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

Deliverable D6.2

Methodology workshop

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ABSTRACT

This deliverable presents the jointly prepared and agreed framework SustInAfrica will apply during i) reviewing systematically literature and databases, ii) processing data gathered from multiple sources (review and surveys) and iii) measuring and evaluating impact and/or progress. Thus, D6.2 will ensure harmonized and standardized knowledge development of multiple tasks and activities in WPs 1, 2 and 5.

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1. Introduction

In SustInAfrica quality assurance and reliable knowledge development will be based on standardized procedures. Thus, the SustInAfrica consortium agreed to introduce and apply a set of standardized procedures during i) baseline assessments and surveys and ii) monitoring and evaluation. The consortium proposed to meet in person at a side event of the project`s kick-off meeting, which was cancelled due to COVID-19. Instead of meeting in-person workshop the consortium agreed to prepare the proposed framework based on a coordinated combination of desk work and online meetings. See below dates of related meetings and names of their participants:

Date	Participant	Major topic
7th October	Pierre Ellssel, Bernhard Freyer, Nils Borchard	Procedures of T1.2a
14th October	Pierre Ellssel, Bernhard Freyer, Nils Borchard, Idalina Dias Sardinha, Rita Queiroga-Bento, Ana Catarina Luz	Procedures of T1.1a and T1.2a
21st October	Kwame Frimpong, Idalina Dias Sardinha, Ana Catarina Luz	Defining criteria and procedures used to select villages and communities (WP1)
2nd November	Nils Borchard and Soil4Food (H2020 no. 862900)	Soil measures and related indicators
3rd November	Cristina Branquinho, Pasi Sihvonen, Pedro Cardoso, Nils Borchard	Insect-related measures and indicators
4th November	Nils Borchard, Bernhard Freyer, Pierre Ellssel	Further coordination of T1.2a, approach for pre-review of keywords
4th November	Paul Wagstaff, Ana Catarina Luz, Generosa Jenny Calabrese, Idalina Dias Sardinha, Dembele Kalifa, Mary Sweeney, Mladen Todorovic, Nicola, Houlihan. Peter Byemaro, Rapahaele Ng Tock Mine	Selecting and aligning indicators and measures used in WPs 1 and 5 for monitoring and evaluating socio-economic changes and impact generation.
5th November	Young Giles, Ana Catarina Luz Abdul-Halim Abubakari, Amos Olertey Wussah, Bernhard Freyer, Nils Borchard, Godwin Badu-Marfo,Hamada Abdelrahman, Idalina Dias	Refining and simplifying approach local partners will apply while selecting villages and communities (WPs 1 and 3)

	Sardinha, Kwame Frimpong, Desire Lompo, Larwanou Mahamane, Michael Adu,Paul Wagstaff, Pierre Ellßel	
11th November	Idalina Dias Sardinha, Ana Catarina Luz, Pierre Ellssel, Cristina Branquinho, Helena Serrano, Michael Schirrmann, Nils Borchard	Preliminary indicator list and their relation to SustInAfrica`s expected impacts
19th November	Ana Catarina Luz, Pierre Ellssel, Nils Borchard	Merging approached drafted to perform reviews and meta analyses in tasks 1.1 and 1.2

Outputs of these meetings are fourfold: i) a jointly drafted and agreed protocol on performing systematic reviews and/or meta-analyses ii) a literature database build up in SustInAfrica`s SharePoint (Tiimeri operated by Luke) and a reference database based on freely available Mendeley citation software, iii) selection criteria and procedures to select communities and gather baseline information and iv) an indicator framework.

2. Protocol definition on reviews and meta-analyses

As described in the proposal for SustInAfrica, a systematic review will be conducted within WP1 (Tasks 1.1.a & 1.2.a). With the review we aim to compile all empirical evidence by applying pre-specified eligibility criteria that serve for answering a specific research question. A systematic review can be characterised by: “a clearly defined question with inclusion and exclusion criteria; rigorous and systematic search of the literature; critical appraisal of included studies; data extraction and management; analysis and interpretation of results; and report for publication.” (Duke University, 2020).

A systematic review is resource demanding (>24 person months) and team work as multiple experts are required; e.g. scientists to screen abstracts and read the full text, statistician who can assist with data analysis and a project leader to coordinate and write the final report. A written protocol specifies in advance the scope and methods to be used during the reviews, which in addition assures scientific quality and reduces the risk of biases (Higgins et al., 2020). According to the Cochrane Handbook for Systematic Reviews of Interventions a systematic review goes along the following steps:

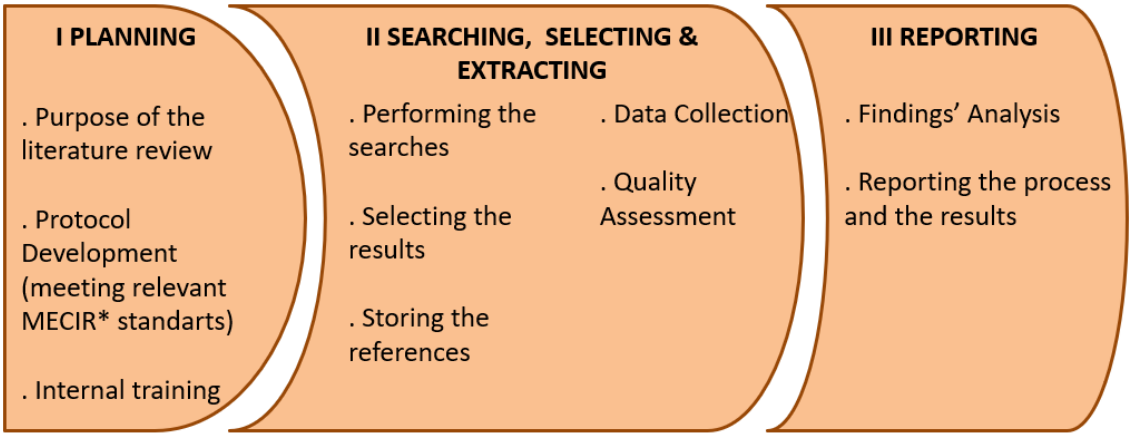


Figure 1 - Main phases of the Systematic Literature Review methodology, adapted from the Methodological Expectations of Cochrane Intervention Reviews (MECIR).

I Planning

Purpose of the literature review: Clarify the key question(s) of your systematic review and the rationale for each question. Thus, an essential part of this phase is definition of research/review questions and/or hypotheses (Pollock and Berge, 2018). Determine inclusion/exclusion criteria. Draft a tentative and short title (ideally not more than 12 words) (Uman, 2011).

Protocol development (this document/D6.2): Draft a protocol (e.g. based on a protocol template made available by Duke University, 2020) outlining the study methodology. The protocol should include the rationale for the systematic review, key questions see for example PICO criteria by Pollock and Berge (2018) and template(s) (see a drafted protocol for Task 1.2a in Annex 1) (Uman, 2011). The Cochrane Community (Community, 2020) proposes considering MECIR standards while addressing following components as published by Higgins et al. (2020): Background, Objectives, Methods, Criteria for inclusion/exclusion of studies, Search methods for identification of studies (e.g. literature searches for published/unpublished literature, data abstraction/data management, assessment of methodological quality of individual studies, data synthesis, and grading the evidence for each key question), Data collection and analysis.

Internal training: Internal trainings will be organized by WPs 6 and 7 to ensure harmonization between multiple partners of the SustInAfrica consortium who perform systematic reviews and/or meta-analyses. Depending on COVID-19 related restrictions trainings will be conducted in-person or online.

II Searching, selecting and extracting

Performing the searches: First, perform a pre-screening to validate relevance of the review`s key questions and key words. Then, identify appropriate databases and conduct comprehensive and detailed literature searches that can be documented and duplicated. Develop search strategy (e.g. keywords, Boolean search expressions, inclusion/exclusion criteria) and agree on used databases (e.g. Web of Knowledge, Scopus). It is important to come up with a comprehensive list of keywords during protocol development (Uman, 2011).

Selecting the results: Once a comprehensive list of abstracts has been retrieved and reviewed sources (e.g. case studies) meeting inclusion criteria will be reviewed fully (Uman, 2011). Software to manage references (e.g. Mendeley, Endnote) is usually required during searching, systematic review and manuscript preparation (Higgins et al., 2020).
Storing the references and data collection: It is highly recommended creating (see also I Planning/Protocol development) and using a simple data extraction form or table to organize extracted information (e.g., authors, publication year, number of participants, age range, study design, outcomes, included/excluded) prior data processing and statistical assessments (Uman, 2011).
Quality assessment: Meeting the Cochrane MECIR standards (see above) assures quality of the systematic review. In particular during review the MECIR standards reduce risk of biases while ensuring reliability and validity of review and meta-analyses results (Higgins et al., 2020).

III Reporting
Data processing and statistical analyses: For data processing and analyses multiple tools are available (e.g. Review Manager [RevMan], MetaWin, R packages) (Uman, 2011).
Reporting and/or publishing results: Writing and publishing summarizes the findings and supports dissemination of the review`s outputs (Higgins et al., 2020; Uman, 2011). Thus, to gain a deep understanding of the current state of the art of all scientific areas relating to SustInAfrica systematic literature reviews and/or meta-analyses will be conducted. Use appropriate guidelines for reporting your review for publication (e.g. https://guides.mclibrary.duke.edu/sysreview/home).

3. Protocol on selecting communities and related baseline data

One of SustInAfrica`s major objectives is to introduce, implement and validate traditional, agro-ecological and smart farming practices to African farmers and communities. Thus, the identification of villages and/or communities must be based on a set of jointly agreed selection criteria and engagement procedures. Thus, the SustInAfrica consortium drafted guidelines to select villages and/or communities and to compile information of targeted villages and/or communities based on jointly prepared protocols and templates (Annex 2) with an aim to:

- Identify three communities per targeted AEZ, i.e., 39 communities.
- Establish field trials in 2021 in one “core community” per AEZ, i.e., in 13 communities representing typical land use and social pattern for the respective AEZ.
- Solutions and practices approved by WP5 (replicability check) will be replicated/ implemented later on in remaining communities, i.e., in the 39 communities.

