Sustainable intensification of food production through resilient farming systems in West & North Africa

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Replicability Indicators

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ABSTRACT

Food production to feed the ever-growing population of the world would have to be doubled by 2050. Achieving such greater strides in the agricultural sector growth requires the adoption of existing and new technologies and innovations. Often, agricultural innovations are tested in pilot environments and, if deemed successful, are expected to scale to a level enabling matching the size of the problem. However, many innovations though promising in terms of increased sustainability, do not scale up to achieve wider impact, cease to exist after a (subsidized) demonstration phase, and fade out after initial funding ends. The Analysis of Replicability is a key activity to effectively and efficiently ensure the wider possible adoption or replication of solutions/projects once adapted to specific contexts. The present document constitutes Deliverable D5.4 “Replicability Indicators” which is a step toward “Developing a methodological framework for replicability analysis” in the framework of the SustInAfrica project. The analytical framework aims to combine qualitative and quantitative research to help to analyze the replicability potential of the SustInAfrica technologies and solutions and to provide a track to perform such analysis in other contexts and concerning the most possible types of innovation. The framework is meant to analyze drivers and success factors, screen replication, and transfer potential in local contexts as well as to explore which are possible ways forward facilitating widespread adoption of innovations. The methods applied for setting the in-depth analysis include primary and secondary literature analysis, desk research, semi-structured, qualitative interviews, and focus groups with relevant stakeholders. Ways for data collection will be integrated into individual case study reports as they are case-specific and based on choices shared among all project partners. The achievements will identify a coherent set of key results and main project messages to be exploited.

Keywords: agriculture, evaluation, exploitation, indicators, innovation, replicability, SustInAfrica

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Abbreviations and Acronyms

AIS	Agricultural Innovation Systems
BAU	Business As Usual
ICT	Information Communication Technologies
NGO	Non-Governmental Organization
PPP	Public-Private Partnership
RA	Replicability Analysis
R&D	Research and Development
SDG	Sustainable Development Goal
TRL	Technology Readiness Level
WP	Work Package

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1. Introduction

Agriculture and the worldwide food system are constantly under pressure by manifold challenges including natural hazards and intense climatic events population growth, water issues, and resource distribution. The consequences of the COVID-19 pandemic have further exposed the vulnerability risks of agricultural value chains against external shocks. In Africa, food systems are now at a crossroads due to the multifaceted nature of challenges facing its food systems. In many countries, substantial efforts are needed to sustain and accelerate agricultural development, increasing the resilience of local food systems. Agricultural innovation development is seen as a powerful means to address the problem of low agricultural productivity in sub-Saharan Africa. Since 2001, much of Africa has enjoyed sustained growth of agricultural value-added (Mukasa et al., 2017). However, agriculture and food innovation systems are facing new and increasingly complex challenges and constantly evolving varying greatly across countries (WIPO, 2017).
Innovation and innovation diffusion is being considered more important than ever before, as the global food system evolves toward "sustainable intensification". Through technological advancements or the adoption of innovative tailored practices, farmers and households can produce more with less, in the meanwhile achieving environmental and socio-economic benefits. Typically innovation is defined as the introduction of a unique product, service, system, process or approach or a combination of more than one, influenced by the specific needs in a certain geography or community that requires alternate approaches for undertaking the technical, technological, financial, and/or dissemination or governance aspects of the solutions (Selco, 2015). Some innovations originate from the private sector, some from informal processes in villages (farmers try out new methods and inputs), and some come from formal public research and extension services. Yet the spread and impact of the technologies/innovations are not felt on the ground because of several challenges that affect the development, dissemination, replication, adoption, and scaling up of technologies and innovations. Many agricultural development projects that appear highly successful on a pilot-scale prove impossible to expand or to be replicated on a larger scale (Anandajayasekeram, 2016). Often they cease to exist after a (subsidized) demonstration phase and fade out after initial funding ends (Woltering et al., 2019). Pilot projects are usually set up and managed in very controlled environments that make it very difficult to transition to the real world at scale (Woltering et al., 2019). In practice, many technologies on the shelf are either not useful in real life or are not reaching enough farmers (Ajayi, T. et al., 2018). Additionally, most farmers and producers in Africa face considerable risks – unpredictable and extreme weather events, weather, pests, disease, and unpredictable prices when selling: risks that deter investment and innovation. The low uptake of innovations is largely attributed to the design of technologies being incompatible with local socio-ecological systems and producers' capabilities or because implementing actors have not sufficiently understood or effectively engaged with the scaling process (Shilomboleni and De Plaen, 2019).
Over the last five years, development organizations have started to look more seriously at how a successful transition from initial farmer adoption in pilot projects to the self-propelling and sustained uptake of technologies can be implemented more systematically (Van Loon et al., 2020). Therefore, the concepts of "transfer", "replication", "scaling-up" and "scaling-out" are being increasingly promoted as important elements to avoid project demonstrators being merely a local experimental exercise. They aim to achieve the desired expansion of beneficial impacts that may result from agricultural research to overcome certain constraints in the agricultural sector for sustainable rural development. Providing improved technologies to producer organizations is essential, but their uptake is often limited by the legal, regulatory, policy, and institutional framework. Understanding the factors that determine the adoption/diffusion of new techniques, practices, processes, technologies is critical in understanding factors hindering uptake and

therefore scaling up of innovations (Ampadu-Ameyaw et al., 2017). Work Package 5 focuses on the analysis of sustainability, replicability, and exploitation of the SustInAfrica project's findings, approaches, and technologies. These have been characterized into domains such as irrigation management, crop pest, and disease, improved agronomic and cultural practices, and solutions to increase access to farmers and simplify transactions throughout the whole agricultural value chains. The project aims to propose to new contexts identified by the project some innovations and practices that already proved to be sustainable in some contexts. Such innovations will be tested and adapted to local contexts and evaluated for productivity and sustainability in new local conditions. It should then describe how the proposed intervention alters the dynamics of the innovation process, identify pathways for optimizing the synergies and managing the trade-offs as well as create and exchange knowledge to facilitate the adoption of agroecological and other innovative approaches. Understanding and overcoming the factors that influence the spread of these techniques and innovations is crucial to scale up not only to accelerate the uptake of such innovations but to increase benefits for the whole agroecological zones.

The analysis of replicability aims to provide a conceptual framework to achieve such a task while the main objective of this deliverable is to deliver a set of indicators to assess the replicability/adaptability of SustInAfrica innovations in heterogeneous territorial and socio-economic contexts of the project. The goal is to set a replicability strategy able to multiply the impact of the project results during its implementation and to replicate and transfer its findings after its end, to reach a wider audience and implement its results in further sites and regions, other than the project demo sites.

Replicability is the potential or a project, innovation or pilot test to be replicated, scaled up, expanded, or adapted (FAO, 2014); it is the property of an activity, process, or test result that allows it to be duplicated at another location or time (http://www.businessdictionary.com/definition/replicability.html). Therefore, the replicability analysis will consider two main components: 1) Transferability - The assessment of the potential to transfer the process, the case study, or the pilot plant (or the Development model) to other geographical areas characterized by other contexts (environmental and socio-economic context); 2) Scalability - i.e. the identification of the research maturity level (related to the Technology Readiness Level - TRL). The methodological framework for the analysis of replicability will be set, applied, and tested through tasks T5.2.2 (T5.2.c: Assess replicability (M13–M48) and T5.2.3.

2. SustInAfrica project

SustInAfrica (www.sustinafrica.com) is a research project aiming to empower West and North African smallholder farmers and small and medium enterprises (SMEs) to promote the sustainable intensification of African farming systems. It aims to apply a systematic approach to develop and deploy tailored agricultural practices and technologies, to intensify primary production to achieve self-sufficient, sustainable production and resilient communities in Ghana, Burkina Faso, Niger, Egypt, and Tunisia (Fig. 1). It will provide business models and policies to help local producers to adopt and further develop practices and technologies supporting farmers in their decision-making. SustInAfrica involves 16 partner organizations from 11 countries. The project started on 1.9.2020 and will continue for five years. The budget of the project is 7 million EUR. Funding for the project comes from European Union's Horizon 2020 program.

Figure 1. Target SustInAfrica Countries (TN = Tunisia, EG = Egypt, NE = Niger, BF = Burkina Faso, GH = Ghana).

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3. Conceptual background beyond actions

To enable a Sustainable Intensification of food production in the frame of facilitating the agroecological transition toward a sustainable food system, SustInAfrica ensures that a wide range of important challenges is addressed through both shared and differing approaches at local and regional scales. Landscape, soil, water, and plant health management strategies, as well as the way toward sustainable agricultural systems, will be ensured by the different combinations of adopted innovations, depending on the requirements of each trial site, through a demand-driven multi-actor approach.

At this stage of the project implementation, most of the activities revolve around local communities and farming systems; therefore this is a key concept to be defined and shared among partners and local stakeholders.

3.1 Agriculture / Farming system and Agroecological Practices

There is a large diversity in definitions for farming systems. One commonly used definition of a farming system is that of Dixon et al. (2001) “A farming system is defined as a population of individual farm systems that have broadly similar resource bases, enterprise patterns, household livelihoods, and constraints, and for which similar development strategies and interventions would be appropriate. Depending on the scale of the analysis, a farming system can encompass a few dozen or many millions of households”.

Table 1. Terms regarding the farming system.

Term	Definition
Farm	A farm is an economic unit in which crop and animal production is carried out to produce economic net returns
Farming	It is a process of harnessing solar energy in the form of economic plant and animal products.
System	A system implies a set of resources and inter-related practices organized into a functional entity i.e. an arrangement of components or parts that interact according to some process and transforms inputs into outputs
Cropping system	Crops and crop sequences and the management techniques used on a particular field over years.
Cropping pattern	It indicates the yearly sequence and/or the spatial arrangement of crops and fallows in an area.
Monocropping	Growing of only one crop on the same piece of land year after year.
Intercropping / crop association	Growing two or more crops simultaneously on the same piece of land with a definite row arrangement.
Food system	Food systems gather all the elements (environment, people, inputs, processes, infrastructures, institutions, etc.) and activities that relate to the production, processing, distribution, preparation, and consumption of food and the outputs of these activities, including socioeconomic and environmental outcomes (HLPE 2014).
Sustainable food systems	Those food systems aim at achieving food and nutrition security and healthy diets while limiting negative environmental impacts and improving socio-economic welfare.

The farming system is a complex inter-related matrix of soil, plants, animals, implements, power, labor, capital, and other inputs controlled in part by farmers/producers and influenced to varying degrees by political, economic institutional, social and cultural forces that operate at many levels. Farming enterprises include crops, dairying, poultry, fishery, sericulture, piggery, apiary, tree crops, etc. ‘Farming’ is a process of harnessing solar energy in the form of economic plant and animal products. ‘System’ implies a set of

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interrelated practices and processes organized into a functional entity, i.e. an arrangement of components or parts that interact according to some process and transforms inputs into outputs. Cropping systems are usually the most important component of a farming system. Depending on the resources and technology available, different types of cropping systems are adopted on farms. Broadly three types of cropping systems can be identified: Sole cropping, monoculture, and multiple cropping (intercropping, mixed cropping, and sequential cropping). Farming systems can entail a diversity of cropping systems that share similar characteristics depending on the context. The farming system has the purpose of achieving sustainable production; this means that farming systems aim to evolve in technically feasible and economically viable farming system models by integrating cropping with allied enterprises to generate income and employment from the farm.

The food system is a complex web of activities involving production, processing, transport, and consumption. It encompasses the entire range of actors and their interlinked value-adding activities (Figure 2). Food systems are composed of subsystems (e.g. farming systems, market systems, waste management systems, and input supply systems) and interact with other systems (e.g. energy systems, trade systems, and health systems). They rely on the availability, both in terms of quantity and quality, of natural resources (e.g. land and water) and ecosystems services (e.g. pollination and biodiversity), and have strong interlinkages with other sectors and policies. Sustainable food systems are those food systems that aim at achieving food and nutrition security and healthy diets while limiting negative environmental impacts and improving socio-economic welfare. Fig. 2 provides a comprehensive view of the food system, the different actors, and the four capital stocks at stake, underlining the complexity of the relationships.

