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

Deliverable D1.1

Survey and assessment toolbox for data collection

Methodological approaches and tools for data collection and assessment of African farming systems

Due date of deliverable: M8

Actual submission date: 30th April 2021

GENERAL DATA

Grant Agreement: 861924
Project acronym: SustInAfrica
Project title: Sustainable intensification of food production through resilient farming systems in West & North Africa
Project website: www.sustinafrica.com

Start date of the project: September the 1st, 2020
Project duration: 60 months
Organisation name of lead contractor: Luke

Funding source: SFS-35-2019-2020 - Sustainable Intensification in Africa
Type of action: Research and Innovation Action

DELIVERABLE NUMBER:	D1.1
DELIVERABLE TITLE:	Survey and assessment toolbox for data collection
DELIVERABLE TYPE:	Other
WORK PACKAGE N:	WP1
WORK PACKAGE TITLE:	Baseline analysis & monitoring system's design of W. & N. African farming systems
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List of abbreviations and acronyms

AEZ	Agro-Ecological Zone
ATB	Leibniz Institute for Agricultural Engineering & Bioeconomy
BOKU	University of Natural Resources & Life Sciences Vienna
CICES	Common International Classification of Ecosystem Services
CGIAR	Consultative Group on International Agricultural Research
CIHEAM	Mediterranean Agronomic Institute of Bari
FAO	Food and Agriculture Organization
FC.ID	FCiencias.ID
ISEG	Lisbon School of Economics and Management
LUKE	Natural Resources Institute Finland
OCDE	Organisation for Economic Co-operation and Development
SHA	Self Help Africa
UNICEF	United Nations International Children's Emergency Fund
USAID	United States Agency for International Development
WFP	World Food Programme
UCC	University of Cape Coast
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
USDA	United States Department of Agriculture
WG	Working Group
WP	Work Package
WFP	World Food Programme

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1. Introduction

The overall objective of **WP1: Baseline analysis & monitoring system's design of West & North African farming systems (WP1)** is to gain a deeper understanding of the current state of selected farming systems of the 13 targeted Agro-Ecologic Zones (AEZs), their institutional environment in five countries in West and North Africa, and to assess regional and local baseline information on factors describing and affecting agricultural performance and development in each specific context.

The WP1 main aim is to contribute and guide the implementation of demonstration trials (WP3), education / training of practitioners and stakeholders (WP4), and exploitation of validated practices and technologies ready for replication (WP5) by gathering knowledge, combining systematic review of scientific and grey literature, surveys, participation, application of diverse disciplinary quantitative and qualitative research tools, as well as tacit knowledge integration. WP1 is a broad working package of ***SustInAfrica*** that encloses the following objectives:

> **OB1.1:** Ensure the success of the project through the use of appropriate research methodologies and tools: Adapting and customising analytical approaches and tools for appropriate and contextualised mixed-method baseline data collection and assessments of selected farming systems in AEZ's.
>
> **OB1.2:** Gain a deep understanding of the current state of agro-ecological and economics of West and North African farming systems.
>
> **OB1.3:** Establish a mechanism for long-term monitoring of transformed agricultural systems in Africa.
>
> **OB1.4:** Achieve a successful synthesis and internal communication of effective research methodologies and tools, and baseline data on African agricultural system, for the implementation of the project.

The present document - **D1.1: Survey and assessment toolbox for data collection** - is the first deliverable of the WP1. More specifically, it refers to the task **T1.1: Develop a baseline analysis toolbox with customized diagnosis and evaluation methods and tools for data collection and assessment**, which is in progress. Task T1.1 include three sequential subtasks:

- T1.1.a: Systematic literature review on research methodologies and tools (M01-04);
- T1.1.b: Evaluation and co-selection of most appropriate research methodologies tools for ***SustInAfrica***'s context (M05-M08);
- T1.1.c: Preparing collection of primary data of African farming systems (M08-14).

