positive work environment
References	Bondarchuk et al. (2022)

S-58	Workplace Accidents Frequency
Domain	Social
KPI	Labour
Description	Employees with injuries in the last 5 years (incidence)
Goal	0 1 2 3 >=4
Interpretation	Recommended Goal: 0 A low rate of injuries suggests good safety practices and worker protection
References	Fourrié et al. (2013); Kelly et al. (2021)

S-59	Wage
Domain	Social
KPI	Livelihood and well-being
Description	Income of the lowest paid employees' respect to minimum wage
Goal	>30% 15-30% 5-15% 1-5% = minimum wage
Interpretation	Recommended Goal: >30% Paying above the minimum wage reflects a commitment to fair compensation
References	Röös et al. (2019); Zahm et al. (2008)

S-60	Wage Magnitude
Domain	Social
KPI	Livelihood and well-being
Description	Difference between minimum and maximum income
Goal	>50% >100% >200% >300% >400%
Interpretation	Recommended Goal: >50% The smaller the difference between the lowest and the highest wage, the better the balance between workers
References	Briamonte et al. (2024)

S-61	Wage Range
Domain	Social
KPI	Livelihood and well-being
Description	Difference between farm average income and national average income
Goal	+50% +25% 0% - 25% -50%
Interpretation	Recommended Goal: +50% Higher income than the national average indicates better performance and employee welfare
References	Adapted from FAO (2014); Carr (2023)

S-62	Compensation & Benefits
Domain	Social
KPI	Livelihood and well-being
Description	Frequency compensation and benefits to employees, production awards
Goal	Always; Frequently; Sometimes; Rarely; Never
Interpretation	Recommended Goal: Always Regular rewards and benefits boost morale and encourage higher productivity
References	Röös et al. (2019)

S-63	Workers' Satisfaction Standard of Living
Domain	Social
KPI	Livelihood and well-being
Description	Level satisfaction for standard of living and personal health
Goal	Very high; High; Medium possibility; Low; Very low
Interpretation	Recommended Goal: Very high High satisfaction with living conditions and health ensures workers´ well-being and talent retention
References	Brown et al. (2021); Fourrië et al. (2013); Kelly et al. (2021); Röös et al. (2019); Santiago-Brown et al. (2015

S-64	Quality of Work
Domain	Social
KPI	Livelihood and well-being
Description	Satisfaction in number of holidays, weekend worked, permits, etc.
Goal	Very high; High; Medium possibility; Low; Very low
Interpretation	Recommended Goal: Very high Providing sufficient time off improves work-life balance and job satisfaction
References	Aparisi (n.d.); Business at Speed (2022); Kelly et al. (2018); Röös et al. (2019)

S-65	Freedom to Quit
Domain	Social
KPI	Livelihood and well-being
Description	Employees' freedom to quit work or raise grievances without fear
Goal	Very high; High; Medium possibility; Low; Very low
Interpretation	Recommended Goal: Very high Ensuring workers can freely express concerns promotes trust and workplace harmony
References	Röös et al. (2019)

S-66	Freedom to Discuss
Domain	Social
KPI	Livelihood and well-being
Description	Employees' freedom to negotiate as individuals or groups
Goal	Very high; High; Medium possibility; Low; Very low
Interpretation	Recommended Goal: Very high Allowing employees the full freedom to negotiate, either individually or collectively, ensures fairness and promotes trust in the workplace
References	Röös et al. (2019)

S-67	Freedom to Associate
Domain	Social
KPI	Livelihood and well-being
Description	Employees' freedom to be part of a union that represents them
Goal	Very high; High; Medium possibility; Low; Very low
Interpretation	Recommended Goal: Very high Providing employees with the ability to join and be represented by a union protects their rights and fosters a sense of security and belonging
References	Röös et al. (2019)

S-68	Safety Workplace
Domain	Social
KPI	Livelihood and well-being
Description	Safe and clean workplace
Goal	Very high; High; Medium possibility; Low; Very low
Interpretation	Recommended Goal: Very high Maintaining a safe and hygienic environment is crucial for preventing accidents and promoting worker well-being, both physical and psychological
References	Röös et al. (2019)