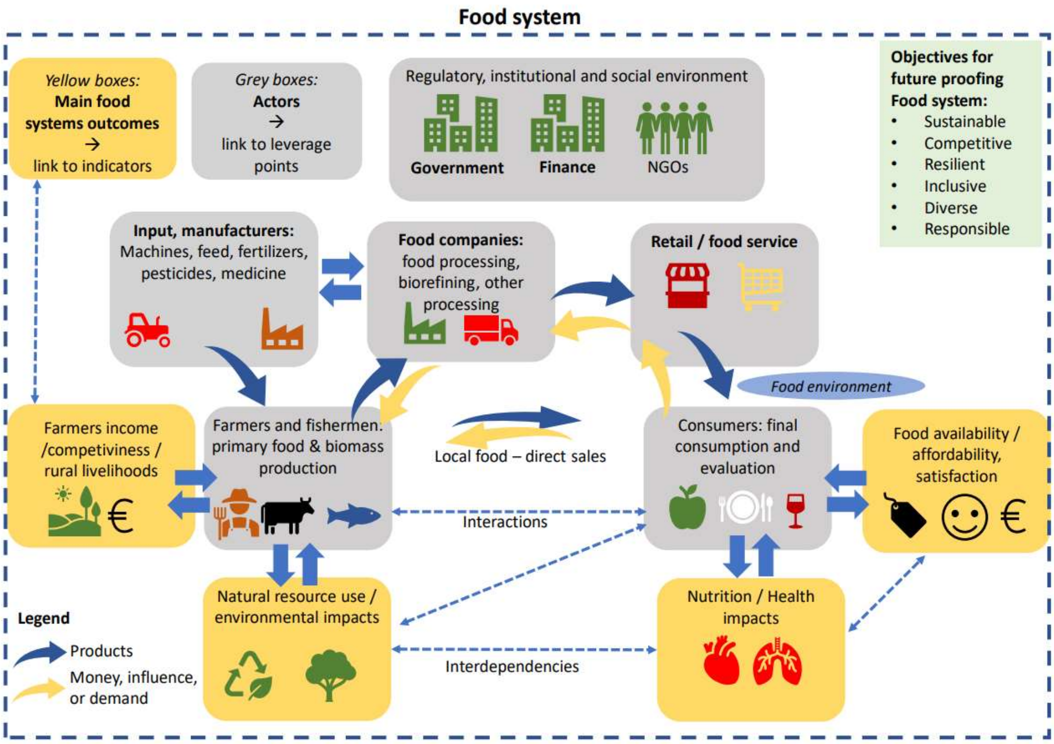

Figure 2. A schematic representation of the food system, with actors, outcomes, and relations.

In most countries, governments provide strategic guidance for research and innovation and provide funding to research institutions, private companies, and advisory systems (Table 2). The activities include fostering knowledge markets through protecting intellectual property rights (IPRs), providing direct or

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indirect financial incentives, engaging in public-private partnerships (PPP), and providing information and sharing the outcomes of public research (spill-overs).

Table 2. Agricultural actors and roles in innovation.

Actor	Example	Role
Producer organizations	i. Family farmers ii. Small-scale farmers iii. Large-scale commercial farmers iv. Fisherfolk v. Pastoralists vi. Landless (honey, butterfly larvae producers, etc.)	Innovate and share innovations, provide demands to agricultural advisory services, agricultural research systems, and agricultural education system.
Agricultural advisory services	i. National governments ii. Regional and local governments iii. Non-governmental organizations iv. Producer organizations v. Private sector	Link producers with other actors in the agricultural innovation system; share information, educate producers, broker, empower, advise, innovate, and share innovations, assess demand.
Government policy and regulatory framework	i. Regulating agencies ii. Parliamentarians iii. Heads of departments, senior managers iv. Ministers v. Global or regional agencies	Regulation, creation of standards; policy dialogue, policymaking, set codes and standards within organizations
Consumer demand	i. Consumers	Purchase products create demand, influence policy.
Agricultural education system	i. Universities ii. Schools (primary, secondary) iii. Colleges iv. Training institutions v. On-the-job training within institutions vi. Informal education vii. Vocational training	Education, advisory services, research, innovation, and share innovations.
Agricultural research system	i. Government actors ii. Private sector actors iii. Producers organizations	Innovate and share innovations, assess demand, conduct and communicate research, advise producers; educate producers, private sector actors, and agricultural advisory services.
Input and service suppliers	i. Agrochemical retailers (fertilizers, pesticides) ii. Machinery manufacturers, mechanics, retailers iii. Seed suppliers and retailers	Provision of goods and services.
Financial service suppliers	i. Banks ii. Microfinance institutions iii. Microcredit, credit agencies	Provide loans and credit, advise producers.
Private sector actors	i. Agriprocessors ii. Input dealers iii. Distributors iv. Traders v. Exporters vi. Large corporations	Innovate and share innovations; assess demand, provide inputs, distribute inputs, purchase, process, trade, and export produce, educate, advise.

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The goal is to ensure that all farmers have access to a competitive supply of advisory services, covering both productivity and sustainability aspects, and types of advice (technology, management, policy, or marketing). Farm advisory systems play an important role in the transfer and successful adoption of innovation, in particular at the early stages of development. They are in transition to adapt to new needs and provide a wider range of advice requiring re-training and flexibility. In addition to established advisory services, farmers receive advice from input suppliers, downstream industries. On the other hand, education institutes (from vocational training to university) could advance education and training toward agricultural innovation system development while stronger research systems may increase the supply of new knowledge and new technologies. Investments in an innovation system require integrated programs (such as subsidies or credit) that allow beneficiaries to adopt innovations.
Optimised and tailored agricultural practices and technologies have the potential to revolutionize agriculture by helping farmers work more precisely, efficiently, and sustainably. Smart farming and precision agriculture, are modern farming management concepts that promote digital techniques to monitor and optimize agricultural production processes. They consist mainly of a combination of new sensor technologies, satellite navigation, positioning technology, and the use of mass amounts of data to support decision-making on farms (Table 3).

Table 3. Examples of technologies that could accelerate the transition to sustainable agriculture.

Type	Examples
Digital technologies	Sensors, smartphones
Precision technologies	Spraying, Spreading livestock manure and organic fertilizers, Precision irrigation, Self-guiding and assisted guidance equipment
Autonomous technologies	Robots, Assisted guidance
Specific technologies supporting new cultivation practices	New machines and equipment for continuous soil cover, Mechanical weed management, Mixed cropping and agroforestry, Efficient livestock, and closed-loop systems

Transforming agriculture in the context of climate change to ensure global food security and safety is a central challenge society has to face. Current crises, including the climate and biodiversity crisis, the COVID pandemic, underemployment, under- and malnutrition, obesity, and health concerns associated with agricultural pollution are renewing the strategic challenges of agriculture and food systems. The COVID pandemic underlined the necessity to develop local food systems that contribute to multidimensional goals, benefiting humans and the environment altogether. The concept of agroecology appears as an appropriate answer to meet both the challenges of global sustainability and local resilience (HLPE, 2019), though it has rarely been considered a solution for the areas under the focus of the SustInAfrica project, and agroecological approaches are not widely adopted. Knowledge, practices, and social capital come together to arrive at agroecological systems of production and can transform agrifood systems (Fig. 2); therefore innovative solutions based on the joint adoption with agroecological practices, tailored to local farming and cropping systems, are urgently required. The term “agroecological practices” emerged in the 1980s with the development of the field of agroecology. "Agroecological practices can be characterised as agricultural practices aiming to produce **sufficient amounts of food** while **valorising naturally occurring ecological processes and ecosystem services**, with their integration as fundamental elements in the development of the said practices (considered as indivisible part of practice) (Wezel et al., 2014).
Agroecology takes **a whole-systems approach to the management of the farm or agroecosystem**, because it assumes that **biological processes** can replace chemical or physical inputs, or interact favourably with

them, while limiting negative externalities, particularly considering the environment. The agroecological approach is seen as an alternative to the widespread model of **simply relying on external inputs** such as chemical fertiliser and synthetic pesticide applications, or some technological solutions such as genetically modified organisms, etc. The agroecological induced in the food system corresponds to the application of 10 agroecological criteria or elements consolidated by FAO (FAO, 2018a) and further elaborated into 13 principles by (HLPE, 2019). **The principles**, which when applied in a particular region take different **technological forms depending on the local socio-economic needs** of farmers and their **biophysical circumstances; as a consequence,** each **practice is linked to one or more principles** thus contributing to the well-functioning of the agroecosystems.

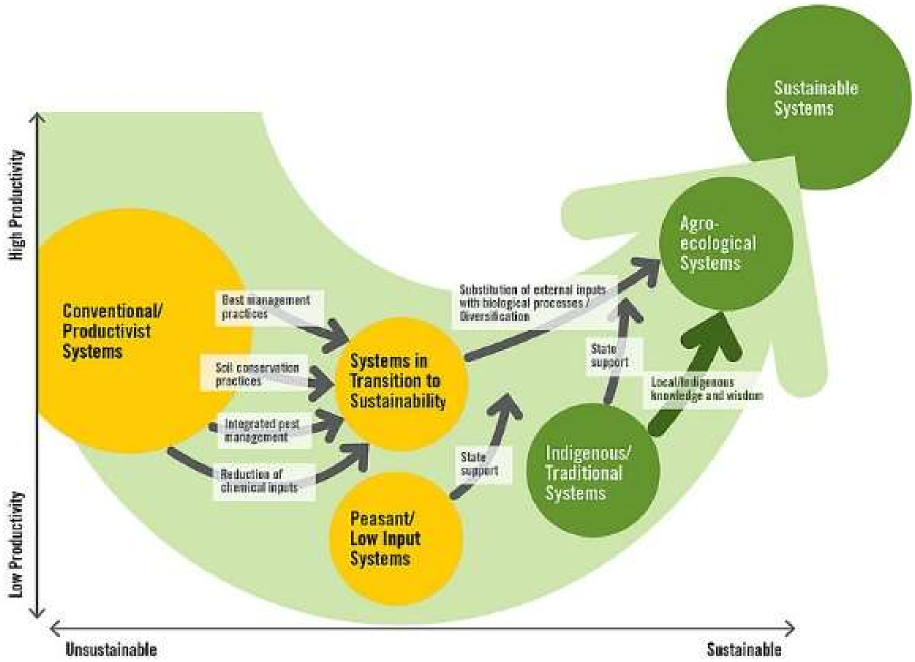

Figure 3. Agroecology for Nourishing the World and Transforming the Agri-Food System (Source: Herren et al., 2015).

Agroecological practices may impact **a set of ecological interactions** that drive key processes for agroecosystem functioning (nutrient cycling, pest regulation, productivity, etc.), and respond to the following three main objectives: **i)** improve resource efficiency, **ii)** strengthen resilience, and **iii)** secure social equity/responsibility, all acting to achieve sustainable food production.

As a consequence of these conceptual connections, the agroecological practices can be grouped into four categories, depending on their impact-induced on the system and the typology of change induced. Here below categories in which practices are grouped are reported:

- **Efficiency** (**E**) increase refers to practices that reduce input consumption (e.g. water, pesticides, and fertilizers) and improve crop productivity.
- **Substitution** (**S**) practices refer to the substitution of an input or a practice (e.g. replacing chemical pesticides with natural pesticides).
- **Redesign** (**R**) refers to the change of the whole cropping or even farming system.
- **Diversification** (**D**) refers to practices that integrate a higher diversity of cultivars, crops, or production systems.

The application of the different agroecological practices can modify the farming system at different scales, a) at crop management/plot scale or b) at the cropping system/field scale or c) farming system scale. In the case

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of a **single practice**, the level of change is usually low because the farmer has changed or adapted only part of the crop management (for example, applying **biofertilisers or changing crop cultivars);** when the practices require modification of the cropping or farming system, the necessary **level of system** change is normally **medium** or **high** because a much larger part of the system has to be reorganised or redesigned (for example, weed management and or redesign of crop rotations). The adoption of a combination of them can be highly innovative in the contexts of the diverse cropping and farming systems focussed by the project.

Agroecological concepts are primarily based on traditional and local knowledge and its corresponding cultures. Agroecology is a set of practices to be built, while agro-equipment and digital technologies are a set of resources to be mobilized, with others, to achieve the objectives of sustainable agricultural production (Table 4).

Table 4. Agroecological management practices: each practice is assessed according to the conceptual framework (efficiency increase (E), substitution (S), redesign (R) and diversification (D), the induced system change and the actual integration into today's agriculture, and medium or high potential for the future (adapted from Wezel et al. 2014 and 2016).