4. Indicators framework

SustInAfrica will use a set of single (Annex 3) and clustered indicators (Table 1) to monitor and evaluate progress in terms of achieving expected impacts (Annex 4) presented in the project`s Grant Agreement. Thus, SustInAfrica aims to ensure a proper: "Results-based monitoring which is a continuous process of collecting and analysing information on key indicators and comparing actual results with expected results in order to measure how well a project, program, or policy is being implemented. It is a continuous process of measuring progress toward explicit short-, intermediate-, and long-term results by tracking evidence of movement toward the achievement of specific, predetermined targets by the use of indicators. Results-based monitoring can provide feedback on progress (or the lack thereof) to staff and decision makers, who can use the information in various ways to improve performance." (Morra Imas and Rist, 2009). "Monitoring involves the measurement of progress toward achieving an outcome or impact. The outcome cannot be measured directly, however; it must first be translated into a set of indicators that, when regularly measured, provide information about whether or not the outcomes or impacts are being achieved. A performance indicator is "a variable that allows the verification of changes in the development intervention or shows results relative to what was planned" (Morra Imas and Rist, 2009). "It is the cumulative evidence of a cluster of indicators that managers examine to see if their program is making progress. No outcome or impact should be measured by just one indicator." (Morra Imas and Rist, 2009) (Fig.1)

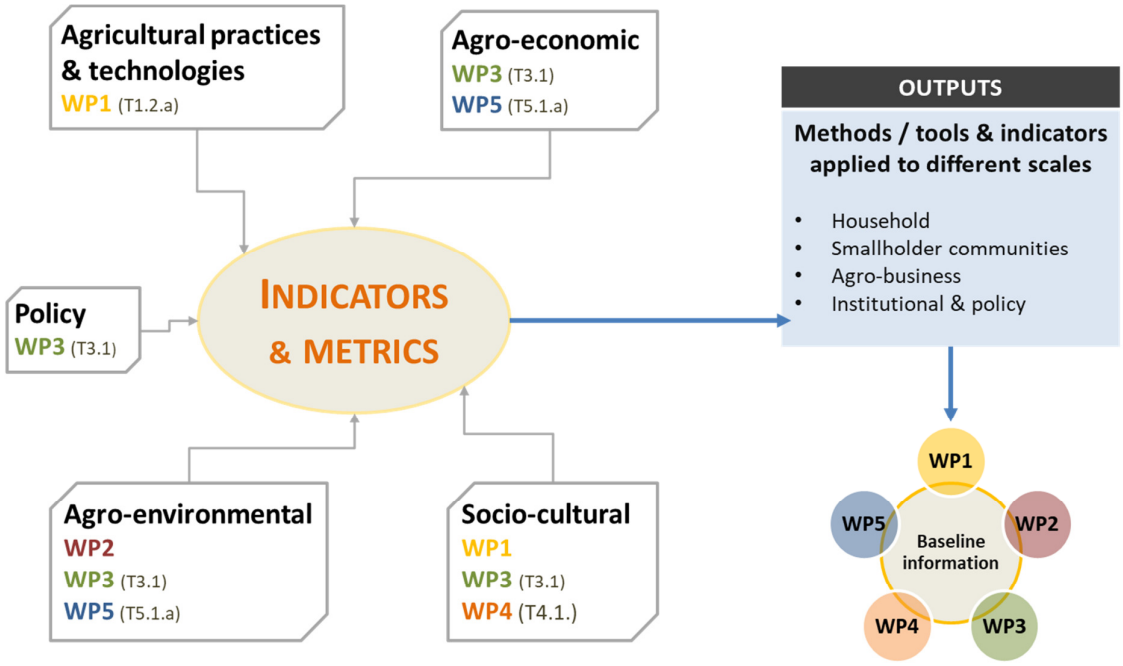


Figure 1. Disciplines and WPs interlinks for the definition of single and clustered indicators and metrics to monitor SustInAfrica impact and subsequent outputs. The figure shows main tasks involved in the indicators definition process.

Table 1: SustInAfrica`s expected impacts expressed as clustered indicator system and their relation to single indicators (Annex 3) per agroecological zone and scale of analysis (a draft).

Discipline-dimension	Single indicators and their sub-categories or Indicator units of analysis	Clustered indicator system for local, regional, national sustainable agricultural intensification							
		Sustainable agriculture	Soil fertility[1]	Ecosystem services	Sustainable economic growth	Resilience	Equality	Replicability	Health and Nutrition
Agriculture	Land area and structure-landscape							x	
	Cropping system [2]	x	x	x	x	x			
	Crop performance[3]	x		x	x	x		x	
	Soil management[4]	x	x	x	x	x		x	x
	Water management[5]		x		x				x
	Productivity per area[6]	x			x	x		x	
	Crop quality[7]				x				x
Agro Environment	Biodiversity	x	x	x	x	x			x
	Functionality	x		x		x			
	Habitats			x		x			
	Soil and water	x	x	x	x	x		x	x
	Climate			x	x				
Agro Economics	Profitability				x	x		x	
	Business Environment				x				
Socio-cultural	Decent livelihoods	x				x			
	Women access and control						x		x

Discipline-dimension	Single indicators and their sub-categories or Indicator units of analysis	Clustered indicator system for local, regional, national sustainable agricultural intensification							
		Sustainable agriculture	Soil fertility[1]	Ecosystem services	Sustainable economic growth	Resilience	Equality	Replicability	Health and Nutrition
	Women workload						x	x	x
	Women involvement in research						x	x	
	Dietary diversity								x
	Micronutrient intake								x
	Health	x				x			x

[1] **Soil fertility** is "the ability of the soil to supply essential plant nutrients and soil water in adequate amounts and proportions for plant growth and reproduction in the absence of toxic substances which may inhibit plant growth" (www.fao.org).

[2] Which crops (incl. fodder crops), Crop rotation, Intercropping, Multi-storey cropping, Agroforestry, Planting time, Harvesting, Cropping intensity, animal types (breeds), heads per area and their feeding system (e.g. grazing, barn)

[3] What pests and diseases, Used pesticides, IPM, Traditional methods and technological methods , Weeding, Agro-ecological methods, Biological methods, Chlorophyll content (SPAD), LAI

[4] Crop residue management, Tillage, Fertilization (organic/inorganic; amount), Soil amendments (e.g. compost), erosion control (e.g. mulching), soil organic carbon and nitrogen, soil pH, total P and K, electrical conductivity (EC), bulk density

[5] Irrigation, Rain fed, Water quality (EC, SAR, , Stomatal conductance

[6] Field/Post harvest losses, Harvest index, Grain yield, LAI, Input efficiency, Input intensity, Resilience

[7] Ripening index, oil content (olive)

5. References

Community, C., 2020. Methodological Expectations of Cochrane Intervention Reviews (MECIR) [WWW Document]. URL https://community.cochrane.org/mecir-manual

Duke University, 2020. Systematic Reviews: the process: Home [WWW Document]. URL https://guides.mclibrary.duke.edu/sysreview/home

Higgins, J.P.T., Thomas, J., Chandler, J., Cumpston, M., Li, T., Page, M.J., Welch, V.A. (editors), 2020. Cochrane Handbook for Systematic Reviews of Interventions.

Morra Imas, L.G., Rist, R.C., 2009. The Road to Results : Designing and Conducting Effective Development Evaluations. World Bank.

Pollock, A., Berge, E., 2018. How to do a systematic review. Int. J. Stroke 13, 138–156. https://doi.org/10.1177/1747493017743796

Uman, L.S., 2011. Systematic reviews and meta-analyses. J. Can. Acad. Child Adolesc. Psychiatry 20, 57–59.

Annex 1

Example of protocol drafted to perform review and/or meta-analyses of WP1 T1.2a.

1. Objectives

The overall objective of WP1 is to gain a deep understanding of the current state of selected farming systems of 13 targeted AEZs and their institutional environment in five countries in W. and N. Africa (GH, BF, NE, EG & TN), and to assess regional and local baseline information on factors describing and affecting agricultural performance and development in each specific context. Thus, WP1 will gather and make available to SustInAfrica's other WPs baseline data on ecological, socio-demographic, cultural, and economic issues, and assessments related to households, smallholder communities, agro-businesses, and institutional and policy contexts in which agricultural systems are embedded. The focus will be on identifying and assessing adequate data and the interactions between economic, agro-ecological, institutional, and societal contexts and best-known practices, in order to support field trials for the sustainable optimisation of African farming systems, and their long-term success. Gathered and processed baseline information will be made available in collaboration with WPs 3, 4, and 6 via SustInAfrica's Tiimeri workspace and Farmerline's Mergdata platform to SustInAfrica participants, practitioners, and stakeholders. A systems theory and systems thinking analytical approach, integrating hard (e.g. material flows), soft (e.g. learning processes) and critical systems (e.g. governance) methods, will enable the systemisation of knowledge and information, and identification of hierarchies, functions and interdependencies, not only within natural and social science disciplines, but also between them.

The specific objective in regard to ***Task 1.2.a*** *is to:* Gain a deep understanding of the current state of agro-ecological and economics of West and North African farming systems, including stakeholder and policy mapping and assessment: Providing a detailed state and assessment overview of selected farming systems and related food chains as to their agro-ecological and economic characteristics. Identifying and assess institutional settings that affect the development, performance and sustainability of selected farming systems, namely, policies, local/multi-scale governance structures and target actors, local interests in existing agricultural solutions or assumed locally as appropriate.

2. Task description

This task will gather information and knowledge on traditional (coordinated by BOKU/Luke), agro-ecological (coordinated by BOKU/Luke), and smart farming practices and monitoring technologies (coordinated by ATB/Luke) from literature (e.g. reviews and meta-analyses) and of selected communities in targeted agro-ecological zones and assess their efficiency on improving agricultural productivity while reducing environmental impacts of agricultural activities. Findings and criteria are defined by the needs of WPs 2 and 3 (e.g., history,

present, future potential, transition). This task will conduct Literature review and/or meta-analysis to elucidate information about existing agricultural practices and smart farming and monitoring technologies, along their effects on productivity and delivery of ecosystem services. The literature review and/or meta-analysis[1] will be done in accordance to gathered data and information collected from the ISI Web of Science, Scopus, data from Ministries in Charge of Agriculture in the 5 countries, and UN FAO database, etc. Screening of smart, open, and affordable monitoring technologies for farmers will be coordinated by ATB and Luke and conducted in collaboration with local experts mentioned in the Grant Agreement of this proposal for plant health (GH, NI, EG, TU), water, and soil management (GH, BF, NI, EG, TU). The screening will search for tools and solutions in previous and current research activities, businesses, research projects, and initiatives as well as already available technologies. A data base will be built, stored at the project`s SharePoint (Tiimeri operated by Luke) and made available in Farmerline`s Mergdata platform (www.mergdata.com). The database can be easily browsed from the web to provide a systematic summary of the findings with access to freely available tools and solutions. The database will be filtered to extract relevant future-oriented technologies that have potential to be tailored to the needs of smallholder farmers in Africa. Each sorted out technology will be ranked for their suitability of practical implementation for smallholder farming in African agriculture. The ranking will take into account the current situation but also the future development in African agriculture.