Accordingly, with ***SustInAfrica*** proposal, the **D1.1** deliverable refers to the process developed under the T1.1b. As mentioned, WP1 includes research activities related to data collection, data assessment and data analysis. However, at this stage of the project (M8), and to better secure the planned research activities in the field, **D1.1** focuses on data collection procedures.

So, in this document, we intend to present the key achievements in the progress of combining the team's **multidisciplinary efforts in developing a common conceptual methodological model for data collection** at baseline, that will further support the assessment of the farming systems in the scope of ***SustInAfrica***, contributing to other WPs' development.

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At this point, the priority was to consolidate data collection requirements for a plural assessment of the farming systems in Africa and select appropriate data collection tools.

The **toolbox** is designed to ensure a multidisciplinary assessment of each farming system studied, within the selected AEZs, and when finalized to contribute to monitoring the impacts of the introduced sustainable intensification practices at the demonstrations trials (WP3). The next subtasks of the project to guarantee the final toolbox, will include the customization of these pre-defined methods as well as the preparation of teams and materials for data collection.

The document is structured as follows. In section 2 (Approach overview), the procedures applied to identify and consolidate data requirements and appropriate data collection tools for the ***SustInAfrica*** project are described. In section 3, an overview is made on the systematic literature review that supported the identification of data requirements for the socio, economic and political characterization of farming systems (T1.1.a). In section 4, the toolbox for data collection is presented. Finally, section 5 is dedicated to the preview of the research's next steps under the scope of WP1. Additionally, this document includes the list of bibliographic references and an Annex section, with the materials that supported the research activities addressed in this deliverable.

2. Approach overview

The overall objective of the baseline data collection are to gain a deep understanding of the current state of selected farming systems of the targeted AEZs, and their institutional environment, and to assess regional and local baseline information on factors describing and affecting agricultural performance and development in each specific context. So, baseline data collection encompasses data on technical, ecological, socio-demographic, cultural, and economic issues, related to households, smallholder farmer's communities, agro-businesses, and institutional and policy contexts in which the targeted agricultural systems are embedded.

Due to the wide scope and the multidisciplinary and multi-actor approach adopted in ***SustInAfrica***, to properly map all data collection needs for the baseline, a set of operational steps were made to identify, centralize and integrate all ***SustInAfrica*** partners perspectives and data requirements. The operational three key steps included:

(1) data requirements screening by research theme;

(2) consolidation of the common data requirements across themes;

(3) consolidation of the appropriated data collection methods by measurement scale.

ISEG team, as the leader of the WP1, assumed a centralized role, proposing the creation of working groups (WG), WG leaders, and task division for the screening and integration of project **baseline data collection toolbox**. The following subsections describe succinctly the procedures applied.

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2.1. Data requirements screening by research theme

First, the ***SustInAfrica*** team was divided into nine thematic WG that covered the main research themes under the scope of the project, namely: **Cropping systems and management; Soils and water; Ecosystem Services; Insects; Landscape and remote sensing; Climate; Health and nutrition; Socio-cultural, institutional, economic and policy; Innovation and replicability**. This exercise was built upon the initial compilation of indicators and metrics initiated by WP1 already reported in deliverables D6.2 and D5.1, for a detailed consideration on data requirements for the ***SustInAfrica*** project.

Each WG was responsible to screen data requirements for each domain and scale, identifying a list of indicators and metrics needed to collect or calculate, and the respective predicted methodological approaches to data collection. This exercise, led by the assigned WG coordinator (previously agreed upon and based on research expertise as in Annex 2 – Sheet 1), including the completion and submission of a form defined for those purposes (Annex 1).