Agricultural practices	Impacts	Description of practice	System changes	Current integration	Future potential
Efficiency increase and substitution practices					
Cultivar and crop choice	E,S E,D	Use of site-adapted cultivars and crops Cultivar mixing	Low Low	High High	High High
Crop fertilisation management	E,S,R	Split fertilisation; Biofertiliser; Organic fertilisation	Low Low Medium	High Low Medium	High Medium Medium
Weed, pest, & disease management	S	Natural plant protection products; Biological pest control	Low Medium	Low Medium	Medium High
Water management	E,R,D	Drip irrigation ; Soil erosion control with integration of landscape elements	High High	Medium High	High High
Redesign and diversification: practices in cropping systems					
Tillage management	E,S,R	Direct seeding into living cover crops or mulch; Reduced tillage	High High	Low Medium	Low/Medium Medium/High
Soil covering	S,R,D	Cover crops	Medium	Low	High
Crop rotations	S,R,D	Diversified crop rotations (legouminous interation, green manuring,)	Medium	Low	High
Crop associations	E,S,R,D	Intercropping and Relay intercropping	High	Low	Medium
Weed, pest, and disease management	S,R,D	Allelopathic plants; Push and pull systems; insectary beneficial arthropods plantings, flower strips, ecological focus areas,	Low Low	Low Low	Medium Medium
Redesign and diversification: integration of production systems					
Agroforestry	E,S,R,D	Integration of timber, fruit, nut, nitrogen-fixing plants and trees and/or shrubs	Medium	Low	High
Management of landscape elements	S, R, D	Integration of semi-natural landscape elements for biological control, pollination, erosion control at field, farm, or landscape scale	High	Low	Low

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3.2 What is innovation?

Innovation is everywhere and it has been the subject of a variety of research studies. Our project assumes that some innovations can influence and act positively on the development of an area, accelerating its transition towards greater sustainability; on the other hand, society, politics, and culture affect scientific research and technological innovation, and therefore the innovations and the studies and observations that have had the innovations as their object, have classified, described and characterized the innovations themselves in different ways, generating different TAXONOMIES of innovation. Generally, the term innovation is defined in one of two ways: "(1) the introduction of something new, or (2) a new idea, method, or device. The first definition mainly considers innovation as an outcome. The second definition introduces the concept of innovation as a process. However, the field of innovation has evolved over the years and nowadays there are different understandings and definitions of innovation (Table 5). Despite the vast body of literature available, it is still very difficult to provide a comprehensive definition of the term and clearly describe its nature (Stenberg, 2016) because innovation is a multidimensional concept that includes varied meanings. The general definition of innovation is as follows (OECD and Eurostat, 2018): "An innovation is a new or improved product or process (or a combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process).

Table 5. Definition of innovation across the literature.

Author	Innovation definition
The New Oxford Dictionary of English. 1998: Oxford University Press	'Making changes to something established by introducing something new'
(Anahita et al., 2009)	Innovation is the multi-stage process whereby organizations transform ideas into new/improved products, services, or processes, to advance, compete and differentiate themselves successfully in their marketplace.
(Lattimer, 2013)	A new approach that has not been tried or tested elsewhere can generate learning for the stakeholders involved, and that has strong potential to be scaled up to bring positive results for the people.
(Fatunbi et al., 2017)	A product of the application of new knowledge and or a combination of new and existing knowledge for economic gain.
(OECD and Eurostat, 2018)	A new or improved product or process (or a combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process).
FAO (2013)	Agricultural innovation is the process whereby individuals or organizations bring new or existing products, processes, or ways of the organization into use for the first time in a specific context, to increase effectiveness, competitiveness, and resilience to solve a problem.

A specific focus deserves agriculture innovation. According to FAO (FAO, 2018b), agricultural innovation is the process whereby individuals or organizations bring new or existing products, processes, or ways of the organization into use for the first time in a specific context, to increase effectiveness, competitiveness, and resilience to solve a problem. Wu and Zhang (2013) define farmer innovation as any technology, invention,

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or improvement made by rural people to cope with the complexity of local resource, ecological, economic, and social conditions. There is a huge variety of new technologies and farm practices as well as organizational and management techniques that can be classified as agricultural innovations. It could be, for example, the adoption of a new seed variety or forward contracting, diversifying the farm business, or implementing the use of a farm accountancy program.

The term innovation can be defined as something original and more effective and, as a consequence, new, that “breaks into" the market or society. To be called an innovation, an idea must be replicable at an economical cost and must satisfy a specific need. Innovation occurs at various levels within an organization, from management teams and departments to project teams and even individuals (Handen, 2014). An innovation system is governed by the prevailing institutions and policies that affect the performance of the actors involved and the regulation of the technologies developed (World Bank, 2007). Innovation systems comprise the complex interplay between the core innovation and the three types of landscapes in which the core innovation is embedded (Sartas et al., 2020):

1. The innovation landscape: the enabling environment or complementary innovations that may impede or support the scaling of the core innovations;

2. The intervention landscape: the set of projects, programs, and other initiatives that are working on similar problems, have similar objectives, and/or are developing and scaling compatible or competing core or complementary innovations;

3. The stakeholder landscape: the networks of stakeholders and their constituencies that can influence, develop, or work on innovations.

These three “landscapes” will be all considered by the analysis of replicability.

3.2.1 Innovation vs. Invention

Innovation is widely recognized as a critical dimension of sustainable development as well as sustainable consumption and production (El Bilali, 2018). The term ‘innovation’ is often confused with the term ‘invention’ although they have quite different (Table 6) meanings in dictionaries (Kotsemir and Abroskin, 2013; Surbhi, 2016).

Table 6. Innovation and invention differences.

Basis for comparison	Invention	Innovation
Meaning	The invention refers to the occurrence of an idea for a product or process that has never been made before.	Innovation implies the implementation of an idea for a product or process for the very first time.
What is it?	Creation of a new product.	Adding value to something already existing.
Concept	An original idea and it's working in theory.	Practical implementation of a new idea.
Skills required	Scientific skills	Set of marketing, technical and strategic skills.
Occurs when	A new idea strikes a scientist.	A need is felt for a product or improvement in an existing product.
Concerned with	Single product or process.	Combination of various products and processes.
Activities	Limited to the R&D department.	Spread across the organization.

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The invention is defined as the act of creating, designing, or discovering a device, method, process, that has not existed before (Ajayi, T. et al., 2018); innovation is the act of applying or adopting an invention. The invention is the first occurrence of an idea for a new product or process, while innovation is the first attempt to carry it out into practice (Fagerberg, 2018). The invention is concerned with a single product or process; as against this, innovation may focus on the combination of various products and services. The process of innovation must be viewed as a series of changes in a complete system not only in its hardware, but also in the market environment, production facilities and knowledge, and in the social contexts of the innovation organization (Kline, 2009).

3.2.2 Classification of innovation

The term innovation is very versatile with various types of innovation about the object of innovation and the degree of innovation. The first classification is thus the object of innovation. The Oslo Manual, an international reference guide from the OECD for collecting and using data on innovation, there are four main types of innovation (Table 7): product innovation, process innovation, marketing innovation, and organizational innovation. Agricultural innovation, as well as innovation in agri-food, can be classified using the same categories (El Bilali, 2018). Complementary innovation strategies refer to the introduction of both technological and non-technological innovations.

Table 7. Classification of innovation according to the object of innovation.

Classification	Definition	Examples
Product innovation	A good or service that is new or significantly improved. This includes significant improvements in technical specifications, components, and materials, software in the product, user-friendliness, or other functional characteristics.	Final goods (e.g. an automated agricultural tool/machine, a new variety of fruit, customized farm management software, drought-resistant seeds, etc..) and services (e.g. specific financial advisory services to farmers, new smartphone apps, new logistic services, etc.)
Process innovation	A new or significantly improved production or delivery method. This includes significant changes in techniques, equipment, and/or software.	Computerized equipment for quality control of production, new farming techniques that can boost yield, smart irrigation, robotics and sensors, mapping by drones.
Organizational innovation	A new organizational method in business practices, workplace organization, or external relations	Producers organize themselves in new ways to increase their bargaining power when buying inputs and selling their produce; reform rural advisory services, participatory research approaches
Marketing innovation	A new marketing method involves significant changes in product design or packaging, product placement, product promotion, or pricing.	Farm website Selling products through e-commerce Having an off-farm short marketing channel

Another frequently used classification for innovation according to novelty is according to the extent of change and novelty (Table 8). They are divided into sustaining, incremental, disruptive, and radical innovation. Disruptive innovation means to reinvent a technology, business model, or simply invent it all together. As opposed to disruptive innovation, sustaining innovation, seeks to improve existing products. An example is the fertilizer market – every year, manufacturers release updated and improved products to meet consumer

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demand and to integrate new technology. Incremental innovations are just a little better than the previous version of the product or service. Companies can use incremental innovation to save costs and differentiate from competitors. While this does not create new markets and often does not leverage radically new technology, it can attract higher paying customers because it fulfills the customer needs. Radical innovation is rare as it has similar characteristics to disruptive innovation. Incremental and radical innovations are often distinguished using one or both of the following criteria (Bell, 2012): the novelty of the knowledge base underlying the innovation and the scale and significance of the innovation consequences. In agriculture, product innovations often involve incremental improvements rather than radical changes meanwhile, food, firms are mainly processing innovation-oriented.

Table 8. Innovation types according to object, degree, drivers, dimensions, and perspective.

Classification sign	The classification categories (types) of innovation
The object of innovation	Product, Process, Service, Marketing
Degree of innovation	Radical, Incremental, Sustaining, Disruptive
Drivers of innovation	Market pull innovations; Technology-push
Drivers of innovation	Bottom-up (originate from the users, from the citizens or farmers); Top-down (research-led) technologies
Dimension of sustainability	Economic (Eco), Environmental (Env), Social (Soc)
Innovation perspective	Technological, Administrative
Applications innovation	The managerial, organizational, social, industrial, agricultural, etc.
The intensity of innovation	Boom, uniform, weak, mass
The pace of implementation of innovations	Fast, slow, decaying, growing, uniform, abrupt
The scope of innovation	Transcontinental, transnational, regional, large, medium, small
The effectiveness of innovation	High, stable, low
Efficiency innovation	Economic, social, ecological, integrated
Innovation activity	Performing R&D, Sourcing patent rights, Buying or leasing equipment, software, hardware, or buildings, Training, Design, or engineering activities

According to drivers of innovation, innovation has been distinguished into 'technology push' innovation driven by technological discovery and 'market pull' innovation developed in response to market demand. From the innovation approach perspective, innovation can be grouped into technological innovation and administrative innovation for supply chain management. From the relationship perspective, innovation can also be distinguished into independent innovation and collaborative innovation. Two important types of technology and innovation are bottom-up (farmers generated) and top-down (conventional researcher generated) technologies and innovations (Ajayi, T. et al., 2018). Top-down approaches are typically research-led and often start with the formulation of visions of future production systems. This involves knowledge generation by scientists, transfer by extension, and adoption by farmers. Classification of innovation is presented in Table 8 (Kogabayev and Maziliauskas, 2017). Innovations can be developed in different ways: a company working alone, a company working as part of a group of companies, a company working with other companies or institutions, such as universities, or a company adapting or modifying goods and/or services originally developed by another company. Innovations can also be developed in-country or abroad. Innovations can be transferred within an organization, outside of the organization to another organization, or into the organization from another organization e.g. by cooperating with other organizations or copying an existing innovation. Generally speaking, any innovation transfer takes place through the transfer of data,

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information, or knowledge, explicitly by exchanging those or implicitly through the copying of products, processes, etc.

3.2.3 Barriers to adoption of innovation

Adoption is not an immediate activity but depends on a large range of variables. Adoption of innovation in agriculture may depend on farmer characteristics, farm structure, location, economic, behavioral, organizational, and institutional factors, and factors related to information. Innovation can be transferred or out-scaled, and barriers to replication of technologies and innovation differ between contexts and over time. Table 9 provides an overview of the key barriers (Long et al., 2016) to the adoption of innovations.

Table 9. Overview of barriers to the adoption of pro-environmental technological innovations (general and agriculture specific).