3. Timeline, milestones and responsibilities

Table 1. Activities, deliverables, milestones and responsibilities

Activities and deliverables	From	to	Involved	Responsible
Review (phase I: planning) protocol development for systematic literature reviews	M01	M05	ISEG, ATB, FC.ID, SHA	Pierre Ellssel (BOKU), Nils Borchard (LUKE)
Aligning methodologies of Tasks 1.1 and 1.2. Participation in workshop for keywords establishment (M03)	M02	M04	BOKU, LUKE, ATB, ISEG, FC.ID	Pierre Ellssel (BOKU), Nils Borchard(LUKE), Michael Schirrmann (ATB), Ana Luz (FC.ID)
Review (phase II: Searching, selecting and extracting) of traditional and agro-ecological practices	M04	M14	all	Pierre Ellssel (BOKU), support Nils Borchard (LUKE)
Review (phase II: Searching, selecting and extracting) of smart	M04	M14	all	Michael Schirrmann, Marius Hobart (ATB)

[1] *Uman, L. S.* (2011): Systematic reviews and meta-analyses. *J. Can. Acad. Child Adolesc. Psychiatry* 20, 57–59.

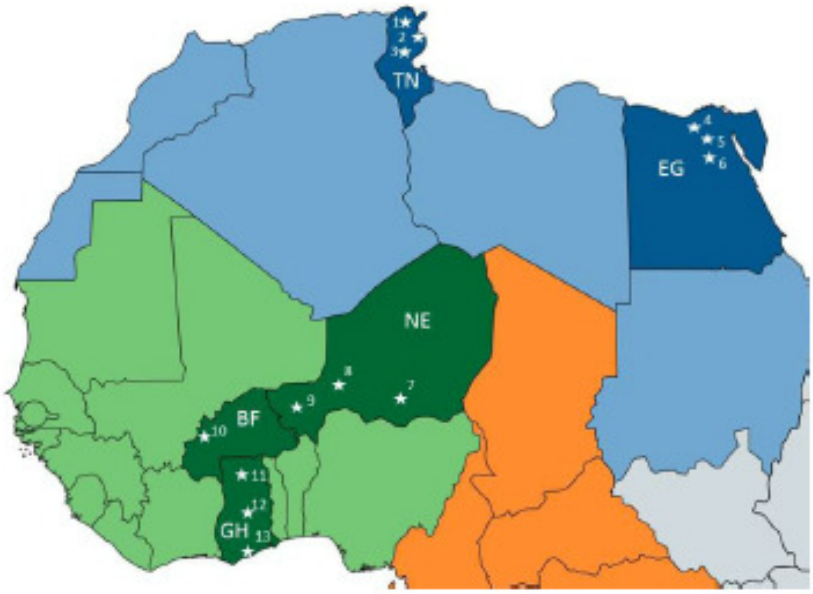
farming tools				
Insects and ecosystem services	M01	M07	*all*	*Luke, ATB, FC.ID*
D1.3 (D1.2a)[2] Farming practices overview	M05	M14	all	Pierre Ellssel, Bernhard Freyer (BOKU), Nils Borchard (LUKE)
D1.4 (D1.2a) Smart farming and monitoring technology overview	M05	M14	all	Michael Schirrmann, Marius Hobart (ATB)
Data processing and manuscript preparation	M10	M24	all	Pierre Ellssel, Bernhard Freyer (BOKU), Nils Borchard(LUKE), Michael Schirrmann (ATB), Ana Luz (FC.ID)

4. Methodology

The SustInAfrica consortia will conduct a systematic review on agricultural practices and technologies to assess their potentials on improving productivity, enhancing the ecosystems capacity to deliver ecosystem services[3], resilience[4] and sustainability[5] of farming systems typically found in targeted agro-ecological zones (Figure 1).

[2] D1.2a: Farming practices overview (Luke, M14): Open access database on sustainable farming practices and their efficacy and efficiency.
[3] "Ecosystem services are the benefits people obtain from ecosystems." These services can be divided into provisioning, regulating, cultural and supporting services (see: Millenium Ecosystem Assessment (2005). Ecosystems and human well-being (Vol. 5, p. 563). United States of America: Island press.)
[4] "Resilience can be described as the capacity of systems, communities, households or individuals to prevent, mitigate or cope with risk and recover from shocks. At first approximation, resilience is the opposite of vulnerability. However, resilience adds a time dimension. A system is resilient when it is less vulnerable to shocks across time and can recover from them. Essential to resilience is adaptive capacity. Adaptive capacity encompasses two dimensions: recovery from shocks and response to changes in order to ensure the 'plasticity' of the system." FAO, 2013. Climate Smart Agriculture – Sourcebook. Food and Agriculture Organization of the United Nations (FAO), Rome. 570 p.
[5] Sustainablity in agri-food systems refers to: "the efficient production of safe, high-quality agricultural products, in a way that protects and improves the natural environment, the social and economic conditions of the farmers, their employees and local communities, and safeguards the health and welfare of all farmed species." (see: http://www.omafra.gov.on.ca/english/busdev/facts/15-023.htm#Intro)

Figure 2. Research locations



In addition of the above-mentioned inclusion criteria (i.e. agro-ecological zones and farming systems) the review will consider soil types with an aim to identify appropriate agricultural practices[6] and technologies[7]:

1. Improving agricultural productivity
2. Preserving and/or increasing ecosystem services
3. Preserving and/or increasing resilience
4. Preserving and/or increasing sustainability

Table 2. Research locations and respective site conditions

Country	**Research locations**	**Climatic zone**	**Soil type**	**Rainfall (mm)**	**Temp. °C**	**Farming / cropping system**
Tunisia	1. Beja					Olive farming system
	2. Sousse					
	3. Kairounan					
Egypt	4. Behira Nile delta					
	5. Giza Nile flats					
	6. Beni Suef Nile flats					
	7. Eastern Niger					

[6] Practices: e.g. Sowing date
[7] Technologies: e.g. Row seeder

Niger	(Zinder & Diffa)					
	8. Northern Central Niger–Tahoua					
	9. Southern Central Niger					
Burkina Faso	10. Hauts-Bassin					
Ghana	11. Tamale					
	12. Ejura					
	13. Komenda					
Total	**13**					

5. Preparation/Background

5.1. Objective

Define terms and objectives (i.e. goals) to summarize evidence from primary studies examining effects of interventions OR to summarize evidence from systematic reviews examining effects of interventions.

- Focus on geographical location (North and West Africa), Tropical, sub-tropical, arid, semi-arid
- Focus on agricultural systems
- Focus on specific crops

Answer following questions:

- What are the characteristics of the targeted populations and/or farming systems?
- Does the review topic have important implications for agriculture, ecosystem services, sustainable development, resilience, policy and research?
- Does the existing evidence (including existing systematic reviews) fails answering the review question(s) or in other words state the knowledge gaps in the state of art?

5.2. Define the review question

Table 3. Proposed review/research questions and/or hypotheses

Research Questions
1. Which agricultural practices and technologies foster sustainability (includes ecosystem

services and productivity) and resilience in North and West African smallholder farming systems?
Hypotheses

5.3. Proposed review title

One promising title: Agronomic practices and technologies enhancing productivity and ecosystem services of farming in North and West Africa: A systematic review and/or meta-analysis.

5.4. Resources, timing and responsibilities

What resources are required to conduct the review, and are they available?

Relevant expertise:	Avaiable (Nils Borchard, Bernhard Freyer, Michael Schirrmann)
Computing facilities:	Available (basically merely a computer necessary)
Research databases:	Available (Access to e.g. ISI WEB of Science secured via research institutions (BOKU, ATB, LUKE etc)
Bibliographic software:	Available (ENDNOTE and Mendeley)
Statistical software:	Available (free software such as R; others available via research institution)

Detailed timeline (see also section 3 “Timeline, milestones and responsibilities):

	Completion date	Lead reviewer
Defining research questions / hypotheses / title	M04 (12/2020)	Pierre Ellssel, Nils Borchard, Michael Schirrmann, Marius Hobart
Searching for reviews / defining key words	M04 (12/2020)	Pierre Ellssel, Nils Borchard, Bernhard Freyer, Michael Schirrmann, Marius Hobart
Draft protocol for internal review	M04 (12/2020)	Pierre Ellssel, Nils Borchard, Michael Schirrmann, Marius Hobart
Protocol for external review	M05 (01/2021)	
Searching and study selection	M08 (04/2021)	Pierre Ellssel, Nils Borchard, Michael Schirrmann, Marius Hobart
Data extraction	M10 (06/2021)	Pierre Ellssel
Quality assessment	M11 (07/2021	Pierre Ellssel, Nils Borchard
Draft report for peer review	M13 (09/2021)	Bernhard Freyer

Submit for publication	M15 (11/2021)	Pierre Ellssel
Celebrate publication	M18 (02/2022)	All

Contributor Roles Taxonomy (CRediT)[8] to manage responsibilities and credentials: „CRediT (Contributor Roles Taxonomy) is high-level taxonomy, including 14 roles, that can be used to represent the roles typically played by contributors to scientific scholarly output. The roles describe each contributor's specific contribution to the scholarly output."

Table 4. Contributor Roles Taxonomy

Contributor roles defined	**Contributor Names**
Conceptualization – Ideas; formulation or evolution of overarching research goals and aims.	Pierre Ellssel, Nils Borchard, Bernhard Freyer, Michael Schirrmann, Marius Hobart
Data curation – Management activities to annotate (produce metadata), scrub data and maintain research data (including software code, where it is necessary for interpreting the data itself) for initial use and later re-use	Pierre Ellssel (Nils Borchard, Bernhard Freyer, Michael Schirrmann, Marius Hobart)
Formal analysis – Application of statistical, mathematical, computational, or other formal techniques to analyse or synthesize study data.	Pierre Ellssel (Nils Borchard, Bernhard Freyer, Michael Schirrmann, Marius Hobart)
Funding acquisition - Acquisition of the financial support for the project leading to this publication.	Idalina Dias Sardinha, Nils Borchard, Bernhard Freyer
Investigation – Conducting a research and investigation process, specifically performing the experiments, or data/evidence collection.	Pierre Ellssel (Nils Borchard), Marius Hobart (Michael Schirrmann)
Methodology – Development or design of methodology; creation of models.	Pierre Ellssel, Nils Borchard, Rita Queiroga-Bento, Ana Luz, Bernhard Freyer, Idalinha Dias Sardinha
Project administration – Management and coordination responsibility for the research activity planning and execution.	Nils Borchard, Bernhard Freyer
Resources – Provision of study materials, reagents, materials, patients, laboratory samples, animals, instrumentation, computing resources, or other analysis tools.	-
Software – Programming, software development; designing computer programs; implementation of the computer	-

[8] https://casrai.org/credit/

code and supporting algorithms; testing of existing code components.	
Supervision – Oversight and leadership responsibility for the research activity planning and execution, including mentorship external to the core team.	Nils Borchard, Bernhard Freyer, Michael Schirrmann
Validation – Verification, whether as a part of the activity or separate, of the overall replication/reproducibility of results/experiments and other research outputs.	Nils Borchard, Bernhard Freyer, Michael Schirrmann
Visualization – Preparation, creation and/or presentation of the published work, specifically visualization/data presentation.	Pierre Ellssel
Writing – original draft – Preparation, creation and/or presentation of the published work, specifically writing the initial draft (including substantive translation).	Pierre Ellssel
Writing – review & editing – Preparation, creation and/or presentation of the published work by those from the original research group, specifically critical review, commentary or revision – including pre- or post-publication stages.	Pierre Ellssel, Nils Borchard, Bernhard Freyer, Michael Schirrmann, Marius Hobart

5.5. Methods

Search strategy

a) Which databases will be used?

b) What are key word and search operators?