The initial selection of indicators and metrics was informed by scientific literature reviews of papers published in peer-review journals, established good practices for evidence-based assessments of farming systems, and partners` expertise. Project aims and analysis of previous research on **sustainable farming intensification** provided enough guidance for the selection of data requirements in most research domains in this phase. Additionally, the *WG on Ecosystem services* refers to the Common International Classification of Ecosystem Services (CICES) framework, developed from the work on environmental accounting undertaken by the European Environment Agency; the *WG Health and nutrition* gather indicators and methodologies used in similar contexts by entities such United States Agency for International Development (USAID), Food and Agriculture Organization (FAO), United Nations International Children's Emergency Fund (UNICEF), or World Food Programme (WFP); and the *WG on Innovation and replicability* guided data requirements identification based on concepts of Smart Farming and FAO's analytical framework for the evidence-based assessment of the sustainability and replicability of integrated food-energy systems and the global indicator framework for the Sustainable development Goals and targets of the 2030 Agenda for Sustainable Development. The *WG on Socio-cultural, institutional, economic and policy* supported their initial selection in a more structured process since they conducted a systematic review on the topic predicted in the proposal application, as presented in the section 3 (section 3. Systematic literature review on research methodologies and tools on the farming system).

2.2. Consolidation of the common data requirements across themes

By cross-analysing the information organized by the WGs, some overlaps and common interests as to requirements and methods were identified, as the need to integrate and jointly discuss methodological approaches to these shared interests. To account for this, a second exercise was proposed following similar procedures to the previous task (WG coordination led to the filling of a common template Annex 2). At this stage, the groups refined more details on which information should be collected, building upon the initial selection of indicators and metrics, and identified the information overlaps among groups to eliminate double collection in the field. The common

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assessment of research themes across WG was pre-signalled to ensure joint discussion and common agreement on what and under which WG information should be collected to respond to project needs.

2.3. Consolidation of data collection methods or toolbox

Based on these materials, a list of 18 approaches and methods hereby designated by field data collection tools, aggregated by the scale of assessment (field/plot, farmer/household, community, AEZ/region/country) was extracted. The list, integrating tools to be used for different disciplines from natural sciences to social sciences, was then refined and validated by the WG coordinators to ensure that the information was properly centralized and interpreted task (Annex 3). The compilation of these methods, organized by the scale of data measurement, linked with data requirements for the ***SustInAfrica*** project composes the **project survey and assessment toolbox for field data collection** presented in this document.

As predicted in the ***SustInAfrica*** proposal, the toolbox will be further developed in the next WP1 research tasks. In this sense, **field protocol templates** are already drafted for further development based on the toolbox (Annex 4). After this compilation, all protocols are to be customized in close cooperation with local partners, to be sensitive to cultural factors and targeted population's social profile, local languages, and fieldwork features constraints as well as to the current COVID situation, under task **T1.1.c: Preparing collection of primary data of African farming systems** (M08–14).

3. Systematic literature review on research methodologies and tools on farming systems

To ensure a comprehensive understanding of the options available for the assessment of socioeconomic and political domains related to the sustainable intensification of farming systems, a **systematic literature review was conducted** (according to Cochrane guidelines, as described in deliverable D6.2). **The review targeted peer-reviewed papers on systematic reviews** and selected publications from the **grey literature** on describing or monitoring social, economic, and institutional dimensions regarding **sustainable intensification**. This section addresses the key points as to the review procedures, and how the extracted information guided the identification of data requirements for the characterization of socioeconomic context themes (depicted in Figure 1).