Barrier category	Type of barrier
Economic	High initial investments
	Poor access to capital
	Hidden costs
	Competing financial priorities
	Long pay-back periods (ROI)
	Switching costs/existence of the installed base
	High implementation costs (actual and perceived)
	Uncertain returns and results
	Temporal asymmetry between costs and benefits
	Over discounting the future
Institutional/regulatory	Low institutional support
	Use of overly scientific language (Jargon)
	Farmer's knowledge not considered in R&D
	Lack of regulatory framework
	Prohibitively prescriptive standards
Behavioral/Psychological	Lack of management support/awareness
	Conflict with traditional methods
	Overly complex technologies
	Results/effects of technology difficult to observe
	Farmer's beliefs and opinions
	The low trust of advisers or consultants/lack of acceptance
	Irrational behavior
	Negative presumed assumptions
Organizational	Lack required competencies/skills
	Poor readiness
	Poor information
	Inability to assess technologies
	Overly short-term/perverse rewards
	Organizational inertia/habitual routines
Consumers/Market	Poor information
	Lack market attractiveness/do not align to preferences
	Uncertainty
	Consumers/farmers' level of motivation
	Market uncertainty
Social	Social/peer pressures

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Eco-innovation implies high-cost investment and maybe risky returns than traditional innovations; on average, investments in environmental innovation are thus more costly and risky than conventional innovations (Guisado-González et al., 2021). Farmers will invest in and implement sustainable technologies and farm practices only if there are good reasons to do so, i.e. be more productive, more profitable, easier to use, cheaper, and with lower risk (Viatte, 2001). The investment cost presents a major challenge in rural areas where rates of poverty are often high (FAO, 2014). Decades of post-independence underinvestment in the sector, together with poor governance, have resulted in productivity levels that fall well below global averages and have pushed many smallholder farmers into subsistence farming (Shah et al., 2021). SustInAfrica project mainly deals with local communities and smallholders that have little cash for much of the year, so liquidity can easily limit innovation. This can prove to be a prohibitive disincentive, especially in the absence of secure land rights and access to financing and credit. Credit is very hard to obtain for most smallholders in rural Africa due to the creditworthiness of most farmers, administrative costs, and associated risks in farming, moreover, the lack of absolute ownership of the land implies insecurity.

Often, regulations can also erect barriers to the development of new, improved products and production processes (OECD, 1996). They can distort the choice of technologies that are explored and adopted. Institutional barriers are related to how institutional organizations and their interactions influence the way individuals are allowed and able to adopt changes. In many agricultural R&D projects, farmers are counted as users, rather than makers, of knowledge, though the advantages of using farmer knowledge to guide scientific research are numerous (Van Asten et al., 2009). If scientists' R&D shall be complemented by farmers' local knowledge this could lead to the development and promotion of sustainable, profitable, or socially acceptable technologies (Toffolini et al., 2017). One of the biggest impediments to the adoption of innovation is organizational inertia. Often, small-holder farmers tend to rely on tried and trusted methods because one wrong decision can jeopardize an entire growing season; but they readily adopt new technologies and practices that they perceive to be beneficial in their specific circumstances (FAO, 2014).

Regarding organizational barriers, lack of information on technology, lack of qualified personnel, and lack of knowledge and skills required to adopt the innovation impose constraints to the adoption of technology. For farmers to be able to make use of innovations, they need to know about them and how to use them. Farmers are more likely to adopt sustainable practices when most neighboring farmers have done so, when they follow the opinion of social referents who support adoption, and when they are willing to gain social status (Dessart et al., 2019).

Information barriers can prevent the uptake of agricultural technologies. For adoption to occur, farmers need to know that technology exists, believe that it will improve productivity, and understand how to use it effectively. Because farmers are not all equally diligent, skilled, experienced, and knowledgeable, the gap between actual farmer yields and the economically achievable yield in the local context can be huge. A major barrier to agricultural technology adoption in sub-Saharan Africa is the low quality of many agricultural inputs (often watered down or counterfeited) – coupled with a lack of reliable information on input quality.

In addition, a longstanding concern in rural Africa has been that markets do not work well in rural areas, and especially do not work well for farm inputs and financial services such as insurance and credit. Moreover, bureaucratic barriers as an important component of encouraging adoption and diffusion (Pratt et al., 2021). Information and communication technologies can play a key role in supporting knowledge sharing. Lack of basic literacy and numeracy presents a significant barrier to using digital technologies. Low overall smartphone ownership in rural areas, combined with the high cost of the internet and limited network coverage, also present challenges to the use of mobile agricultural applications and limit the scope to use

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social networks (FAO, 2019). However, the traditional models used to spread advice to farmers, such as agricultural extension services, are expensive and often ineffective. Trust is an essential component of the advisor-farmer relationship and the ability to build sustainable farming systems. A close connection between education level and the advisory and extension services may improve the effectiveness of the knowledge services as well as the mutual understanding between scientists and farm managers, which is not always fruitful as it could be (Ramos-Sandoval et al., 2019). On other hand, ICTs can help maximize the impact of existing rural advisory services, financial services, and social protection programs. ICTs facilitate access to markets, information, and entrepreneurship opportunities. The nature of interactions between farmers and advisors is the focus of a growing body of research. Overall, the adoption of technologies for sustainable farming systems will be facilitated by a wider participatory approach involving a range of stakeholders and multiple instruments. These stakeholders should include farmers, the agri-food industry, consumer groups, and non-government organizations with an interest in sustainable farming. Fostering greater adoption of improved inputs and technologies relies on education, training and extension services to support diverse production models, as well as access to credit and basic income or savings (Shah et al., 2021).

4. The SustInAfrica methodology and indicators for assessing Replicability

This chapter provides a general overview of the proposed approach to evaluate the potential replicability of the selected SustInAfrica solutions. Few analytical frameworks are available for the analysis of scalability and transferability components of replicability analysis; they include the scaling up management (SUM) framework; the ASAT - Agricultural Sustainability Assessment Tool (USAID, 2018); the Scaling Scan, a framework developed by the International Fund for Agricultural Development (IFAD) and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) (Woltering et al., 2019); the ADOPT (Adoption and Diffusion Outcome Prediction Tool) (Kuehne et al., 2017); and the Scaling Readiness (Sartas et al., 2020).

The replicability analysis, from a conceptual point of view, follows a sustainability analysis; in fact, only the innovations or solutions that have already proved to be "sustainable" are replicated in other contexts or adapted to other intervention scales. The innovations proposed in the SIA project are very diverse and require an effort for reframing a conceptual framework able to include this wide diversity in scope, readiness, and scale in the analysis; to analyze the replicability potential the SustInAfrica or conceptual framework will build on the IFES Analytical Framework developed by FAO (Bogdanski, 2014). This framework provides a glimpse on the replicability potential mainly through guiding the criteria to identify a set of quantitative and qualitative indicators that will help the SustInAfrica to help to understand inherent attributes of the innovations, screen innovations based on their impact on gender, nutrition, and farm-level sustainability (environmental, social, and economic sustainability), identify and analyze the barriers to replicability also on the base of information coming from the demo-sites experience as well as understand the availability of local capacity for adoption and upscaling as well as stakeholders and institutions that may promote the replication. As illustrated in Fig. 4, the methodology is implemented in 6 steps. Replicability analysis will heavily rely on other tasks of the project that analyze related aspects, namely tasks T1.2a, T1.2.b, T3.1, T5.1, and T.5.2. The steps necessary to carry out the analysis are also shared/in common with other WPs, for example with the WP1, for the analysis of the stakeholders, or the data collection.

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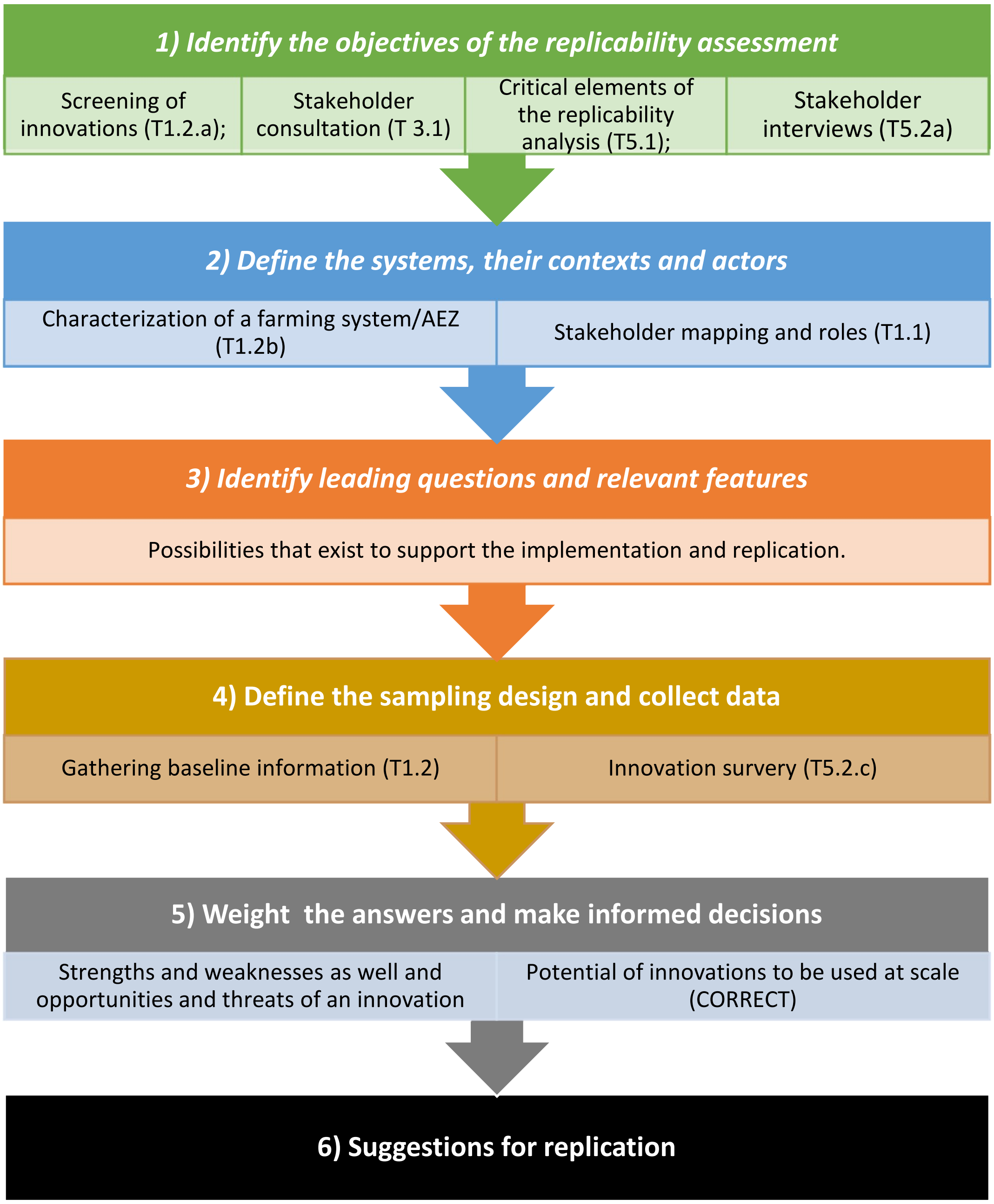

Figure 4. The general framework for replicability analysis.

The analytical framework uses a series of sample questions that highlight the different steps of interest to a replicability assessment (Table 10). These questions should help to generate the necessary data and describe the strengths and weaknesses and opportunities and threats of each innovation in a given context.

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Table 10. A detailed version of the sample questions to be used when analyzing replicability.

Stage/Step	Sample questions
Identify the exact objectives of the replicability assessment	▪ What kind of results do I expect from the assessment? ▪ What kind of problems do farmers face? Is there a demand for a specific innovation? ▪ What is going to be replicated? Why is such a replicability assessment necessary? ▪ Who tested the innovation? Who benefits from the innovation? Is the innovation compatible with local circumstances and preferences? What is the evidence of efficacy and impact?
Define system context and actors	▪ What boundaries are considered? ▪ What is the geographical and biophysical context where the inn. is going to be replicated? ▪ Who are the actors/stakeholders, their characteristics, and interactions? ▪ Which are the problems, changes, and opportunities that people have experienced while implementing innovations? ▪ Which organizations/groups/individuals influenced/discouraged the implementation of innovations?
Leading questions and relevant features	▪ What are the enabling or constraining features that simplify or complicate the replication of each innovation? ▪ What is the role of stakeholders and institutions in the replication of innovations? ▪ How does the policy environment (fiscal incentives, public finance, regulation, R&D) incentivize or disincentive the replication of innovations? ▪ How do human and technical capacity (education, training, and knowledge transfer) shape the replication of innovations?
Data elaboration: Weighting answers	▪ What are the strengths and weaknesses as well as opportunities and threats of an innovation? ▪ What challenges are likely to arise for farmers or other adopters in effectively adopting, implementing, and using these innovations? ▪ What are the obstacles to innovation, through what processes, and to what degree? ▪ What are the key success factors? ▪ How many years or seasons would a farmer or adopter need to recover the cost of adopting this innovation?
Suggestions for scale-up and replicability	▪ What public or private organizations are or are expected to be involved in the adoption of the innovation, or other relevant inputs? ▪ Which are the relevant financial mechanisms available, accessible, and affordable for innovation ▪ Who should be responsible for monitoring and evaluation? ▪ Which are planning actions to increase the scalability of the innovation?