1. Pre-review of possible keywords

2. Keyword definition for main search

Selected keywords (Tables 5 and 6) are based on the drafted and approved protocol (Planning phase). The keywords and their combinations as described in the protocol, for instance:

- Agroecological practices AND technologies
- Organic farming practices AND technologies
- Traditional farming practices AND technologies
- Smart farming AND monitoring practices AND technologies
- Sustainable intensification practices AND technologies
- Ecological intensification practices AND technologies

Regarding targeted groups SustInAfrica will include « smallholder agriculture » and the respective agro-ecological zones. Selected publications (see protocol drafted during planning phase) will be screened for practices and technologies that are of relevance (i.e. questions and/or hypotheses; Table 4) for actors of targeted agro-ecological zones (e.g. a second screening step based on a subset of keywords described in the protocol).

Table 5. Definition of major keywords

Keywords	Source

Table 6. Definition of sub-keywords

Keywords	Source

c) What other sources will be used?

Selection criteria

a) What are the inclusion / exclusion criteria?

What kind of studies are considered? → on-station trial results, on-farm trial results (statistic design of such studies – randomized/non-randomized), only peer reviewed or not

b) Will you impose any additional limits, e.g. language, publication type, study design?

c) How will study selection be performed?

Quality assessment

a) What criteria will be used to assess methodological quality?

Assessment of methodological quality of individual studies

b) How will quality assessment be performed?

Data extraction / data management

„There are numerous tools and software to assist you with screening, risk of bias assessment, and data extraction during your review. Some tools may be more appropriate during different phases of your review.“ Potential tools are:

- Covidence
- Rayyan
  Rayyan is a free screening tool with some machine learning capability.
- DistillerSR
  Fee-based systematic review software with some machine learning capability.
- Abstrackr
  From Brown University. Open and free to all. It's set up to automatically pull in abstracts from NLM using PMIDs. One can also transfer abstracts over from Reference Manager or EndNote. Allows for collaborative screening of abstracts.
- EPPI-Reviewer 4
  EPPI-Reviewer 4 is software for all types of literature review, including systematic reviews, meta-analyses, 'narrative' reviews and meta-ethnographies.
- Systematic Review Data Repository (SRDR)
  From AHRQ, SRDR is a tool for extraction and management of data for systematic review or meta-analysis. It is also an open and searchable archive of systematic reviews and their data.
- Colandr
  Free open access, machine-learning assisted tool for screening and extraction
- SysRev
  Collaborative web-based application that uses machine learning to optimize systematic literature reviews. The free platform supports open access/public projects only. There is a fee to apply privacy settings.

a) What are the key data to be extracted?

b) How will data extraction be performed, and how will extracted data be presented?

Data analysis / synthesis / Grading the evidence for each key question

a) How will data be combined (statistical or narrative), and why?

b) What are the potential sources of effect heterogeneity and how will they be assessed?

Annex 2

3.2 What we need to know to select the "Core communities"

Collect data at different levels till April 2021:

1. Information at the community level

Collect the information through conducting a survey (see point 5. Communities characterisation) with the community leader, someone who knows very well the community, or based on your expertise, mainly about:

Key data

- Farmers willingness to participate in *SustInAfrica*
- Land availability for plots implementation
- History of community participation in projects
- Farmers and other stakeholders current and desired farming practices and crops
- Farmers revenue expectations
- Farmers technological readiness
- Market accessibility and influence from outsiders (e.g., commercial farming)

Other relevant data

- Community social and physical structures (e.g., number of households (HH), average literacy level, infrastructures, school)
- Livelihood activities besides agriculture
- Water availability (existing borehole or any irrigation system)
- Gender & youth participation in agriculture
- When available location of the nearest weather station

2. Information at the AEZ level and regional/administrative levels

To be done through literature, open databases, Global Information Systems (GIS) & Remote Sensing (RS)

- Bio-geo-physical data information: land use land cover types, soil types, climate, etc. (based upon Kwame's table and Bernhard and Pierre template they are drafting)
- Administrative areas (e.g., region, province) to cross analyse with AEZ area
- Socio-economic and policy data if available

3. Community selection criteria

Criteria in the proposal

i. Willingness of farmers to participate & technical, institutional, and social readiness (e.g., vocational school in place, already part of agricultural research and development projects, target community by local and national government)
ii. Availability of land and interest in new cropping systems and crops (*is there a min of area we need to have to implement trials?*)
iii. Access to potential markets is given or easily to ensure
iv. Regional and agroecological diversity

Other criteria we can have into account

- Need of financial compensation and if so, how to transfer (cash or mobile payment)
- Water availability (e.g., borehole, irrigation system)
- Camping conditions for field teams to collect data
- Other (*please indicate*)

3.3 How to collect the information

A. IF YOU ALREADY KNOW (SOME OF) THE COMMUNITIES

1. **Establish your key contacts**
   - Establish contact(s) with the key person(s) you know already, e.g., community leader, local associations, extension agricultural technicians to collect detailed information about each community.
   - Information can be collected from different sources. It can also be done based on your knowledge or experience working with the community.

2. **Fill tables 1 & 2 (presented in points 4 and 5)**
   - Collect the possible information with your contact person(s).
   - Table 1 lists the communities settled in each AEX.
   - Table 2 identifies priority and secondary data that will help selecting communities.
   - This information can be collected over time and based on different contact people and your own experience/knowledge, when appropriated.

3. **Obtain the coordinates of the community centre**
   - When there is the possibility to visit communities, please obtain a GPS point of the community centre.
   - Otherwise, if you know the community already, it is possible to collect the coordinates by using Google Earth (we can support this procedure – see image below).

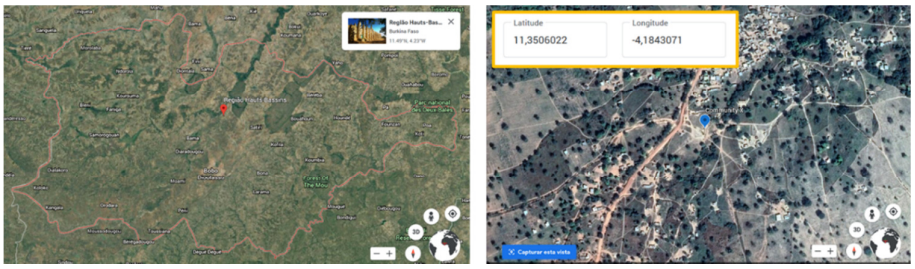


Figure 1. Example of a community in Burkina Faso identified trough Google Earth, and corresponding coordinates.

B. IF YOU DO NOT KNOW ANY COMMUNITY OR FEW

1. **Establish contacts at different levels – national to local – to identify potential communities**
   - Establish contact(s) with key person(s) from, for example, the Agriculture relates Ministries / local NGOs / Associations working with communities' agriculture to identify and obtain information about the existent communities in the selected AEZ or to obtain other contacts that will know the communities.

2. **In each of these contacts, when possible, obtain specific information about:**
   - Existing communities in each AEZ. When possible, identify communities that have worked already with agricultural projects and identify associated crops and projects results.
   - Collect maps or GIS shapefiles and other information available related with the AEZ and communities.
   - Identify contact persons at the regional and local levels (community) to support contact with communities to collect the information described in point 1.
   - In each new contact established present the *SustInAfrica* project to the person.

3. **Fill tables 1 & 2 (presented in points 4 and 5)**
   - Collect the possible information with your contact person(s).
   - Table 1 lists the communities settled in each AEX.
   - Table 2 identifies priority and secondary data that will help selecting communities.
   - This information can be collected over time and based on different contact people, depending on what they know.

4. **Obtain the coordinates of the community centre**
   - When there is the possibility to visit communities, please obtain a GPS point of the community centre
   - Otherwise, if in this case you can locate the community in Google Earth and extract the coordinates (Fig. 1).

C. ANALYSE THE INFORMATION COLLECTED AND IDENTIFY INFORMATION GAPS

- After doing the contacts described above and collecting the available information, analyse all the data collected and evaluate the necessity of going to the field to collect missing data.
- In case there is a need to visit communities to complete the survey, prepare in advance fieldwork campaigns to each AEZ to maximize effort and minimize costs and time.

D. IF NEEDED, VISIT THE COMMUNITIES TO COMPLETE THE SURVEY

- Organize field trips to each AEZ to fill the missing information at the community level.
- Identify properly the missing data and contact persons before going to the field.

3.4 List of communities identified in the AEZs

All the identified or know communities should be listed in a table as example showed in Table 1. This listing will allow to justify why we select some communities in regarding others with very simple criteria. For the most interesting communities, according to the selection criteria, Table 2, must be filled. A table with all the contacted stakeholders can also be provided and shared with the project partners.

Table 1. Information on the existent communities in each of the several AEZs for every country.

Country	Administrative location	AEZ	Community name	Contact person, position & contact	Involvement in agricultural projects	Main crops	Main livelihood & commercial activities	Others (e.g., accessibility)	GPS point (UTM or Lat/Long cood)
Example									
Burkina Faso	*Hauts-Bassin*	*Bush-grass savanna*	*Community Z*	*Leader, Phone: + 123 456789*	*Yes. Involved in the Agro project from XXX*	*Cotton-, maize-legume rotation systems*	*Subsistence agriculture & livestock*	*Accessible to the nearest market town (30 min walking)*	*UTM X 370768; Y 1255009 Lat 11,3506022 Long -4,1843071*

3.5 Communities characterization

Interviewees: To collect the most accurate information about each community identified, a survey / interview should be conducted, ideally to the community leader or a substitute that knows well the history, structure, economic activities, and habitants of the community. Yet, during the contacts established over time, some of this information can also be obtained before.

Approach: The interview or talk ideally happens face-to-face or if not possible via telephone/videoconference. If you desire, you can record the conversation (and if the interviewee authorizes) and fill the table after.

Table 2. Detailed survey for the communities' characterisation. The table presents two levels of necessary information – the priority and the secondary data.