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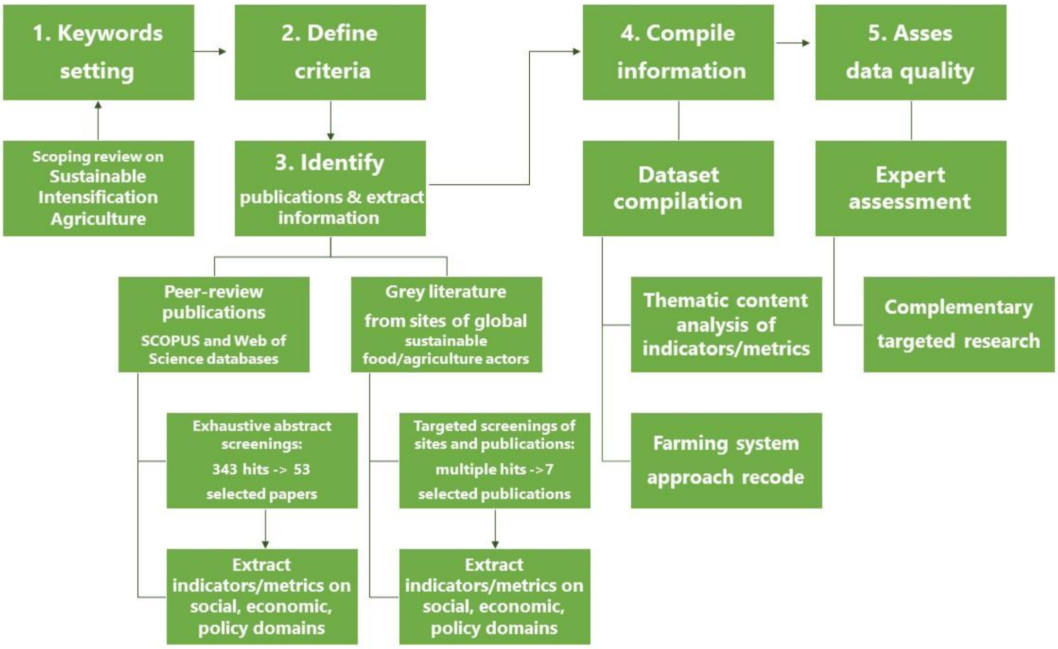

Figure 1. Global approach of the systematic review process.

3.1. Systematic review process

The protocol for a systematic review starts with the definition of a set of keywords (see D6.2 if needed). The keywords selection was informed by a preliminary consultation of the literature on **sustainable intensification agriculture** concept based on highly cited recent publications (e.g., Jain et al. 2020; Vanlauwe et al. 2019; Jiao et al. 2019; Dawson et al. 2019; Taveira et al. 2019; Franke et al. 2018; Weltin et al. 2018; Grassini et al. 2017; Mahon et al. 2017; Sims & Kienzle 2015; Vanlauwe et al. 2014; Charles et al. 2014; Tittonet & Giller 2013; Rudel 2020; Nassary et al. 2020; Xie et al. 2019; Thomson et al. 2019; Jayne et al 2019; Pretty 2018; Liao & Brown 2018; Struik & Kuyper 2017; Smith et al. 2017; Wezel et al. 2015; Prett & Bharucha 2014; Tittonell 2014; Flavell 2010).

The consulted literature review advised to:

(1) include different formulations for "sustainable intensification" term, since there are other close conceptual terms (such ecological/agroecological/sustainable);

(2) include different formulations for the "assessment" term, since there are multiple methodological approaches;

(3) include different formulations concerning the "socioeconomic" domain, since there is not a consistent term for it across the literature (socio, social, cultural, political).

Thus, the following keywords were considered:

(sustainab AND intensification AND agricult*) OR (ecologic* AND intensification AND agricult*) OR (agroecolog* AND agricult*) AND*
(method OR tool* OR indicator* OR assessment OR evaluation OR monitor*)*

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AND (well-being OR soci OR econom* OR governance OR policy OR institutional) OR (training OR education) OR innovation).*

The preliminary literature review also supported the definition of the criteria of inclusion and exclusion of the papers in the revision concerning the: (1) time limitation (from 1997, when the term sustainable intensification is first published); (2) publications type (only revisions, given the high level of systematization of the literature). Additionally, according to the team's available language skills, (3) only papers in English, Spanish and French were considered. Under these criteria, Scopus and Web of Science search engines were used to identify relevant publications in peer-review journals.