4.1 Identify the exact objectives of the replicability assessment

The first step of RA is to identify the expectations and motivations behind doing a replicability assessment, i.e. the effects that may be expected from the implementation of the solution at a larger scale, at a different time and location. The main objective of WP5 "Replicability" is to assess the replicability of methods, technologies, and solutions developed/implemented by SustInAfrica (Table 11). SustInAfrica focuses on two regions: W. Africa, where soils typically suffer from poor fertility, due to loss of organic matter, acidification, reduced capacity to retain nutrients and erosion, caused by inappropriate soils management; and N. Africa, which suffers from water scarcity, land degradation, and desertification due to salinization, wind erosion,

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formation of crusts and compaction caused by poor land and water management. Therefore, SustInAfrica addresses the most common AEZs (i.e. forest-savanna, grass/bush-savanna, and desert) in W. and N. Africa and the most common farming systems of these AEZs. Once the geographical context took place, the first screening of information about farming challenges and agricultural practices and smart farming and monitoring technologies developed by WPs 1, 2 & 3 proposed in each crop/AEZ is conducted (Table 11). This part includes also the impact that the innovation adoption is expected (quantification) to have on the ecosystem services provisioned by ecosystems and agroecosystems of the local areas and communities. For each specific case and its context, local stakeholders are going to be invited to identify replicable solutions to their issues.

Table 11. Overview of farm challenges and proposed technological & agro-ecological practices in each country, cropping and AEZ.

Country	Farming challenges	Crop/AEZ	Proposed technological & agro-ecological practices
Ghana	Poor soil fertility; soil erosion; water scarcity; poor management knowledge (especially with regards to plant protection, climate change adaptation, and mitigation, production of preferable certified organic products).	Mango (Tamale)	Bluleaf, InsectaMon, Intercropping, flower strip, UAV.
		Maize (Ejura)	Push-pull system (with desmodium and apiergrass), compost and biochar, InsectaMon
		Pineapple (Ghana)	Insectamon, UAV, the impact of surrounding vegetation structure on pest and disease
Burkina Faso	Poor and declining soil fertility; soil erosion; water scarcity; food security threats; poor management knowledge (especially with regards to the production of certified organic products, sustainable soil, plant and water management, and climate change adaptation and mitigation), pest insects reduce yields	Cotton	Compost and biochar, UAV
Niger	Water scarcity; salinity and desertification in oases; erosion and desertification in savanna; competition for land between agriculture and livestock in Central Niger; introduction of non-palatable species in Central Niger.	Cowpea, Millet	Farmer managed natural regeneration (FMNR), alternate bands, living hedges, and FMN
Egypt	Low to very low soil fertility; water scarcity; poor management knowledge (especially with regards to peat management and organic farming).	Cotton	Compost application, Biochar application, Cover cropping
Tunisia	Water scarcity, Low soil carbon stocks, maintenance of plant health.	Olive	No-till, intercropping

The technologies developed by WPs 1, 2 & 3 will be benchmarked against an agreed set of internationally accepted metrics for potential climate resilience and impact on gender, nutrition, and the environment (socio-economic and environmental screening) (Task 5.1). Technologies that pass this stage will then be assessed for replicability. The critical elements of the replicability analysis will be identified based on the results of sustainability analysis (task 5.1) for each cropping system, production phase, and/or "output" of the project. A set of impact indicators will be selected (based on SDG indicator framework) by partners with different competencies and backgrounds for each of the proposed outcomes, analyzed for sustainability

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performance in WP5.1, and found sustainable. Meanwhile, structured interviews (Annex 1) were developed for implementing and supporting organizations to identify what the innovation is and list all components. It helps to describe innovation profile (the elements of the innovation) intervention profile (elements of the intervention) and replicability context (identify relevant elements and limiting factors to highlight (and overcome) the bottlenecks and stumbling blocks that can hamper the replicability of the solutions in the target areas). Then, validation of the descriptions of the innovation packages and their core and complementary innovations is carried out.

4.2 Define systems, their contexts and involved actors

Innovation arises in a particular socio-economic context and is shaped by the presence or absence of favorable conditions in which it can thrive; therefore, understanding this context is important to facilitate innovation. The second step of the RA includes the specific description of agro-food systems with components and boundaries, characterization of smallholder farming systems, the context in which the innovations will be replicated and actors to be involved (stakeholder profile), and the external influences[1]. Characterization of smallholder farming systems refers to describing the various categories of farms—their demographics, cropping systems, the farm household system, the principal inputs and outputs and processes and participants in crop production, attributes, production trends, and main constraints in the farming systems. Through characterization, existing farming systems within a study case can be studied. Maps and cartographies and GIS can be of great support in describing AEZs and also the farming and cropping systems. The characterization of farmers will include farmers participating in the SustInAfrica on-farm trials, and also compare these with non-SustInAfrica farmers. To achieve a characterization relevant criteria leading the sustainability analysis should be considered and appropriate indicators should be included in the next step to design the sampling and the collection of data. In our case reference will be made to D5.1 and primary data collection supported by T1.2.b: Baseline data collection and analysis of farming systems. The farming system is characterized by its actors (farms and other actors with mutual influence) and locality (Table 2). Once the key actors are identified, it is important to understand how they link together and where interacting with one may influence relations with another. Stakeholder mapping is supported by WP1 Task 1.1.

4.3 Identify leading questions and relevant features

The third step of the RA contains a set of leading questions and related features that will help to identify enabling environment (conditions that need to be in place for core innovations to have an impact at scale), the innovation landscape (the enabling environment or complementary innovations that may impede or support the replicability of the core innovations), the stakeholder landscape (the networks of stakeholders and their constituencies that can influence, develop, or work on innovations), policy environment and human capacity to adapt and put to use innovations. To answer some of the questions listed in Table 10, feedback from the main stakeholders will be obtained. A qualitative appraisal will be conducted using a checklist based upon CORRECT criteria: Credibility, Observability, Relevance, Relative Advantage, Easy-Transferability, Compatibility, and Testability, which are recognized critical elements for assessing innovation diffusion

[1] Include the actions of NGOs and pressure groups, innovations in science and technology, labour unrest and geopolitical events, together with natural hazards such as flooding and drought.

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potential. Doing so, a systematic analysis describing the strengths and weaknesses and opportunities and threats of each innovation and its enabling environment is obtained.

- Credible –based on sound evidence or advocated by respected persons or institutions.
- Observable – to ensure that potential users can see results in practice.
- Relevant – for addressing persistent or sharply felt problems.
- Relative advantage – over existing practices so that potential users are convinced that the costs of implementation are counteracted by the benefits.
- Easy to install and understand – not complex and complicated.
- Compatible – with potential users' established values; fits into larger programs and context.
- Testable – without committing potential users to complete adoption before results are seen.

4.4 Define the sampling design and collect data

The fourth step of the RA involves the collection of data and the measurement of the indicators. Criteria and indicators are the "tools" that help assess the replicability of selected innovations. As a consequence indicators are grouped according to three main aims: i) Characterize systems, contexts, and actors, ii) Identify relevant features that may hamper the adoption of innovations, and iii) Monitor the adoption of innovations. This research uses questionnaires/surveys as well as modeling as instruments for data collection and data analysis. The first step is to understand the baseline system which constitutes the basis for the sustainability and the replicability assessment. It includes biophysical data, agronomic, environmental, and socio-economic data (Table 12, see Annex 2 for the detailed description of each criterion). For that purpose, farm/household surveys will be used (Annex 3).

Table 12. Selected set of baseline indicators to characterize farming systems/AEZs.

Indicator category	Variables
Region	Agro-ecological zone, Recent weather patterns
Farm profile and manager characteristics	Location, Utilized Agricultural Area, Cropping pattern, Age of the farm manager, Years of experience as a manager, Sex of farm manager, Education, Degree of agricultural education of farm manager, Type of ownership, Production Technique, Human labor, Crop diversity
Agronomic	Crop yield, Minimum, maximum, and average yield in driest years, Food loss/increment index, Amount of yield losses from pests, Days and months without sufficient food in the past year
Economic	Net revenue per hectare, Total annual cost, Financial autonomy.
Water and water quality	Gross irrigation water requirement, Water use efficiency, Water productivity, Water dependency, Level of water stress, Pollutant loadings (fertilizer, manure), water quality
Agro-biodiversity	Species Richness, Plot Size (Crop Field Size = patch area), Field density, Duration of rotation, Crop rotation, Crop diversity, Permanent crop diversity, Herbaceous crop density.
Environmental	Vulnerability to climate change, Greenhouse gas emissions, Water footprint,
Resource use	Electricity (pumping, conveyance, water application), Machinery (tractors, pumps), Fertilizer use (NPK), Pesticide use.
Social	Farming challenges, technological capabilities, adoption of key conservation practices, Assessment of working conditions, Quality of life and farming; Social engagement, Access to credit, Access to extension services, Days of training, Access to electricity

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Annex 4 presents the complete interview questions needed to analyze the baseline and innovation process. It should be noted that baseline data collection is supported by T1.2.b, therefore, from Annex 4, only a series of questions will be used for WP5 innovation and replicability. Analyses are carried out at the level of a farmer, farm household, farm, and AEZ. After achieving a baseline assessment, an innovation questionnaire and systematic literature review will be conducted to analyze the country's innovation performance, innovative capability, and innovation adoption process. A composite set of indicators will be produced to describe and analyze the performance of innovation activities (Table 12, see Annex 2 for the detailed description of each criterion).

Table 13. List of indicators to understand the innovation process.

Indicator category	Variables
Country's innovation performance	· Global Innovation Index (GII) - Human capital and research, Market sophistication, Business sophistication, Knowledge and technology output, Creative outputs
Innovativeness: Knowledge and attitude, Barriers to innovation, Access to services	· Farmers' motivations in the work environment to implement innovations · Inhibiting factors in the work environment to implement innovations · Availability of credit · Source of financing and information innovations · Perception of importance for innovative farming technologies · Level of awareness about smart technologies and tools for farming · Level of risk with the uptake of Information and Communication Technologies (ICT) in agriculture · No. of farmers and percentage of the total applying new practices, new knowledge, skills · No. of farmers and percentage of the total that receive advisory services · No. of farmers and percentage of the total with full agricultural training · No. of farmers and percentage of the total with usages of ICT for farm management purposes · Managers/ farmers satisfied with agricultural services as a percentage of all managers/farmers · No. of farmers and percentage of the total who are eligible to obtain a business loan · No. of farmers and percentage of the total who are aware of key market information · No. of farmers and percentage of the total who are below 40 years.
Innovation effectiveness	· Change in crop Revenue and Income · Change in cost · Change in productivity (crop yield) · Change in labor · Change in resource use (water, energy, fertilizer, pesticides, phytosanitary measures, etc.) · Change in product quality · Change in access inputs such as fertilizer and seeds · Change in access to market
Intention to use	· Perceived Usefulness (PU) · Ease of use (PEOU) · Intention to use
Perceived characteristics of the innovation (CORRECT)	· Credibility, observability, relevance, relative advantage, easy to install and understand, compatibility, testability

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To understand the innovation landscape and annual performance the Global Innovation Index (GII) will be reviewed. The GII includes two sub-indices: the Innovation Input Sub-Index and the Innovation Output Sub-Index. The first sub-index is based on five pillars: Institutions, Human capital and research, Infrastructure, Market sophistication, and Business sophistication. The second sub-index is based on two pillars: Knowledge and technology outputs and Creative outputs. (Annex 4) will be reviewed. The Global Innovation Index (GII) is an annual publication that ranks economies for their innovation environments & output. A list of indicators (knowledge and attitude about new agricultural technologies, barriers to innovation, access to services) is produced to measure the "Innovativeness" of agriculture.

For monitoring the adoption, the impact and the effectiveness of innovations a provisional set of individual KPI has been proposed and will be integrated. They relate to productivity increase (crop yield), increased production efficiency, cost reduction, lower environmental impact, and better social outputs (e.g. reduction of working time). Finally, technology usage intentions will be examined. Intention to use innovation is governed by perceived ease of use, perceived usefulness, attitude, and social influence, as proposed in different versions of the Technology Acceptance Model (TAM). The model suggests that perceived usefulness (PU) and perceived ease of use (PEOU) are the major factors that influence technology adoption and usage. Perceived Usefulness refers to "the extent to which a person believes that using a particular technology will enhance her/his job performance. Perceived Ease of Use as "the degree to which a person believes that using a technology will be free from effort". To measure PU and PEOU a seven-point Likert scale, ranging from "strongly agree" to "strongly disagree." The perceived characteristics of innovation (e.g., relative advantage, compatibility, testability, observability, complexity, and security) will be evaluated.

The indicators produced will be linked to the indicators SDGs of the 2030 Agenda for Sustainable Development allowing to develop a wider picture of their progress towards addressing different food systems challenges.