S-69	Quality of Life Satisfaction
Domain	Social
KPI	Livelihood and well-being
Description	Satisfaction level of physical and psychological wellbeing
Goal	Very satisfied; Satisfied; Partially satisfied; Not complete satisfied; Not satisfied; stressful working
Interpretation	Recommended Goal: Very satisfied High satisfaction with both physical and mental health is essential for ensuring the productivity and happiness of employees
References	Brennan et al. (2018); Fourrié et al. (2013); Kelly et al. (2021); Röös et al. (2019)

S-70	**Financial Satisfaction**
Domain	Social
KPI	Livelihood and well-being
Description	Satisfaction level of financial situation
Goal	Very satisfied; Satisfied; Partially satisfied; Not complete satisfied; Not satisfied, stressful working
Interpretation	Recommended Goal: Very satisfied Ensuring that employees feel satisfied with their financial compensation helps with retention and improves moral in the workplace
References	Röös et al. (2019)

Appendix 3: Environmental indicators detailed description

EN-1	Human Tox Score
Domain	Environmental
KPI	Health
Description	The indicator assesses a chemical's hazard to humans
Goal	Score from 0 to 5
Interpretation	Recommended Goal: 0 The higher the score, the more negative the evaluation
References	FP7 project INNOVINE (ID:311775), KBBE.2012.1.2-04

EN-2	Dose Area Index
Domain	Environmental
KPI	Health
Description	The indicator assesses the exposure of individuals to chemical products
Goal	Score from 0 to 5
Interpretation	Recommended Goal: 0 The higher the score, the more negative the evaluation
References	FP7 project INNOVINE (ID:311775), KBBE.2012.1.2-04

EN-3	Treatment Frequency Index
Domain	Environmental
KPI	Health
Description	The indicator assesses the chemical pressure on the fields
Goal	Score from 0 to 5
Interpretation	Recommended Goal: 0 The higher the score, the more negative the evaluation
References	FP7 project INNOVINE (ID:311775), KBBE.2012.1.2-04

EN-4	Carbon Footprint
Domain	Environmental
KPI	Air
Description	The indicator assesses the amount of greenhouse gases directly or indirectly released into the atmosphere due to human activities
Goal	Score from 0 to 5
Interpretation	Recommended Goal: 0 The higher the score, the more negative the evaluation
References	FP7 project INNOVINE (ID:311775), KBBE.2012.1.2-04

EN-5	Carbon Sequestration
Domain	Environmental
KPI	Air
Description	The indicator assesses how much carbon is sequestered by plant tissues (both above- and below-ground) during the growing season
Goal	Score from 0 to 5
Interpretation	Recommended Goal: 0 The higher the score, the more negative the evaluation
References	FP7 project INNOVINE (ID:311775), KBBE.2012.1.2-04

EN-6	Ecological Footprint
Domain	Environmental
KPI	Soil
Description	The indicator assesses the productive land and water surface areas necessary to both provide the resources and to absorb the emissions created by producing a certain good or service
Goal	Score from 0 to 5
Interpretation	Recommended Goal: 0 The higher the score, the more negative the evaluation
References	FP7 project INNOVINE (ID:311775), KBBE.2012.1.2-04

EN-7	Organic matter
Domain	Environmental
KPI	Soil
Description	The indicator assesses the percentage of organic matter contained in the soil
Goal	Score from 0 to 5
Interpretation	Recommended Goal: 0 The higher the score, the more negative the evaluation
References	FP7 project INNOVINE (ID:311775), KBBE.2012.1.2-04

EN-8	Soil Coverage
Domain	Environmental
KPI	Soil
Description	The indicator assesses the time in a year that the soil has coverage
Goal	Score from 0 to 5
Interpretation	Recommended Goal: 0 The higher the score, the more negative the evaluation
References	FP7 project INNOVINE (ID:311775), KBBE.2012.1.2-04