The strategy to find relevant grey literature was done by searching targeted websites of notable international, bilateral and multilateral agencies and organizations identified in the areas of agriculture, development and sustainability. Those included FAO, UN, UNDP, UNESCO, World Bank, OCDE, Oxfam, USAID, USDA National Library and CGIAR - Global Agricultural Research Data Innovation Acceleration Network. These key websites showed a wide diversity in search functionalities, ranging from a simple search box to an advanced search with filters and additional queries. As such, researchers adapted the search phrase to fit each search engine's options. Indeed, as opposed to the academic databases search, where one search strategy was used combining all search terms, the grey literature search required creating different search strategies with multiple combinations of the search terms. In some instances, document searches resulted in thousands of hits. In such cases, the first 100 links were searched.

The search in Scopus and Web of Science databases led to 343 hits. A first screening of the titles and the abstracts of the selected publication eliminated duplicate and non-compliant papers with the criteria set. A set of 53 peer-reviewed publications was selected for analysis. Additionally, from the grey literature, 7 resources were identified as relevant. A total of 60 publications was deemed for detailed consideration.

3.2. Socioeconomic sustainable intensification assessment themes

To guide the selection of data requirements for the socioeconomic characterization of farming systems, information on indicators, metrics or assessment themes related to socioeconomic, cultural and political features was extracted from each publication. Information was organised in a tabular format using Excel.

After the initial compilation of indicators, metrics and assessment themes referred in the publications, the information was integrated using the technique of content analysis, coding the extracted information. First, all inputs were aggregated in three main categories (social, economic, and governance). Themes were subsequently identified, aggregating similar contents under common designations, following the grounded theory approach (Bardin 1979). The process allowed the organization of a list of codes and subcodes that covered the scope of socioeconomic features highlighted in the consulted literature on sustainable intensification. This set was considered as the initial list for the data requirements accounting for the socioeconomic dimension of the farming systems (WG Socio-cultural, institutional, economic and policy).

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A total of 20 assessment sub-themes were identified. To better integrate the codification with ***SustInAfrica*** socio-ecological approach, a secondary codification was operated linking each main theme according to the analytical framework that describes agriculture as a socio-ecological system, as depicted in Figure 2 (Mahon et al. 2017). The final selection of assessment themes and data collection approaches was based on expert assessment, resorting to multidisciplinary science advisors' online meetings (with ISEG's expert's assessment, project advisors and project coordination). The respective data collection approaches were also informed by complementary review on scientific literature aiming to identify and integrate the best practices and as much as it is possible to opt for field approaches already tested in similar contexts (FAO 2011; Schreckenberg et al. 2012).

Theme	Sub-theme	Theme	Sub-theme
Resource users	1. Farmer household	Governance	12. Community structure
	2. Health and wellbeing		13. Governance policy
			14. System resilience/ vulnerability
Resource system and units	3. Farm and farming		15. Equity
	4. Economic capital		
	5. Income	Interaction	16. Knowledge and information access
	6. Labour		
	7. Input costs and access		17. Collective action
			18. Market orientation
Outcomes	8. Profitability		
	9. Intensification	Socioeconomic context	19. Cultural context
	10. Efficiency		20. Economic context
	11. Farming productivity		

Figure 2. List of themes that informed data requirements for describing the socioeconomic sustainable intensification of farming systems.

4. Toolbox for data collection

The ***SustInAfrica*** survey and assessment toolbox meets the following aims: to **list and describe the necessary field tools for data collection** essential to the characterization of AEZ's farming systems, ecological, socioeconomic, cultural and political contexts, and to **provide generic guidance on how to implement these tools on the ground** in each ***SustInAfrica*** community.

The toolbox is composed of 18 field tools that will be used to collect baseline data on field and defines the objectives of the implementation of each method and corresponding scale(s) of application (Table 1). The tools were organized by the scale of data collection (National/Regional/AEZ, Community/Landscape, Household/Farmer, Field/Plot) and according to the data requirements established by each WG to accomplish ***SustInAfrica*** objectives, as referred to in section 2.