4.5 Weight the answers and make informed decisions

The key impact (quantitative) or performance (process or qualitative) indicators will be analyzed in the model for replication potential and compared with business as usual (BAU). The two scenarios (innovation versus BAU) constitute the basis for the replicability assessment. The assessment won't provide a yes or no answer. The purpose is to assess and evaluate each of the innovation's replicability potential for each demo site, i.e. to explore the factors determining the scaling up of innovations and technologies to inform policy about the factors needing critical focus in the area of scaling up agricultural innovations. Successful technologies will then be further assessed for Scaling Readiness (innovation readiness and innovation use). Technologies that fail these screening stages will be referred back to WP2 & 3 for further development.

4.6 Suggestions for replication

The replicability framework closes with a summary of the main lessons learned and recommendations for the implementation of SustInAfrica solutions. It will provide suggestions for up-scale/out-scale considering technology readiness levels (Table 14). WP5 will lead discussions (if needed also at a workshop organized by WP6) on identifying, developing, and prioritizing actions to overcome the barriers to adoption for each shortlisted technology and relevant issues for scaling up.

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Table 14. Technology readiness levels (TRLs) for technology-based innovations & social readiness levels (SRL) for knowledge-based innovations associated with SustInAfrica.

Technology	Starting & target TRLs & route to achieving target TRL
Technology-based innovations (TRL)	
InsectaMon smart AI-based pest insect monitoring tool	2-5: Smart pest insect monitoring tool to facilitate tailored insect pest management tobe designed, developed, and trialed at test sites to assess their efficacy and efficiency (WP2).
BLULEAF real-time irrigation management smartphone application	7/8-9: Existing system for irrigation management already piloted by CIHEAM at Various Mediterranean test sites to be further developed, implemented, verified, andbrought to market readiness (WPs 2, 3 & 5).
Low-cost assessment toolfor monitoring crop yields	7/8-9: Existing technologies utilizing digital camera RGB images obtained by UAVs, remotely sensed data (e.g. COPERNICUS) or on the ground, already developed and piloted by groups of scientists in Europe, Africa, and elsewhere, to be adapted to local crops, implemented, verified, and brought to market readiness (WP2).
Farmerline's Mergdata platform	6/7-9 Integrating interactive learning material/courses and decision-making platform with newly developed and verified tools (InsectaMon, BLULEAF) and existing systemsfor pest management (e.g. Plantex,) and for monitoring and managing plant performance verified and brought to pre-commercial readiness (WPs 2, 3, 4 & 5).
Knowledge-based innovations (SRL)	
Sustainable landscape and soil management systems	5/6-8: Existing technologies for sustainably improving primary productivity and provision of ecosystem services in targeted agro-ecosystems, partially piloted by African participants at test sites (**Table 1.3.g**), to be further developed, implemented, and verified (WP3).
Sustainable business models for targeted crops& markets	5/6-8: Periodisation of market-driven opportunities for high-value crops, husbandry, and their processed products (WP5). Farming system and market assessment (WPs 1 & 5) and subsequent development and testing of sustainable business models (WPs 3 & 5) will improve market access and reduce dependency on retailers.
Farming management knowledge and notification infrastructurefor end-users	5/6-8: Gathering, translating, summarizing, and disseminating training, education, and dissemination materials end-user friendly knowledge (e.g. comics for illiterate in NE, short YouTube videos) on baseline knowledge and ***SustInAfrica***'s context-specific outputs (results and technologies) via social media (WPs 4 & 6) will boost Understanding and uptake.

5. Conclusions and next steps

The purpose of the replicability plan is to transfer to the different stakeholder's technical knowledge, results obtained in the project, problems encountered and lessons learned during and after the end of the project. This deliverable provides a first coherent framework and a set of indicators for assessing the replicability potential for innovations developed under the SustInAfrica project.

Innovation is an essential ingredient to future success in West and North African agriculture and replication is a key activity for the success and scalability of every project. Globally or locally, practical feasibility, transferability, or replicability of innovations could face challenges or be hampered by constraints or barriers

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related to policy, legal, governance, or regulatory framework; therefore, replicability (transferability + scalability) identify the most favorable conditions and potential barriers against the adoption of innovations. The replicability of the project results and solutions will be supported by specific and clearly defined activities. Technologies that pass the replicability screening stage will be screened for scaling readiness.

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Annex 1

Sustainable intensification of food production through resilient farming systems in West & North Africa

Funded by EU Horizon 2020 Research and Innovation Programme under Grant Agreement 861924.

Innovation Survey with researchers and private sector partners

WP5: Sustainability, replicability, and exploitation of successful practices

Prepared by CIHEAM Bari

The present interview form aims to collect/harvest data and information related to technology-based and knowledge-based innovations proposed for transferability and up-scaling in the SustInAfrica project (see table 1.3.e of the project proposal). Doing so, the scope is to study innovation landscape (identify possible issues and elements that could hinder/hamper the implementation or adoption of innovation in the target areas) and stakeholder landscape (the networks of stakeholders and their constituencies that can influence, develop, or work on innovations). The analysis will help to find or propose possible solutions to overcome the issues to boost the innovation potential in the target territories and promote sustainable development of the areas by ensuring replicability of project outcomes.

Person Interviewed:

Name:	
Job title:	
Organization:	
Email	
Date of interview	
Interview mode	

Q1. Which innovation are you proposing/studying?

- Bluleaf ☐
- InsectaMon ☐
- Farmerline's Mergdata platform ☐
- Remote sensing tool ☐
- Farming management knowledge ☐
- Sustainable business models ☐
- Sustainable landscape and soil management systems ☐

Q2. When did this innovation start developing?

Insert Year when developed	(e.g., 2015)
Status of innovation	Proof of concept, field testing, commercial viability?

Q3. What category you will list your innovation in?

Technology-based ☐ Knowledge-based ☐ Both technological and knowledge-based ☐

Q4. What type of innovation are you proposing?

Product innovation ☐ Service innovation: ☐ Organizational innovation ☐ Marketing innovation ☐

Q5. What type of innovation are you proposing (agriculture related)?

Selection and genetic ☐ Technical and technological and industrial ☐ Organizational, managerial, and economic ☐ Socio-ecological ☐

Q6. What category you will list your innovation in?

Agriculture practice ☐ Smart farming technology ☐ Extension, Technical, and vocational education and training (TVET) ☐

Q7. What crops or livestock is this relevant to?

Open question

Q8. What agro-ecological conditions is this applicable to?

Open question

Q9. What the main purpose of this innovation is? What is the problem or challenge that this innovation or new technology seeks to address?

Open question

Q10. Has the innovation been shown to be effective when used by actual adopters under real conditions?

☐ Yes ☐ No

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Q11. In the short term (less than one year), what is the main direct benefit that may derive from the adoption of such innovation (ecosystem services)?

Main ecosystem services[1]					
Provisioning	☐	Regulating & Maintenance:	☐	Cultural	☐
Food, Freshwater Raw materials (Fibre, Timber, Ornamental, Biochemical), Genetical materials		Water purification and water treatment, air quality regulation Atmosphere regulation Disease & pest regulation Erosion regulation Natural hazard regulation		Recreation and ecotourism Knowledge systems and educational values,	

1 Haines-Young, R. and M.B. Potschin (2018): Common International Classification of Ecosystem Services (CICES) V5.1 and Guidance on the Application of the Revised Structure.

Q12. Is there are other direct benefits potentially derived by its adoption?

Reached new markets	☐	Developed new intellectual property (IP)	☐	Increased biodiversity preservation	☐	Increased water preservation	☐	Improvement in soil fertility	☐
Increased revenue	☐	Reduced unit production costs	☐	Reduced greenhouse gas emissions	☐	Increased crop yield/livestock / farmed birds (turkeys, chickens, pigeons, geese), fish, etc.	☐	Other	☐

Q13. What are the indirect benefits connected to the adoption of the innovation in the medium time (more than one year, less than 5 years)?

Open question

Q14. Who is going to enjoy the indirect benefits deriving from the adoption of the innovation?

Open question

Q15. What is the level of adoption of the innovation? What is the minimum scale that a farmer et al could adopt to try it for the first time?

Field level	☐	Farm-level	☐	Agroecosystem AEZ/ Watershed	☐	Landscape/ agroecosystem	☐	Regional/ National	☐

Q16. At what level of adoption the benefits of your innovation are maximized?

Field level	☐	Farm-level	☐	Agroecosystem AEZ/ Watershed	☐	Landscape/ agroecosystem	☐	Regional/ National	☐

Q17. What challenges are likely to arise for farmers or other adopters in effectively adopting, implementing, and using this technology?

Open question

Q18. How sensitive is the impact of the adoption of this innovation to climatic conditions?

Open question

Q19. What is the time necessary for the effective and successful adoption of the innovation (starting from implementation to full operational conditions)?

Open question

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Q20. What are the skills required for adopting innovation?

Work experience	☐	Tools and applications	☐	Technical	☐	Others	☐

Q21. Is there any need for specific training to adopt and run the innovation?

☐Yes, Innovation is likely to require multiple pieces of training or ongoing support

☐ Innovation requires little or no training

If yes: What kind of training, mentoring, handholding, and technical support is recommended?

Product training	☐	Technical training	☐	Soft skills training	☐	Mandatory training	☐

Q22. Is investment in new equipment or infrastructure required?

Yes	☐	No	☐

Q23. What infrastructure or capital goods and equipment need to be in place for farmers or adopters to successfully benefit from this innovation?

Agricultural inputs & Equipment	☐	Communication Systems	☐	Electronic components &accessories;	☐	Engineering & scientific instruments	☐
Construction equipment	☐	General industrial machinery & equipment	☐	Special industry machinery & equipment	☐	Office machines & equipment;	☐

Q24. In addition to the innovation itself, what other technologies, inputs, or agricultural practices would producers need to adopt or already be doing to effectively adopt this innovation? Where such equipment can be found?

Open question

Q25. Is there any initial investment required to adopt the innovation?

Yes	☐	No	☐

Q26. Does the innovation require annual or regular purchases to maintain effectiveness or vigor?

Yes	☐	No	☐

Q27. What is the status of the ownership of the intellectual property relevant to this innovation? Will some sort of transfer, licensing, etc. be necessary as part of scaling?

Open question

Q28. Will the innovation, whenever scaled, contribute to achieving relevant SDG goals? If yes, specify

(1) No Poverty	☐	(2) Zero Hunger	☐	(3) Good Health and Well-being	☐	(4) Quality Education	☐
(5) Gender Equality,	☐	(6) Clean Water and Sanitation,	☐	(7) Affordable and Clean Energy,	☐	(8) Decent Work and Economic Growth,	☐
(9) Industry, Innovation, and Infrastructure	☐	(10) Reducing Inequality,	☐	(11) Sustainable Cities and Communities	☐	(12) Responsible Consumption and Production	☐

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(13) Climate Action	☐	(14) Life Below Water	☐	(15) Life On Land	☐	(16) Peace, Justice, and Strong Institutions	☐
(17) Partnerships for the Goals.	☐						

Q29. Is the innovation likely to face opposition from vested interests in the private value chain or from public sector actors that could impede scaling?