PRIORITY DATA	
COMMUNITY IDENTIFICATION	
Name of community	
Province or other administrative designation	
AEZ	
Land tenure system [type of tenure (governmental, community, private land, natural reserve) and land rights (right to hunt, fish, recollect, etc.)]	If is the same for the whole country, delete the question, and describe the land system for the country
GPS point & coordinates	If you do not go to the field, you can identify the community on Google Earth and collect the coordinates.
COMMUNITY STRUCTURE	
Land available for trials implementation [hectares]	
Household (HH) number [count woman and man houses; often man is polygamy]	
Access and roads [nearest market town, accessibility in hours walking/car; visits from outside market to buy/sell at community]	
COMMUNITY ENGAGEMENT	
Willingness to participate during the project	

period (5 years) [describe number of HH/farmers, and typology of farmers (smallholder, large or commercial) that what to be involved]	
Indicate main reason of interest or not to participate	
Expected compensation [expects or not compensation; type of compensation]	
Previews participation in agricultural projects	
Technology use [It can be technology associated to agriculture, use of smartphones, etc.]	
AGRICULTURAL PRACTICES	
Present agricultural practices [agricultural systems (monoculture, mixed farming, large-scale, etc.) and crops; main seasons and harvests actors (smallholder and large farmers);]	
Agricultural support system [presence of extension administrators, NGOs, women's work associations, private organisations, business markets integration, products exporting experience]	
Livestock [livestock system and integration with agriculture]	
Main challenges and future expectations [challenges lived by farmers associated to their agricultural practices and future expectations regarding practices and crops]	
SECONDARY DATA	
HH List / farmers list willing to participate [collected or not]	
School [Describe year of settlement, # of teacher, average education levels, average attendance (# children)]	For example: *Since 2005 till 7th grade; two teachers; after 7th children must go to the nearest city _____ where they stay in families or rented houses. Most families cannot afford that.*
Average literacy level [per gender & age classes]	
Water availability [type of water sources for HH & agriculture]	
Electricity availability [type & if reaches the whole community or a few families]	
Health services [health centre or nearest extension]	
Migration [farmers or young people permanent or seasonal movements; seasonal work]	
Other	
MAIN ACTIVITIES	
Other commercial activities [hunting, fishing, charcoal, small agrobusiness	

packaging]	
Forest use [agroforestry, fruits, firewood, construction, medicinal plants, hunting)	
Other	
CHANGES THE COMMUNITY HAD IN THE LAST DECADE	
Social change [changes in education, facilities, roads, health system, poverty, security / conflicts, community structure; changes of livelihoods, etc.]	
Environmental changes [deforestation, land degradation, wildlife loss, fires, soil fertility loss, pests, droughts, major fears, etc.]	
Other [e.g., new mine location]	
GENDER	
Women's role in agriculture	
Family labour and workload	
Women's work in association	
Other [e.g., women have power to the land, women have right to lend money]	
YOUTH	
Participation in agriculture [Youth participation % and type of activities]	
Youth technology interests	
Youth agriculture interests	
Other	

3.6 Team and material for data collection work

Please, below indicate if you need any support and material and describe how you expect your team to be, both during the data collection of the communities screening until April 2021, and also during the baseline assessment data collection.

Communities screening data collection
Example: *1 enumerator* *1 tablet* *1 GPS*
Baseline data collection
Example: *3 enumerators, 1 coordinator* *3 tablets*

Annex 3

Table(s) 3: Prelimiary list of proposed single indicators and metrics by disciplines. Abbr.: 1 = Just baseline survey or as part of a single/satellite experiment, 2 = Repeat measurement to monitor => simple approaches, 3 = Repeat measurement to monitor => advanced approaches, 4 = Not clear?, VI = vegetation index, RS = remote sensing, GT = ground truthing, UAV = unmanned aerial vehicle

1. AGRICULTURE

Unit of analysis	Indicators / Metrics	Metric units & scale	Description & links	Reference source(s)	Methods	Phase
Land area and structure	**Area:** **. Holding size** **. Agricultural land** **. Crop land** **. Grazing land** **. Kitchen garden**	Hectare (ha or m^2) & % Scale: Field, farm/HH and/or community	Needed to compare ratios of land use, stocking rates		Farmers/HH survey RS: From UAV imagery can be directly vectorized with highly accurate field boundaries and direct assessment of crop type. From Copernicus with time series data with Sentinel 2 possible within experimental plugin in SNAP (Linux version available)(GT Validation strongly recommended); this approach relies heavily on time series analysis of sentinel imagery (experts and resources needed to follow this approach), or after Watkins et al., 2019 (field boundary estimation) and random forest classification (GT needed) (e.g. Vuolo et al., 2018)	1 and 2
	Field boundaries	Limits. Field, farm/HH and/or community	Important to compare locations and physical structure within communities		GIS RS	1
	Fragmentation / connectivity	Indexes of fragmentation	Link with biodiversity, pests, ES		RS	1
	Small woody features	Object delineation (hedges, bushes, tree rows, isolated trees) Scalability: Communities level (UAV) regional level	Ecosystem services may relate to shadowing, wind erosion etc. e.g. effects of height of hedgerows on crop yield determined (Van Vooren et al., 2017)		GT: Survey RS: Object based classification based on machine learning with textural, spectral and temporal features or manually by digitizing high resolution RS data (e.g., UAV) (Aksoy et al., 2009) Height of hedges, bushes trees could be estimated from UAV point clouds (Hobart et al, 2020)	1

		(Sentinel, highly uncertain, only larger structures)				
	digital terrain model (DTM),	Delineated by digital terrain model (DTM), height in [m], secondary parameter e.g., slope, aspect, watershed directly Scalability: with UAV possibly community scale.	Relates to erosion processes but also crop productivity		GT: Accurate ground control points necessary RS: UAV can delineate surface heights by structure from motion (overlapping imagery). High geometrical accuracies possible (D'Oleire-Oltmanns et al., 2012)	1
Cropping system	**. Crop diversity . Crop rotation / . Intercropping . Multi-storey cropping . Agroforestry**	. Crop type count & % . Ha or % Farming system	Include relay cropping Crop diversity is also a proxy indicator for dietary diversity. Crop diversity also links with ES Maintenance of seed dispersal	IFPRI: "If they grow it will they eat it" Kumar et al. 2015 CICES v5.1	Farmers/HH survey RS	2, 3, and/or 4
	Seed source and classification	% by crop	Proportion of seed accessed by farmers from formal seed dealers, general markets, save/ shared/ exchanged. Proportion of seed that is: Landraces, improved, certified Quality Declared, other	https://seedsystem.org/	Farmers/HH survey Secondary data: access to seeds index https://www.accesstoseeds.org/about/	4
	Planting date/ timing	Ha, % or number of farmers with				1

	Broadcasting, row seeding	improved technology				
	Provision of seeds for the next season crops	metrics of amount of seeds/crop/area of production	If one of the project goals is to produce seeds for farmers to use in the next season crops???	CICES v5.1	yield of seeds available for reseeding	?
	Livestock diversity	Types, breeds				1
	Stocking density	Number per ha	Pressure on land		determine yield of animals & products produced in the cropping system	2 and/or 4
	Weight gain Milk yield	Litres per day milk	Productivity, ES			1
	Animal health	Disease incidence; Farmer reported condition; Growth rate; Mortality	Measuring productivity and intensification; T1.2.b; T3.1; T3.3; T5.1		HH survey or field sampling / monitoring by farmers. Herd record sheet / app	1
	Conversion efficiency	Kg meat / kg grain consumed	Measuring productivity and intensification; T1.2.b; T3.1; T3.3; T5.1		HH survey or field sampling / monitoring by farmers	3 or 4
	Livestock management	Type of fodder Amount of fodder Hours of grazing Time in stable Free roaming Cut & carry				1
Crop performance / Inputs	**. Crop protection . Weeding . Fertilization**	Kg/ha or l/ha or % of reduction Ha, % or number of farmers with improved practice	Amount of pesticides, herbicides, compost/manure, inorganic, mechanical Integrated pest management (IPM),			2

			Traditional methods			
	Threshing, cleaning	Ha, % or number of farmers with improved practice Or increase kg/ha				1
	Input efficiency	Efficiency equivalent ratio of nutrient and water inputs; Eco-efficiency score; all inputs; Partial factor productivity of nutrient inputs; Energy efficiency analysis; all inputs	Measuring productivity and intensification; link to ES T1.2.b; T3.1; T3.3; T5.1			3
	Input intensity	Capital intensity in $/ha; Intensification index; Energy intensity in Mj/ha; Fertilizer rate in kg/ha	Measuring productivity and intensification; link to ES, soil quality T1.2.b; T3.1; T3.3; T5.1			1 and 3
	Pest pressure	Farmer reported pest pressure; # pests/plant or sample; # pest species suppressed; % crop plants damaged; Weed infestation score	Measuring productivity and intensification; T1.2.b; T3.1; T3.3; T5.1 Pest control ES.	Sticky traps (Dimitrova et al., 2020), trap technology, InsectaMon	Surveys **InsectaMon**	1 and 2
	Crop Growth stage	Use industry standard stages.	We found that crop growth stage was an	Ground Truth surveys	Visual. Will depend on crop	

			important factor for predicting insect damage to maize from satellite images			
	Resilience	Relative crop loss due to disaster; Ability to maintain yield under a range of future scenarios, modelled	Measuring productivity and intensification; T1.2.b; T3.1; T3.3; T5.1			3
Soil management	**Crop residue management**	Ha or %	Burning, removal, incorporation, mulching			2
	Compost/Manure management	Nutrient content g/kg, Ha, % or number of farmers with improved practice	Nutrient content, preparation, storage			2
	Tillage	Ha, % or number of farmers with improved technology. Type of plow Depth No. of crossings Use of minimum tillage/ no till/ Conservation Agriculture. Use of Zaï holes, Demi Lunes	Tillage will impact on soil erosion, women workload, resilience to droughts, weed and pest levels.	http://www.act-africa.org/	Farmer interviews	2
Productivity	**Crop yield**	Output/area (kg/ha); disaggregated by Crop, AEZ, HH socioeconomic	Measuring productivity and intensification	FAO; SGD 2.4.1	Crop Cuts for field crops Point-to-Plant for tree crops. Farmers / HH survey RS: Empirical relationships specifically for VI similar AGB, best to include multiple Vis (e.g. with random forest), time series	2