EN-9	Erosion
Domain	Environmental
KPI	Soil
Description	The indicator assesses the tons of soil lost per hectare due to water-caused erosion
Goal	Score from 0 to 5
Interpretation	Recommended Goal: 0 The higher the score, the more negative the evaluation
References	FP7 project INNOVINE (ID:311775), KBBE.2012.1.2-04

EN-10	Soil compaction
Domain	Environmental
KPI	Soil
Description	The indicator assesses the risk of soil compaction
Goal	Score from 0 to 5
Interpretation	Recommended Goal: 0 The higher the score, the more negative the evaluation
References	FP7 project INNOVINE (ID:311775), KBBE.2012.1.2-04

EN-11	Biodiversity (land use-based)
Domain	Environmental
KPI	Biodiversity
Description	The indicator assesses the farm's biodiversity, on the base of the different types of land use
Goal	Score from 0 to 5
Interpretation	Recommended Goal: 0 The higher the score, the more negative the evaluation
References	FP7 project INNOVINE (ID:311775), KBBE.2012.1.2-04

EN-12	Eco Tox Score
Domain	Environmental
KPI	Biodiversity
Description	The indicator assesses the chemical ecosystem hazard score
Goal	Score from 0 to 5
Interpretation	Recommended Goal: 0 The higher the score, the more negative the evaluation
References	FP7 project INNOVINE (ID:311775), KBBE.2012.1.2-04

EN-13	**Fuel use**
Domain	Environmental
KPI	Energy
Description	The indicator assesses the liters of fuel used for all mechanized operations carried out in the field
Goal	Score from 0 to 5
Interpretation	Recommended Goal: 0 The higher the score, the more negative the evaluation
References	FP7 project INNOVINE (ID:311775), KBBE.2012.1.2-04

EN-14	**Renewable fuel**
Domain	Environmental
KPI	Energy
Description	The indicator assesses the farm's use of fuel from renewable sources
Goal	Score from 0 to 5
Interpretation	Recommended Goal: 0 The higher the score, the more negative the evaluation
References	FP7 project INNOVINE (ID:311775), KBBE.2012.1.2-04

EN-15	**Waste**
Domain	Environmental
KPI	Energy
Description	The indicator assesses the farm's waste management
Goal	Score from 0 to 5
Interpretation	Recommended Goal: 0 The higher the score, the more negative the evaluation
References	FP7 project INNOVINE (ID:311775), KBBE.2012.1.2-04

EN-16	**Water Footprint**
Domain	Environmental
KPI	Water
Description	The indicator assesses the sustainability of the types of water used for crop irrigation
Goal	Score from 0 to 5
Interpretation	Recommended Goal: 0 The higher the score, the more negative the evaluation
References	FP7 project INNOVINE (ID:311775), KBBE.2012.1.2-04

EN-17	Water supply
Domain	Environmental
KPI	Water
Description	The indicator assesses the sustainability of the types of water used for crop irrigation
Goal	Score from 0 to 5
Interpretation	Recommended Goal: 0 The higher the score, the more negative the evaluation
References	FP7 project INNOVINE (ID:311775), KBBE.2012.1.2-04

EN-18	Water Use Technical Efficiency
Domain	Environmental
KPI	Water
Description	The indicator assesses the sustainability of the irrigation system used in crop production
Goal	Score from 0 to 5
Interpretation	Recommended Goal: 0 The higher the score, the more negative the evaluation
References	FP7 project INNOVINE (ID:311775), KBBE.2012.1.2-04

EN-19	Acidification
Domain	Environmental
KPI	Water
Description	The indicator assesses the emissions into the air of acidifying gases due to the production process
Goal	Score from 0 to 5
Interpretation	Recommended Goal: 0 The higher the score, the more negative the evaluation
References	FP7 project INNOVINE (ID:311775), KBBE.2012.1.2-04

EN-20	Eutrophication
Domain	Environmental
KPI	Water
Description	The indicator assesses the effect of added phosphoric and nitrogenous compounds on water ecosystems
Goal	Score from 0 to 5
Interpretation	Recommended Goal: 0 The higher the score, the more negative the evaluation
References	FP7 project INNOVINE (ID:311775), KBBE.2012.1.2-04

List of Figures

List of Tables