☐ There are no vested interests
☐ Some opposition or resistance is likely but can be overcome with effective advocacy and coalition building
☐ Vested interests would be experienced

End of Questionnaire

Thank you

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Annex 2

List of Baseline indicators

Indicator	Definition/meaning	Metric (unit)	Collection
Farming characteristics			
Country	Area of land with own government and borders	-	Survey
Utilized Agricultural Area	The total area taken up by arable land, permanent grassland, permanent crops, and kitchen gardens used by the holding, regardless of the type of tenure or of whether it is used as a part of common land.	ha	Survey
Age of the farm manager	Age of farmer	years	Survey
Years of experience as a manager	Years of experience involved in farming activities	years	Survey
Sex of farm manager	Gender of farm manager	Gender	Survey
Education	Level of agricultural (technical) or management training undertaken by farm family members (by gender)	Level of attainment	Survey
Degree of agricultural education of farm manager	Level of agricultural (technical) education undertaken by farm family members (by gender)	level	Survey
Type of ownership	Control over an enterprise, providing the power to dictate the operations and functions.	type	Survey
Production Technique	Process of producing food, feed, fiber and many other desired products by the cultivation of certain plants using organic or conventional practices	type	Survey
Agronomic			
Crop yield	The site-specific yield is achieved using the available resources and current practices (labor and inputs) of the farmer, generally affected by pests and diseases.	kg/ha	Survey
Minimum, maximum, and average yield in driest years	Minimum, maximum, and average yield in driest years.	kg/ha	Survey
Food loss/increment index	This sub-indicator measures changes in the food losses from along the supply chain from the point of maturity on the production site	kg/ha	Survey
Amount of yield losses from pests	Loss in the quality and quantity of farm yield to pests and diseases	kg/ha	Survey
Water and water quality			
Gross irrigation water	Depth of irrigation water applied for irrigation.	m^3/ha	Survey
Water use efficiency	For selected irrigated crops, the mass of agricultural production (tonnes) per unit volume of irrigation water is utilized.	kg/m^3	Survey
Water Productivity (WP)	Crop yield per unit of water consumed (beneficially used by crop).	kg/m^3	Modelling
Water dependency	% of irrigated land on total cultivated land	%	Modelling
Pollutant loadings (fertilizer, manure)	Nitrate (or phosphorus) concentration in water	(kg/m^3)	Modelling

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Level of water stress	How much freshwater that is being withdrawn by all economic activities, compared to the total renewable freshwater resources available	%	Literature
Resource use			
Energy (pumping, conveyance, water application)	Amount of energy used for operating irrigation systems and water application.	(MJ/ha)	Survey
Machinery (tractors, pumps)	Amount of energy used for operating different types of machinery	(MJ/ha)	Survey
Fertilizer use (NPK)	Any material of natural or synthetic origin that is applied to soil or to plant tissues to supply plant nutrients.	(kg/ha)	Survey
Pesticide use		(kg/ha)	Survey
Social			
Farming challenges	Challenges to the future of agriculture and food security	variables	Survey
Adoption of key conservation practices	Conservation practices mean land treatment techniques designed to conserve, enhance, or protect soil, water, vegetation, and other natural resources.	variables	Survey
Assessment of working conditions	Working environment and aspects of an employee's terms and conditions of employment.	Likert scale (quality)	Survey
Quality of Life	Satisfaction with different areas of their lives.	Likert scale (quality)	Survey
Access to credit	The ability of individuals or enterprises to obtain credit.	variables	Survey
Access to extension services	The ability of individuals or enterprises to gain access to systems that facilitate the access of farmers, their organizations, and other market actors to knowledge, information, and technologies.	variables	Survey
Access to electricity	Percentage of farmers with access to electricity.	variables	Survey
Days of training	Number of days of training provided to women and men farmers	Days	Survey
Economic			
Net revenue per hectare	Net revenue per hectare of utilizable land area. calculated by subtracting the cost of goods sold from gross revenue	€/ha/ year	Survey
Change of income	The KPI will measure the change in income both as a baseline and when ICT is implemented, e.g. the effect of shifting the demand to consume from the grid when the electricity price is lower	€/ha/ year	Modelling
Total annual cost	The total annual costs are defined as the sum of capital-related annual costs (e.g. interests and repairs caused by the investment), requirement-related costs (e.g. power costs), operation-related costs (e.g. costs of using the installation), and other costs (e.g. insurance).	€/ha/ year	Survey
Cost reduction (water, energy, pesticide, etc.)	The project generated cost savings for end-users. Cost savings can be generated, for example, through a reduction in water, energy use, or reduction in labor costs	€/ha/ year	Modelling

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Investment payback period	Time required to recoup the funds expended in an investment	Years	Modelling
Agro-biodiversity & Ecosystems (Structure of AEZ)			
Species Richness	The number of herbaceous and arboreal plant species present in the ecological community, landscape, or region	Number/ha	Survey
Plot Size (Crop Field Size = patch area)	The size of the plots gives us an indication of the agroecosystem unit. The plots should be large enough to be identified as an ecosystem by micro and macro-organisms and insects. The minimum size of the plots must be no less than 1 ha	Number/ha	Survey
Field density	It expresses the relationship between the number of plots and the UAA. The higher the number of plots on a farm and the greater the chances of having field margins available for the ecological colonization of plant communities (grassy strips, hedges, etc.) and consequently, animals.	Number	Survey
Duration of rotation	Duration of the practice of growing a series of different types of crops in the same area across a sequence of growing seasons.	Number	Survey
Crop rotation	The number of years of crop rotation within the company. The value of the index is calculated as a weighted average of the number of years of duration of the changes compared to the total area of arable land excluding set-aside (defined by direct interview with the tenant of the company). The objective of the index is to evaluate the agro-ecological efficiency of the company's plots	Number	Survey
Crop diversity (CD)	It expresses the diversity of land use classes within the company and with it the complexity of the spatial distribution of the plots. It is measured by identifying the total area of each crop of each plot on the company cartography.	Number/ha	Survey
Environmental			
Vulnerability to climate change	Vulnerability of agricultural production to a changing climate	Likert scale (value)	Survey
Greenhouse gas emissions	Quantity of greenhouse gases (GHG) emitted by farms measured at farm level per hectare (ha) of utilized agricultural area (UAA)	$kgCO_2$-eq/ha	Modelling

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List of innovation indicators

Indicator	Definition	Unit	Scale	Source
Innovation trends				
Global Innovation Index (GII)	Ranking of countries by their capacity for, and success in, innovation.	Number	Country	Literature
Knowledge and attitude				
Level of importance	Indicator related to the perception of importance for innovative farming technologies	Likert scale	Farm; Farmer/ Household/	Survey
Level of awareness about smart technologies and tools for farming	Indicator related to awareness for innovative farming technologies	Likert scale	Farm; Farmer/ Household/	Survey
Level of risk with the uptake of Information and Communication Technologies (ICT) in agriculture	Indicator related to perceived risk with the uptake of ICT technologies	Likert scale	Farm; Farmer/ Household/	Survey
Farmers' motivations in the work environment to implement innovations	Motives for farmers to participate in investing in innovations.	Variable	Farm; Farmer/ Household/	Survey
Inhibiting factors in the work environment to implement innovations	Motives for farmers to not participate in investing in innovations.	Variable	Farm; Farmer/ Household/	Survey
Innovation adoption				
No. of farmers applying new practices, new knowledge, skills	Indicator related to farmer' use level of use of innovation	Value	AEZ	Survey
No. of farmers that receive advisory services	Indicator related to advisors support farmers in developing farming systems	Value	AEZ	Survey
No. of farmers with full agricultural training	Indicator related to influence on the environmental impact of farming	Value	AEZ	Survey
No. of farmers with usages of ICT for farm management purposes	Level of farmer' use of information communication technology for farm	Value	AEZ	Survey
Managers/ farmers satisfied with agricultural services as a percentage of all managers/farmers	Level of satisfaction with agricultural services, disaggregated by women and men	Value	AEZ	Survey
Innovation effectiveness				
Yield increase	Indicators to understand the potential impact, positive and negative of implemented innovations.	Value	Farm; Farmer/ Household/	Modelling
Work time use efficiency		Value		Modelling
Water and energy use reduction		Value		Modelling
Water use and energy efficiency		Value		Modelling
NPK reduction		Value		Modelling
Phytosanitary measures		Value		Modelling
Product quality improvement		Value		Modelling
Intention to use innovations				

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Perceived Usefulness (PU)	The extent to which a person believes that using a particular technology will enhance her/his job performance	Likert scale	Farm; Farmer/ Household	Survey
Ease of use (PEOU)	The degree to which a person believes that using technology will be free from effort	Likert scale		Survey
Intention to use	User's desire to use technology in the future	Likert scale		Survey

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Annex 3

Sustainable intensification of food production through resilient farming systems in West & North Africa

Funded by EU Horizon 2020 Research and Innovation Programme under Grant Agreement 861924.

Innovation Survey with smallholder farmers and their communities

WP5: Sustainability, replicability, and exploitation of successful practices

Prepared by CIHEAM Bari

The goal of this survey is to explore current farming challenges, understand the local context, analyze farm-level innovation, explore e key barriers to/facilitators of innovation and understand farmers' interests regarding farming and smart farming technologies.

Survey Questionnaire (farmer household)

Interviewer Name_____Sex: (M/F)____ __ Phone number: ______Date and time of interview_________

A. Background information

A1. Where do you live (regency/district)?

________________________________ **(**regency/district/country**)**

A2. What is your gender?

- ☐ Male
- ☐ Female

A3. How old are you?

________________________________ **(years)**

A4. What is the highest level of education that you have?

- ☐ Literate
- ☐ Primary school
- ☐ Secondary school
- ☐ Graduate

B. Farming characteristics

B1. How many hectares of land is?

Cultivated on this farm ________________________ (hectare)
Land owned ________________________ (ha or %)
Land rented ________________________ (ha or %)%)
Land irrigated ________________________ (ha or %)%)
Land is fertile and suitable for agriculture________________________ (ha or %)

B2. What is the most type of plant do you plant in one normal year? How many resources do you use?

Crop	Unit	Crop name 1	Crop name 2	Crop name 3
Area	ha			
Sowing/planting date - harvesting date	dd.mm.yy			
Quantity Harvested (Fresh biomass)	kg			
Quantity Harvested (Dry biomass)	kg			
Normal, Dry, and Wet Year Average Yield	kg			
The amount consumed by household	kg			
The amount consumed by livestock	kg			
Amount lost due to disease and pests	kg			
Seed/Seedling rate	kg or seeds			
Irrigation water	m^3			
NPK use	kg			
Total hours of machinery for all work processes	h			
Tractor size	kW			
Tractor weight	kg			

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B3. Are the crops you currently cultivated for?

- ☐ Market
- ☐ Subsistence
- ☐ Mix

B4. What is the main market in which this establishment sells its main product or service?

- ☐ Local
- ☐ National
- ☐ International

B5. Do you use hired labor for crop production?

- ☐ Permanent
- ☐ Sometimes
- ☐ Sometimes and permanent
- ☐ No

B6. What production technique do you apply?

- ☐ Conventional farming
- ☐ Organic farming
- ☐ Other

B7. Are there any non-agricultural activities on-farm?

- ☐ Yes
- ☐ No

B8. The legal status of the farm:

- ☐ Family farm or family company
- ☐ A company without family shareholder
- ☐ Cooperative
- ☐ Other

B9. Is the farm connected to an electricity supply?

- ☐ Yes
- ☐ No

B10. How do you evaluate the current working conditions (refer to issues such as equipment, security, and facilities for workers)?

- ☐ Poor
- ☐ Fair
- ☐ Good
- ☐ Very good
- ☐ Excellent

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B11. What kind of problems do you face for your farming activities?

	Tick all that apply
1. Soil degradation (erosion, salinization, loss of organic matter, etc.)	
2. Nitrogen enrichment of groundwater	
3. Water availability	
4. Biotic stress (e.g. pests, diseases, parasites, etc.)	
5. Extreme weather events (e.g. droughts, floods, storms, etc.)	
6. Lack of access to credit	
7. Lack of access to land (i.e. no land available for lease or sale)	
8. Economic situation of the farm	
9. Market conditions (e.g. regulations, prices, etc.)	
10. Bureaucracy	
11. Other, namely: …………………	

B12. How do usually you cope with it?

- ☐ No strategy
- ☐ Sale of animals
- ☐ Sale of land
- ☐ Loan taken
- ☐ Levy on savings
- ☐ Other, please specify

B13. How do you make major strategic farm decisions?

- ☐ Alone
- ☐ With spouse
- ☐ With family
- ☐ With advisory services/specialist
- ☐ Other, please specify

B14. Do you plan to give up the farm in the next 5 years?

- ☐ Give up for retirement
- ☐ Give up for other reason
- ☐ No plan to give up for the next 5 years
- ☐ Don't know

C. Financial capital

C1. What is the average value of the production per hectare?

Value ___________________________ **(local currency, USD or Euro)**

*****Note: If A10yes, list the other activities you are presently involved with alongside farming.**

C2. What is your most important machine or technology? (Combine, tractor, dryer, motorcycle, Water tanks, etc.).

____ (type)

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C3. Do you possess a bank account?

☐ Yes
☐ No

C4. In the last year (12 months), has any member of your household borrowed any money?

☐ Yes
☐ No

*****Note: If C4 yes, specify the source of credit.**

C5. Access to services/institutions?

Distance to asphalt road ________________________ **(km)**
Distance to market ________________________ **(km)**
Distance to district town ________________________ **(km)**
Distance to input dealer ________________________ **(km)**
Distance to farmer training center (FTC) ________________________ **(km)**
Distance to micro-finance institution (MFI) ________________________ **(km)**

D. Use of ICT on farm

D1. How do you document your farm data?

☐ By hand
☐ Digitally (pc, smartphone, tablet)
☐ Both
☐ I don't keep records

D2. Who manages the data collected?

☐ You
☐ Family member
☐ Someone else (e.g. extension worker)
☐ A combination

D3. Do you use a mobile phone?

☐ Yes
☐ No

D4. Do you use a mobile phone with the internet?