		levels, gender of HH head.			advantageous, previous historic data possibly advantageous (strong environmental background influences required, e.g. soil, relief etc.), Sentinel 1 radar data improves modelling. Biophysical variables e.g. LAI strongly improves modelling. (Lambert et al., 2018, Jin et al.,2019). UAV 3D point clouds can provide vital information into models (e.g. crop height). The combined use of thermal, multispectral, RGB camera outperforms single sensor use for yield prediction (Maimaitijiang, et al., 2020) For upscaling crop type specific information layer needed.	
	Yield variations for ES assessment - Yield of each crop parts used for **. food or animal feed** **. fibres (e.g. cotton)** **. mulch** **. production of energy (e.g. fire)***	Metrics of plant density and total area of cultivation, and of amounts of product produced: e.g. kg/m2 of each crop, or kg/tree, tree density	Amount of collected plants used for nutritional purposes	CICES v5.1	Determine crop area of cultivation and yield (pineapple, cereals, corn, olive (fruits), cotton, legumes, vegetables, root crops) *biomass above ground in a certain LU?	3
	Above ground biomass (AGB)	[kg/m^2] Usually measured as fresh and dry biomass Scalable from crop to regional level (but needs calibration)	All living biomass above the soil including stem, stump, branches, bark, seeds and foliage (FAO). An important indicator of agro-ecosystems is usually used as a key factor in predicting crop production and estimating water use		GT: involves the manual removal of all plant material within a specific crop canopy area (e.g., in wheat usually 1x1m^2) and weight measurement including dry biomass after drying the crop plant material (e.g. wheat: with compartment dryer 60°) RS: multiple approaches are possible: Empirical modelling with VI and LAI derived from multispectral / RGB data can provide good estimates, inclusion of crop height derived from UAV point clouds improves estimates a lot. (e.g. Niu et al. 2019, Schirrmann et al., 2016) More sophisticated modelling with crop growth models thinkable (e.g. SAFY) with LAI or crop cover as RS input but many	1

			efficiency [6–8]. The rapid, accurate, and economical estimation of AGB is of great importance. AGB remains one of the basic indicators to assess the performance of agricultural practices [9,10], to research agro-ecosystem processes [11], and to estimate global market risk [12] (see Niu et al. 2019)		secondary parameters necessary (weather, soil etc.) (Dong et al. 2020)	
	Cropping intensity	# of crops/unit time; R factor (cropping frequency)	Measuring productivity and intensification; link to ES T1.2.b; T3.1; T3.3; T5.1			1 and/or 3
	Fodder quality	Nutritional content of fodder; Presence of toxins; Consumption of legumes	Measuring productivity and intensification; link to ES T1.2.b; T3.1; T3.3; T5.1			1 and/or 3
	Yield quality	Kg/ha % of harvest that meets appropriate quality standards. Disaggregate by storage type, crop, variety.	Productivity Measure against appropriate quality standards Includes food safety		It is better to measure against an appropriate quality standards as this will provide a better indication of marketability and safety. These should be national or international standards. Ghana National Bureau of Standards, World Food Program, national cotton standards, …	?
	Yield profit	$ product/ha;	Measuring		Crop cuts from quadrates demarcated before harvest.	2, 1

		kg product/ha; kg product/animal/day; Land equivalent ratio	productivity and intensification; T1.2.b; T3.1; T3.3; T5.1		Point to plant for tree crops.	
	Yield gap	Attainable yield–actual yield; Locally attainable yield–actual yield	Measuring productivity and intensification; T1.2.b; T3.1; T3.3; T5.1	http://www.yieldgap.org/	Crop cuts from quadrates demarcated before harvest. Point to plant for tree crops.	3, 1
	Yield variability	Coefficient of variation	Measuring productivity and intensification; T1.2.b; T3.1; T3.3; T5.1		Crop cuts from quadrates demarcated before harvest. Point to plant for tree crops.	3
	Field/Post-harvest losses	Kg/ha % of harvest that meets appropriate standards. Disaggregate by storage type, crop, variety.	Productivity Measure against appropriate quality standards: national standards, WFP grain quality standards; IFOAM	It is better to measure against an appropriate quality standards as this will provide a better indication of marketability and safety. These should be national or international standards. Ghana National Bureau of Standards, World Food Program, national cotton standards, IFOAM for organic exports, …	Random sampling of harvest following national/ international sampling protocols. Use a grain spear to sample sacks. For grain quality use 100 grain test: Mix samples from sacks, quarter, mix, quarter again, mix again and quarter. Count 100 grains. Sort 100 grains into: WFP classes: . Other colour maize: **5.0%** w/w max. . Pest damage grains: **3.0%** w/w max. . Rotten& diseased grains: **4.0%** w/w max. . Discoloured grains: **1.0%** w/w max. . Immature/shrivelled grains: **2.0%** w/w max. . Total defective grain: **5.0%** w/w max. . Other grains: **2.0%** w/w max. . Broken grains: **4.0%** w/w max. Use moisture meter/ salt/ teeth to assess moisture . Moisture: **13.5%** w/w max. Aflatoxins (B1+B2+G1+G2): most African countries = 10ppb. I use	1 or 3

					https://www.neogen.com/solutions/mycotoxins/reveal-q-plus-max-aflatoxin/ but this looks like a much better option for our work: https://app.r-biopharm.com/	
	Storage	Ha, % or number of farmers with improved practice Or increase kg/ha Better: type of storage. Note that quality would be an outcome indicator for storage.	Types of storage (traditional, improved…)			1
Crop quality - Physiological traits	**Stomatal conductance**	Leaf level	Stomatal openings regulate the exchange of water vapor and CO_2 between a leaf and the air. Stomatal conductance to water (gs), which responds to light, CO_2, temperature, and humidity, among others, is a measure of the degree of stomatal openness and the number of stomata. It is an indicator of a plant's genetic makeup and physiological response to environmental conditions.	G.D. Farquhar and T.D. Sharkey(1982)	Measurements will be conducted with porometer on abaxial leaf conductance per tree in each treatment to monitor the diurnal variation of stomata conductance	3 and 4
	Performance index	Leaf level	chlorophyll *a* fluorescence represents a promising tool for detection of	(Strasser et al. 2000)	Chlorophyll *a* fluorescence will be measured by a portable non-modulated fluorimeter Handy PEA (Plant Efficiency Analyser, Hansatech Instruments, Kings Lynn, UK).	3 or 4

			plant tolerance to various environmental stresses		Plant vitality will be characterized by performance index(PI_{abs})	
	Chlorophyll index (SPAD chlorophyll meter)	Leaf level	The chlorophyll index is a quick and non-destructive in situ measurements of the leaf chlorophyll content of each crop.	Andreas Süß et al. (2015)	A non-destructive method will be applied to determine the amount of chlorophyll present in the leaf sample using the SPAD-502 m (Spectrum Technologies, Inc, Aurora, USA).	1
	Leaf chlorophyll content (Cab)	Crop canopy level	Cab is strongly related to leaf nitrogen content.	Bacour C. et al. (2006)	Vegetation biophysical parameter (Cab) will be derived from each Sentinel level 2A product using the ESA-SL2P integrated in the Sentinel-2 SNAP toolbox. Satellite images.	3 and 4
	Ripening Index	Crop fruit level.	For the farmer, Ripening index is of high importance for olive tree management (e.g., site specific fertilization, irrigation, mulching).	El Yamani et el. (2020)	Hundred olives from each tree of each treatment will be randomly sampled immediately after harvest to determine the ripening index. It is based on a scoring system of the colouring of the skin and flesh.	3 or 4
	Oil content	Crop fruit level.	For the farmer, oil content is of high importance for olive tree management (e.g., site specific fertilization, irrigation, mulching).	Mena et al. (2018)	The industrial oil yield (oil content %), given in percentage of fresh olive paste weight (W)	1
	Leaf Area Index (LAI)	Dimensionless or [m^2/m^2] Scalable from crop to regional level (e.g. with Copernicus data)	Total one sided leaf area per unit ground area (Watson 1945) It is one of the key structural plant	LAI described as a powerful scalable indicator for several key ecosystem services. (Taugourdeau, 2014)	GT: Direct measurement is problematic because it involves manual leaf measurements which is very tedious; indirect measurement systems available (LI-2200C Plant Canopy Analyzer, SunScan Canopy Analyser, PocketLAI), works best under randomized canopies (e.g. wheat) RS: Copernicus data usable to estimate LAI from surface	1

			canopy parameters. Relates to WP2 T2.3 (crop monitoring systems) WP1 T1.3 (multiscale monitoring) Validation of Sen2Agri model for African crops would be sensible → improves LAI estimation with Sentinel for Africa. UAV related studies could provide meaningful details in specific agronomic experiments (intercropping)		reflection and directional satellite data (10-20m) -> integrated in SNAP/Sen2Agri This is a calibrated ML model with no need of GT input (validation needed) UAVs would enable smaller GSD down to individual plant level however need empirical calibration with GT (multispectral but also RGB VI are related, SfM 3D point cloud could be tried also)	
	Nitrogen status	e.g. in terms of N concentration [%], nitrogen uptake (NUP, kg N ha) or more specifically nitrogen nutrition index (NNI) with NNI > 1 N excess and NNI < 1 N deficiency Scalable (calibration needed)	N essential macronutrient in plants. Relates strongly to crop fertility important for decision making in N management		GT: involves sampling of biomass, drying, grounding and analysing N in lab (Kjeldahl); best to analyse leaf, stem and panicle N separately. For NNI, dry matter weights necessary as well as critical N dilution curve coefficients (e.g. for wheat Justes et al., 1994 and for cotton Xiaoping et al., 2007). Cab can be measured with chlorophyll meters hand sensors (e.g. SPAD-501,Dualex) RS: Empirical relationships to specific multispectral VI e.g., Green band/red edge chlorophyll index indirectly via Cab (Niu et al., 2019), Biophysical variables LAI, AGB should be also integrated for dry matter estimation. High relationships with Cab and CCC (Deloye et al, 2018). Cab can be modelled in SNAP (Sens2Agri) with Sentinel-2 data	1
	Canopy water content (CWC)	g m^{-2} Scalable (validation needed)	Refers to the mass of water within the canopy for a unit ground area	Rollin and Milton, 2008.	GT: Determined with drying biomass or leaves. Latter can be upscaled with LAI to CWC (e.g. Cernicharo et al. 2013). RS:	3

			(Pasqualotto et al., 2018). Water is the most abundant molecule in leaves and its availability in leaf tissues is essential for cell enlargement, and, hence, plant growth. The knowledge of leaf water content (LWC) is important for assessing the physiological state, especially for detecting drought stress of the plant. crop water content provides vital information for making correct decisions regarding irrigation planning and is used for productivity estimation (Pasqualotto et al., 2018)		Empirical relationships established with certain multispectral VIs (NDWI, e.g., Zhang et al., 2017) Can be tried to estimate with S2Toolbox directly from Sentinel 2 (validation needed) Thermal camera UAV can provide additional information e.g., evapotranspiration (Qwater model, Ellsäßer et al., 2020)	

2. ENVIRONMENT

Unit of analysis	Indicators / Metrics	Metric units & scale	Description & links	Reference source(s)	Methods	Phase
Biodiversity	**Insect biodiversity: . Metrics associated with**	Crop level	Relates to functional biodiversity, e.g., assessing antagonists in integrated pest	(Jetz et al., 2019)	Sticky traps (Dimitrova et al., 2020), trap technologies, InsectaMon and Cristina`s ES approach.	1 (inventory) and 3

	. Species distribution . Species abundance		management, pest predator relationships, improve crop monitoring for more effective pest management		Experiments should be conducted in GHA, BFA and TUN. (Luke do research on how to implement field trapping experiments) InsectaMon needs training data from images collected from traps and annotated insects within the images (Experts need to be involved).	
	Pollinators diversity and abundance	abundance (e.g. area, density) and diversity of crop species pollinated by insects (or other animals)	diversity of crops attracts a more diverse range of pollinators, maintaining local biodiversity	**Maintenance of pollination** CICES v5.1	Based on list of species present in crop systems, area and density (layout?) of crop systems, trait databases on pollination type	2
	Diseases	incidence of plant diseases in crop systems	The presence of native disease control agents such as microbial antagonists, would amount in less crop diseases	CICES v5.1 **Disease control**	??? NDVI or other reflectance indexes??? physiological measurements of plants???	3-4
Soil Soil4Africa (S4A)	**Soil org Carbon**	g/kg soil	plays a central role in the maintenance of soil fertility and other soil functions. Measuring soil org c (soc) can indicate the impact of management on soil quality and evaluate the sustainable intensification (SI) impact	doi.org/10.1016/j.soilbio.2018.01.030 doi.org/10.1016/j.ecolind.2018.12.008 ISQAPER (website) and project	Soil samples	2
	Soil pH	pH Units	important, and easily		Soil Samples	2

			measured, soil quality indicator			
	Penetration resistance (or bulk density)	N Values or (g/cm3 for BD)	SI management should improve soil organic matter content in soil and thus, reduces its compaction, i.e. lowering the penetration intensification mana		In field measurement	2
	Soil respiration	mg C/kg soil			In field measurement or soil samples	3 or 4
	EC (Soil Electrical Conductivity)	Soil salinity in crop systems	Saline soils have higher reflectance values within the visible and near-infrared parts of the spectrum in comparison to non-saline soils. The application of spectral indices to investigate soil salinity is built upon the different spectral behaviour.	FAO 29rev (1985)	Soil samples sieving through a 2-mm mesh, and soil electrical conductivity measurement through the saturated paste extracts method using conductometry. NDSI Normalized Differential Salinity Index SI Salinity Index UAV/Satellite data	2
	Microbial community level	Soil Microbial community in crop systems	Estimating the functional diversity of a soil bacterial community by Biolog technique	Sofo and Ricciuti. 2019	Soil samples are shaken in a suitable solution and then the soil solution is inoculated into the plate wells. After incubation, colour development is measured spectrophotometrically.	3 or 4
	Decomposition rates	Decomposition of teabags	Decomposition processes in soil of crop systems are indicators of	CICES v5.1 Regulation of soil quality	teabag index?? (teabags are buried in soil for ≥3	3 or 4

			biodiversity and physic-chemical quality		months and the loss of mass – decomposition- is evaluated)	
	Soil enzymes				soil samples	4
	Soil texture		Fundamental indicator for crop choices and calculating other soil parameters.		soil samples	1
	Soil pH (either H2O or CaCl2/KCl)		Fundamental indicator for crop choices and limits to crop yields.		soil samples	2
	total C/N, SOM, OM		Soil health, water and nutrient holding capacity		soil samples	2
	some nutrients (N, P, K)		Fundamental indicator of soil fertility		soil samples	2
	EC (Soil Electrical Conductivity)		Indicator of soil salinity/ sodicity		soil samples	2
Water	**EC**	Irrigation water quality	To guarantee a non-destruction of the soil/crops by the saline irrigation water.	FAO 29rev. (1985)	Measurement using conductometry.	2
	SAR	Irrigation water quality	The sodium adsorption ratio (SAR) is used as an index for evaluating the sodium hazard associated with an irrigation water supply.	Richards (1954) FAO 29rev.(1985)	The SAR is defined as the square root of the ratio of the sodium (Na) to calcium + magnesium (Ca + Mg)	2
	Heavy metals, fluorine	Irrigation and drinking water quality	Arsenic in irrigation and drinking water pumped from shallow wells in the Ganges valley has created a public health crisis and all irrigation and potable water		Review of literature to identify risks. Interviews with key staff of National Geology/ Mineral Resources/ Water Depts). Standard lab tests of water	2

			projects are now expected to test for heavy metals during planning and commissioning. Fluoride in ground water is a serious problem in the East African Rift Valley (damage to teeth and bones).		samples for arsenic and other heavy metals	
	Microbial contamination	Irrigation and drinking water quality	Contamination of shallow wells with animal manure increase the transmission of a range of pathogens. Cryptosporidium contamination of wells shows a strong positive correlation with risk of child stunting	Tuft Uni/ Concern Worldwide, Chad.	Sample well water during the wet season for E.coli. Crypto testing is expensive and E coli can be used as a proxy indicator of contamination.	2
Climate	**Microclimate** reflectance indexes	Crop system local regulation of temperature and humidity, including ventilation and transpiration	CICES v5.1	UAV or satellite (WP2?)	3 to 4	reflectance indexes
	Current rainfall, temperature trends	Season rainfall, PET, Maximum day and night temperatures	Rainfall, PET, max day and night temp will determine which crops/ varieties can be grown without irrigation	World Bank Climate Portal https://climateknowledgeportal.worldbank.org/ https://www.worldclim.org/ CCAFS http://www.ccafs-climate.org/ http://www.ccafs-climate.org/climatewizard/		1
	Future rainfall, temperature	Season rainfall, PET,	Predictions of Rainfall, PET max day and night	World Bank Climate Portal.	World Bank Climate Portal CCAFS	1

		Maximum day and night temperatures	temp will determine which crops/ varieties can be grown, their yields and "life expectancy" of SustInAfrica outputs.	Downscaled GCM data. Climate Analogues Software		

3. ECONOMIC

Unit of analysis	Indicators / Metrics	Metric units & scale	Description & links	Reference source(s)	Methods	Phase
Income	**Gross Margins**	EUR per kg Crop	Fundamental economic indicator for agricultural enterprises. Total Variable costs – total cash revenue		Record volume and cost of inputs and activities through the crop cycle. Exclude family labour and capital investment. Record income from sales of crop.	1, Field trials
	Returns to Family Labour	EUR per person day per Crop	Measure of the economic returns from investing time and labour in a farm enterprise. critical indictor for smallholder farmers		Record the time spent on field operations by the farmer and her family. Disaggregated by gender	1, Field trials
	Benefit: cost ratio	ratio	Standard metric for assessing planned investments (Project Appraisal)		Derived from data collected for other indicators	1, Field trials
	Net Present Value (NPV)	EUR	For longer term investments. Discounts the value of future returns. The longer the wait the less valuable the returns are. Includes capital investment.		Derived from data collected for other indicators	3 (most crops are annuals - probably only olives count as long-term investments). Field trials
	Internal Rate of Return (IIR)		Comparison of the discounted costs and returns for an enterprise.		Derived from data collected for other indicators	3 (most crops are annuals - probably only olives count as long term investments). Field trials
Business Environment	**Availability of Business support**	List/ summary of formal and	Indication of the support available locally to commercialise the technologies		Interviews with farmers and Chambers of Commerce.	1

	services	informal Financial services, BDS, R&D				
	Investment climate	WB ease of doing business. Financial services Business survival rates	Indication of potential commercialise the technologies		Secondary data: World Bank Country stats. Global Impact Investment Network	1
	Macro-economic data:	Inflation, cost of living, food basket	Indication of potential commercialise the technologies		Secondary data: Trading Economics website https://tradingeconomics.com/ National stats World Bank	1

4. SOCIO-CULTURAL

Unit of analysis	Indicators / Metrics	Metric units & scale	Description & links	Reference source(s)	Methods	Phase
Decent Livelihood Quality of Life	**Wage Level**	HH / region ration Living wage for the region	Amount paid to employees or earned by an individual within a standard work-week that meets basic needs for subsistence, including nutrition, clothing, health care, education, potable water, child care, transportation, housing, and energy, plus savings. Relate with income (economic dimension)	SAFA indicators (FAO)	National / regional estimations. Local surveys	1
	Employment Relations	Type of contracts	Refer to enterprises maintaining legally-binding transparent	SAFA indicators (FAO)	Interviews	1

		ratio	contracts with all employees that are accessible and cover the terms of work.			
	Freedom of Association and Right to Bargaining	Review contracts, agreements and opportunities	Freedom of Association and Right to Bargaining form the necessary conditions for fair trading practices, should these be established and flourishing into the future.	SAFA indicators (FAO)	Interview to farmers, HH, and enterprises (if existent)	1
Gender Equality	**Gender Equality**	W / M ratio	Ensure that barriers to the employment of women on an equal basis with men are removed, that women receive equal pay for the same or similar work, and have equal opportunities for training and advancement.	SAFA indicators (FAO)	Interview to farmers, HH, and enterprises (if existent)	1
	Women's workload	Person-days Crop level	Number of person days of labour during the cropping cycle disaggregated by gender	Standard agriculture tool	Interview farmers at each stage of the cropping cycle to record the number of hours spent on each operation, disaggregated by gender.	1, 2
	Activity Profile	Farming System Level	Who does what in the farming system? What are the roles of men, women and children and elders in each of the farm enterprises that constitute the farming systems? This will help determine how the SustInAfrica outputs may impact on women.	Asian Development Bank Framework https://www.adb.org/publications/gender-checklist-agriculture	Interview farmers, men and women,	1
	Access and Control Profile	Farming System Level	Who has access to and control of resources and services and decision making in each of the farm enterprises that constitute the farming systems.	Asian Development Bank Framework https://www.adb.org/publications/gender-checklist-agriculture	Interview farmers, men and women,	1