☐ Yes
☐ No

D5. (Only if "yes" was chosen in Question D4)
What do you use your mobile phone for? (Tick all that apply)

☐ Agricultural apps
☐ Weather apps
☐ Photos

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- ☐ Communication with other farmers/cooperatives/associations (phone or message)
- ☐ Emails
- ☐ Social media from other farmers, demonstrations, etc.
- ☐ Internet surfing

D6. Do you use a computer/tablet?

- ☐ Yes
- ☐ No

E. Knowledge and skills

E1. Years of experience as farmer/manager?

_________________________ **Years**

E2. What is the level of training?

- ☐ Only practical experience
- ☐ Basic agricultural training
- ☐ Full agricultural training

E3. How many extension agents approached you during last year?

_________________________ **number**

E4. Type of Advice

- ☐ Public Advisor
- ☐ Farmers' Cooperative
- ☐ Other Farmer based providers
- ☐ Private Advisor
- ☐ Companies
- ☐ Others

E5. How many days of training did you receive during last year?

Number of days of training provided _________________________ **(days)**

E6. Have you ever trained for?

Category	Yes/No
Post-production techniques (treatment and handling)	
Soil conservation, water improvement, and agroforestry	
Management of production units	
Composting techniques	
Irrigation management	
Biodiversity	
Machinery use	

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E7. Which mode do you mostly follow to learn about new farming methods and technologies?

Parameter	Select most appropriate
1. Direct (face to face) interactions with people	
2. Farm advisor/ Agriculture Department offices	
4. Reading farming press or media	
4. Attending organized events	
5. Searching information on websites	
6. Reading literature received in the mail	
7. Others, namely: ……………….	

F. Social capital and engagement

F1. Are you a member of any group or organization (e.g. farmer's union, professional organization, other farmers group, environmental association, civil association, local government)?

☐ Yes
☐ No

*****Note: If F1 no, go to F5.**

F2. What type of group/organization is it?

_________________________ **(free text)**

F3. What role do you play in this group i.e. leader, very active, active, or just a member?

_________________________ **(free text)**

F4. Does the group help your household get access to any of the following services?

☐ Education or training Health services
☐ Water supply or sanitation
☐ Credit or Savings
☐ Agricultural input or technology
☐ Irrigation
☐ Other (specify)

F5. Are there any community activities in which you are unable to participate?

☐ Yes
☐ No

*****Note: If F5 yes, state the activities and reasons for not participating.**

G. Working conditions

G1. How satisfied are you being a farmer?

☐ Very satisfied
☐ Satisfied
☐ Neither
☐ Dissatisfied
☐ Very dissatisfied

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G2. How satisfied are you with your quality of life?

- ☐ Very satisfied
- ☐ Satisfied
- ☐ Neither
- ☐ Dissatisfied
- ☐ Very dissatisfied

G3. How satisfied are you with your daily job tasks?

- ☐ Very satisfied
- ☐ Satisfied
- ☐ Neither
- ☐ Dissatisfied
- ☐ Very dissatisfied

G4. How satisfied are you with your freedom of decision-making?

- ☐ Very satisfied
- ☐ Satisfied
- ☐ Neither
- ☐ Dissatisfied
- ☐ Very dissatisfied

G5. Average working days?

__________________________ **(days)**

G6. Number of holiday days taken by the farmer during the accounting year?

__________________________ **(days)**

G7. Has there been an accident on your farm in the last year?

- ☐ Yes
- ☐ No

G8. If G5 yes, how many workdays were lost?

__________________________ **(days)**

G8. Replacement during illness?

- ☐ Yes
- ☐ No
- ☐ Do not know

H. Knowledge, attitude, and adoption for innovations

H1. How important are innovations to the well-being of your household?

- ☐ Very important
- ☐ Important
- ☐ Moderately important
- ☐ Somewhat important
- ☐ Not important

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H2. How aware are you of smart technologies and tools for farming?

☐ Extremely aware
☐ Moderately aware
☐ Somewhat aware
☐ Slightly aware
☐ Not at all aware

H3. Do you think that there are problems with the uptake of Information and Communication Technologies (ICT) in agriculture?

☐ Yes
☐ No

*****Note: If G3 yes, ask for details.**

H4. Have you made any innovations on your farm within the last 5 years in one of the following categories?

Category	Yes/No
Innovations in management and farm administration (e.g. IT or accounting systems)	
Innovations in farm practices (e.g. change from conventional to organic agriculture, introduction of no-till farming)	
Adoption of more advanced technological equipment (e.g. machinery, GNSS, sensors, pumps)	
Investment in new knowledge	

*****Note: If you made any other innovations, can you please specify in a few words (maximum 1 sentence) which innovation you made?**

If H4, *4 x no* Go to Question H14.

H5. If H4, *4 x no skip*: Where did you get the information you needed for getting it?

H6. If H4, *4 x no skip*: Was it successful?

☐ Yes
☐ No

H7. If H4, *4 x no skip*: How long did it take for you to become comfortable using the innovation?

________________________________ **(days, weeks, months, years?)**

H8. If H4, *4 x no skip*: Did you test the innovation before getting it?

☐ Yes
☐ No

H9. If H4, *4 x no skip*: Did the introduction of innovation changes your farming practices?

☐ Yes
☐ No
☐ I don't know

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H10. If H4, *4 x no skip*: What are some of the changes, if any, that you have experienced as a result of the implementation of innovation?

- ☐ Higher profitability
- ☐ Improved working conditions
- ☐ More detailed information
- ☐ Better market access
- ☐ Other (please specify)

H11. If H4, *4 x no skip*: What are the major factors or conditions that led to innovation?

Factors	**Yes / No**
1.Ecological risks/changes	
2.Major climatic event that led to crop failure/scarcity	
3.Economic and market needs	
4. Social and culture needs	
5. Labor shortage/saving	
6. Repatriation/collaboration with scientists (= supporting factor)	
7. Discovered by accident	
8. Experiment and exploration	
9. External subsidies	
10. Replace outdated products or process	
11. Other, specify	

H12. If H4, *4 x no skip*: Did you implement innovation with financial support from specific institutions and organizations?

- If yes, from which entity did you receive financial support?

H13. If H4, *4 x no skip*: Did you implement innovation with technical support from specific institutions and organizations?

- If yes, who provided the technical support?

H14. If H4, *4 x no*: What were your reasons for not adopting innovations? [Multiple answers possible]

Note: Barriers are categorized as economic [E], institutional [I], behavioural/psychological [B], organizational [O], market [M] and social [S] barriers.

	Tick all that apply
1. High initial investment cost [E]	
2. Poor access or lack of capital or funds for investment [E]	
3. Low institutional support [I]	
4. Low trust in new technologies [B]	
5. Lack of management support/awareness [B]	
6. Negative presumed assumptions [B]	
7. Lack required competencies/skills [O]	
8. Poor information and knowledge [O]	
9. Lack market attractiveness [M]	
10. Lack of market information [M]	
11. Social/peer pressures [S]	
12. Environmental factors (weather/climate change) [S]	
13. No need because of no demand for innovations	

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H15. What kind of information would you need before deciding to get/adopt an innovation?

- ☐ Demonstration
- ☐ Cost-benefit model
- ☐ Video
- ☐ Conversations with unofficial contact (neighbor, another farmer)
- ☐ Conversations with office contact (advisor, official, someone paid for their service)
- ☐ Personal test
- ☐ Other (please specify)

H16. Would you get innovative technologies if they were supported through subsidies?

- ☐ Yes
- ☐ No
- ☐ Maybe

H17. Would you get innovative technologies if you share costs with others?

- ☐ Yes
- ☐ No
- ☐ Maybe

I. Perception

I1. Perceived usefulness - I think using the Innovation "XXXXXXXX" is/can:

Innovations are/can	Strongly disagree	Disagree	Agree	Strongly agree	Don't know
Useful for farming					
Improve farming, i. e crop/plant performance					
Increase farm productivity compared to not using it					
Decrease input costs					
Help make better management decisions					
Help reduce pollution from farms					
Improve farmers' work processes					
Improves farmers' work comfort					
Improves farms' income					
The cost of adopting is affordable					

I2. Perceived Ease of Use - I think using the Innovation "XXXXXXXX" is/can:

- ☐ Would be easy for me.
- ☐ Would be clear and understandable.
- ☐ Interacting with the Innovation learning environment requires a lot of my mental effort.

I3. Intention to use - How likely are you to use Innovation "XXXXXXXX" after the demonstration?

- ☐ Very unlikely
- ☐ Unlikely
- ☐ Neither likely nor unlikely

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- ☐ Likely
- ☐ Strongly likely

End of Questionnaire

Thank you

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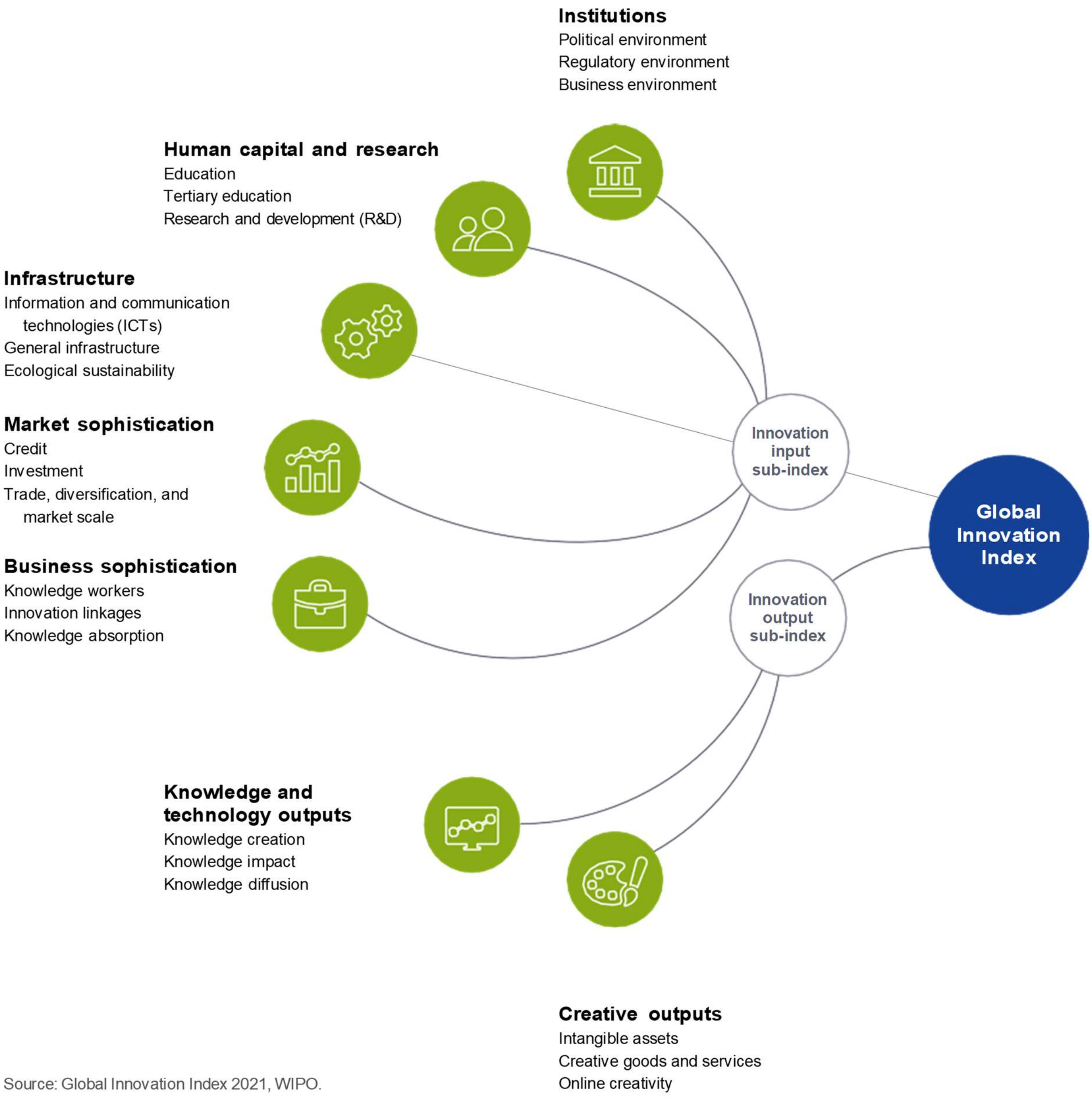
Annex 4

Global innovation index indicators

The Global Innovation Index provides detailed metrics about the innovation performance of countries and economies around the world. Its 81 indicators explore a broad vision of innovation, including political environment, education, infrastructure, and business sophistication.



Source: Global Innovation Index 2021, WIPO.

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