			This will help determine how the SustInAfrica outputs may impact on women.			
	Analysis of factors and trends	National/ Regional	How activities, access and control patterns are shaped by structural, cultural, religious and attitudinal factors. How are these trends changing?	Asian Development Bank Framework https://www.adb.org/publications/gender-checklist-agriculture	Secondary data: National statistics UNICEF UNIFEM Key informant interviews (academics, women leaders).	1
	Women's Access to capital	Community	How do women access capital for investing in agriculture: formal system, micro finance, traditional savings schemes (tontines)?		Household interviews	2
	Women's Involvement in the research (User Led Design)	Experiment level	The direct involvement of the users in the research projects should reduce the barriers to adoption (User Led Design)	Feed the Future: Assessing How Agricultural Technologies can Change Gender Dynamics and Food Security Outcomes: Part One http://ingenaes.illinois.edu/wp-content/uploads/Part-One-Learn-Final-10_17.pdf	Field trial reports	1
Cultural Diversity / resilience	**Local knowledge**	E.g., Measure of used practices	Range of cultural knowledge, such as art, rituals and indigenous customs in general, but more specifically knowledge concerning growing and catching methods, seeds/breeds and their usage, and medicinal plants and their uses.	SAFA indicators (FAO)	Interview to farmers, HH, and enterprises (if existent)	1
Food and nutrition security	**Social knowledge of crop monitoring/management**	Perhaps ordered scale in terms of a rating, e.g. before and	Increase of community-based knowledge due to the use of advisory/social tech e.g., advisory apps, crowdsourcing and incorporation and sharing knowledge as well as information	Needs to be researched yet. Perhaps not defined anywhere but correlates well with an existing social indicator…	Survey, questionnaire	1

		after the introduction of a new tech Community level in connection with global level	with other / global communities			
	Technical knowledge of crop monitoring/management	Perhaps ordered scale in terms of a rating, e.g. before and after the introduction of a new tech	Increase of community based knowledge after the introduction of a new technology	Needs to be researched yet. Perhaps not defined anywhere but correlates well with an existing social indicator…	Survey, questionnaire	1
	Minimum Dietary diversity for Women (MDDW)	Disaggregate by Farming System.	Measures the number of food groups consumed by Women of reproductive age, 15-49 years in the past 24 hours. SustInAfrica technologies should have the potential to increase dietary diversity, or at least not reduce dietary diversity (Do No Harm).	USAID/ FAO indicator adapted by SHA.	Baseline Secondary data UNICEF https://www.unicef.org/research-and-reports DHS https://dhsprogram.com/	1
	Stunting rates	AEZ/ farming system	Stunting is a standard indicator of long term malnutrition caused by inadequate diet and feeding practices, poor sanitation, micronutrient deficiencies, unsafe food, presence of nutrition inhibitors in the diet and repeated gastro-intestinal	Stunting is measured as **Height for Age scores** or Mid Upper Arm Circumference (MUAC). These are rates are international indicators. Stunting rates are described as Z-scores.	Secondary data only: UNICEF https://www.unicef.org/research-and-reports DHS https://dhsprogram.com/	1

			infections and parasite burdens. SustInAfrica does not propose to collect anthropometric data but rely on secondary data to build a picture of risks within the farming systems.			
	Sever Acute Malnutrition (SAM) **Global Acute Malnutrition (GAM)** **Weight for Age Scores**	AEZ/ farming system	Acute malnutrition is an indicator of short-term acute deficiencies in food intake. SustInAfrica does not propose to collect anthropometric data but rely on secondary data to build a picture of risks within the farming systems.	Stunting is measured as **Height for Age scores** or Mid Upper Arm Circumference (MUAC). These are rates are international indicators. Stunting rates are described as Z-scores.	Secondary data only: UNICEF https://www.unicef.org/research-and-reports DHS https://dhsprogram.com/	1
	Food calendars/ seasonal availability	Household	The calendar will identify seasonal food gaps (lean/ hunger season). To maximise impact on nutrition SustInAfrica outputs should increase food availability during the food gaps.	SHA food calendar	baseline	1
	Food safety	Farming System	Identify potential food safety risks in each of the farming systems that may impact on nutrition.		Baseline Secondary data/ literature Internal discussions	1, 2
	Household Food consumption score	Household	A standard WFP score based on 7 day recall of 7 weighted food groups The sum of the weighted food group values is the FCS.	SHA WFP food consumption score card (revised) https://www.wfp.org/publications/meta-data-food-consumption-score-fcs-indicator#:~:text=The%20%E2%80%9CFood%20consumption%20score%E2%80%9D%20(,comprise%20the%20food%20consumption%20score. Starch staples, pulses, vegetables, fruit, fats, sugars, meat/fish/eggs,	Baseline SHA digital tool	1, 2

				milk/dairy, condiments.		
	Micronutrient deficiencies/ hidden hunger?	Farming System	Identification of potential micronutrient deficiencies in the diet (Iodine, zinc, iron, vitamin A, calcium, selenium).	IFPRI Global Hunger Index https://www.ifpri.org/sites/default/files/ghi/2014/feature_1818.html#:~:text=Hidden%20hunger%20is%20a%20form,and%20development%20(Box%203.1)	SustInAfrica does not proposed to collect data directly on the micronutrient deficiency but to estimate risks from secondary data. IFPRI GHI UNICEF/ DHS Joy, E. J. M., Stein, A. J., Young, S. D., Ander, E. L., Watts, M. J., & Broadley, M. R. (2015). Zinc-enriched fertilisers as a potential public health intervention in Africa. *Plant and Soil*, *389*(1–2), 1–24. https://doi.org/10.1007/s11104-015-2430-8	1, 2
Health	**Water sources**	Community Type of water source	Indication of exposure to water borne disease that can impact on nutrition.		Field survey	1
	Water quality: biological tests Chemical contamination (heavy metals, fluoride)	Community	See environment section			1
	Health risks for irrigation systems	Community	Indication of levels of water borne and vector borne disease that can impact on nutrition and morbidity as a result of the use of	Local health centres stats on water borne diseases, vector-borne diseases: schistosomiasis, cholera, typhoid, malaria, Rift Valley Fever,	# of cases of water borne diseases per month.	1

			irrigation.	etc.		

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Annex 4

SustInAfrica`s specific objectives and expected outcomes aiming to fulfil all of the expected impacts of Horizon 2020 topic "SFS-35-2019-2020, Scope A (RIA)"

A. "Boost the impact of Africa-EU joint research at local level by addressing the entire value-chain, strengthening capacity-building and focusing on demonstration projects and pilot actions to bring research and innovation results to the users."
Through its multi-actor approach, the impacts of SustInAfrica's research, innovation, and technological outputs will reach various stakeholders and end-users (incl. smallholder farmers) across the West and North African value chains and across the European research and innovation community, contributing significantly towards: i) Strengthening capacity building and subsequent boosting of Africa-EU joint research at the local level; ii) Demonstration, implementation and proliferation of sustainable intensification practices across the regions; iii) Enhanced use of smart and integrated pest management for plant protection; iv) Delivery of ecosystem services; v) Improving water use efficiency; vi) Delivery of ecologically-produced food products to consumers; vii) Development of sustainable business models. This will be achieved by implementing context-specific, demand-driven demonstration trials (WP3) based on extensive analysis of each target AEZ (WP1), with incorporation of developed smart farming and monitoring technologies (WP2) and strong, multidisciplinary, and multi-actor approaches to ensuring uptake and continuation beyond the project's duration. **Indicators of success**: Significant improvement of targeted, reliable, and widely accepted indicators appropriate to evaluate impact of sustainable intensification[9] on agronomic production, ecosystem services, sustainability, resilience and profitability, and increased African food sector.
B. "Provide simple tools and solutions for preserving and increasing natural resources of specific agro-system."
Farmerline's Mergdata Platform (www.mergdata.com) will host SustInAfrica's services and tools that are freely available to any stakeholder and end-user (incl. smallholder farmers) and simple. Agricultural services and tools are based on traditional and modern technologies and solutions used to preserve and rehabilitate ecosystems and their capabilities to and increase productivity of agro-food systems adapted to local conditions and perceptions, multiple actors and complex drivers at multiple scales (WPs 2 & 3). **Indicators of success**: Developed, used, and downloaded SustInAfrica technologies and tailored solutions developed, tested and implemented in targeted AEZs, freely available through FMP.
C. "Identification of methods and tools for improving soil condition for water retention, increase in nutrient and organic matter."
SustInAfrica will collect, review, and test agricultural practices and tools appropriate to

[9] Smith et al. (2017). Measuring sustainable intensification in smallholder agroecosystems: A review. *Glob Food Sec* 12:127-138

significantly improve water and nutrient retention in soils, and augmentation of soil organic carbon. Both water retention and nutrient availability depend on hardly modifiable soil texture and mineralogy (e.g. expensive application of clay, silt, minerals) and easily alterable soil organic carbon (e.g. carbon management by organic farming, agroecology, and agroforestry). Promising carbon management technologies for sustainable soil management will be evaluated and evaluated for their overall potential to increase soil organic carbon substantially to enhance the soils' capacity to retain water and nutrients, including impacts on quality and quantity of produced crops in targeted AEZs covered by SustInAfrica. **Indicators of success**: Significantly increased water and nutrient use efficiency and reduced net-removal of carbon from arable land and uptake of SustInAfrica carbon management tools in regions not targeted by SustInAfrica; increased yields and profitability[18].
D. "Proposed methods and solutions for different farming systems should include potential of transferability and scale at which solution can be implemented."
SustInAfrica addresses most common AEZs (i.e. forest-savanna, grass/bush-savanna, and desert) in West and North Africa and most common farming systems of these AEZs, basically ensures local and regional replicability. Enhancing replicability to a level that generates significant impact on agricultural productivity, delivery of ecosystem services, employment in the food sector and lasting economic growth SustInAfrica will train and educate farmers and smallholder farmers, private and public extension services and young researchers (WP4), develop and implement methods and technologies that promote creation of resilient and sustainable agro-businesses that empower role of farmers, women and youth within food value chains (WP5) and FMP that offers easily accessible and simple methods and solutions for different farming systems (WPs 2, 3, 4 & 5). **Indicators of success**: Download statistics and geographical location; number of participants per workshop; assess acceptance and impact of workshops and training by follow up surveys[10]; direct transfer due to collaboration among projects; increased participation/ empowerment of women and youth.
E. "Solutions and tools for increasing farm income within sustainability of long-term farming."
Although sustainable intensification of agricultural production at farm level is a crucial aim of SustInAfrica by implementing and testing various smart, modern and traditional agricultural practices and technologies, but lasting impacts are generated by integrating factors of interrelating ecosystems, communities, and economies. Therefore, SustInAfrica addresses i) interrelation of farming activities with ecosystem services (WPs 1, 3 & 5), ii) training and education of stakeholders, end-users, youth, and PhDs (WPs 4 & 5) & iii) implementing sustainable agro-business models to ensure sustainability, resilience, and lasting empowerment of farmers, women, and youth by enhancing profitability of agricultural production and promoting sustainable value chains.

[10] Smith et al. (2017). Measuring sustainable intensification in smallholder agroecosystems: A review. *Glob Food Sec* 12:127-138 & Sattler & Jens (2010): Land Use Policy Factors affecting farmers' acceptance of conservation measures — A case study from north-eastern Germany 27, 70–77.

Indicators of success: Increased profitability at individual (e.g. smallholder farmer) and farm level; significant relation between intervention (e.g. workshops organised by WP6 to serve WPs 1, 2, 3, 4 & 5), uptake (e.g. integrated and biological pest management to replace use of pesticides; WPs 2 & 3), and income.