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Table 1. Field tools included in the SustInAfrica toolbox for baseline data collection. For each tool presented, the description, objectives of implementation, scale of application, and stakeholders involved (when applicable) are given.

1. National and regional workshop

Description: Multi-stakeholder workshops to promote the exchange of knowledge and experience among key stakeholders and promote discussion regarding the agro-food system.

Objectives: To map institutional organisms and actors involved in the agricultural sector, identify current policies and programs, discuss governance processes at different scales, examine stakeholders' interests and needs, existing supportive programs and productivity; to map available technological tools and knowledge/ information programs and their accessibility to small rural farmers men, women and youth, among others.

Scale: Country/Region/AEZ

Stakeholders: Ministries in charge, local governments, agencies, NGOs, cooperatives, SME, farmers.

2. Stakeholders' mapping

Description: Data collection during activities such as the community meetings, focus group discussions, and interviews about the actors involved in the agro-food system, e.g., regional and national government officers, policy-makers, private sector and civil society actors.

Objectives: To identify the key stakeholders (institutions, agencies and individuals) relevant to the agro-food system of each country and region, and to the implementation of the project activities. Furthermore, determine the interests and needs of these stakeholders', and identify their relationships and relative importance.

Scale: Country/Region/AEZ, Community, Household/Farmer

Stakeholders: All involved in the studied farming systems.

3. Value chain mapping

Description: Set of qualitative and/or quantitative tools to map and analyse the value chain, i.e., the full range of activities and actors from its crops' production to consumption.

Objectives: To identify the key actors in the value chain of the selected crops, and collect data on chain activities, networking processes, revenues and relative strengths and weaknesses over different stages and stakeholders in the value chain. Also, to comprehend crop and value chain valorisation or enhance points, particularly of the local agro-businesses sector and its food products.

Scale: Country/Region/AEZ, Community

Stakeholders: All involved.

4. Mapping and monitoring

Description: Production of several landscape maps based on GIS information and remote sensing imagery.

Objectives: Collect information of the land cover, biomass, landscape elements, Normalized Difference Vegetation Index, and on crop performance parameter (Leaf Area Index, yield potential, crop pests), among others.

Scale: Community/landscape, field/plot

Stakeholders: Not Applicable (NA)

5. Community meeting

Description: Community gathering comprising the community leaders, religious leaders, and representatives of key groups and associations, with adequate participation by women and youth. When adequate outside stakeholders that make part of the farming system such as extension technicians may also participate.

Objectives: To present the *SustInAfrica* research plans to the community, determine its interest in participating in the research and collect informed decisions about taking part in the research. Also, to contribute to mapping stakeholders at the community and regional levels.

Scale: Community

Stakeholders: Community leaders, committee members, farmers, cooperatives, local authorities, relevant technical government bodies, extension technicians, agro-business.

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6. Community survey

Description: Semi-structured questionnaire conducted to the community leaders or representatives to portrait the community.
Objectives: Collect data about the community context, infrastructures, HHs and livelihoods, cooperatives and associations, NGOs presence, main challenges, etc.
Scale: Community
Stakeholders: Community leaders or representatives.

7. Season calendar

Description: Done within a community meeting of key informants such as community leaders, religious leaders and representatives of local organizations. Separated meetings with women, men, and youth may be considered.
Objectives: Collect information on annual seasonal variations of the weather seasons, principal agricultural and non-agricultural activities, and the division of tasks among family members, i.e., gender and youth distribution.
Scale: Community
Stakeholders: Community leaders, women, men and/or youth smallholder farmers.

8. Historical timeline

Description: Method to discuss the most relevant historical events, main achievements and setbacks, both socioeconomic, political, and environmental-related, experienced in the community during the last 15-20 years, regarding project focus. It relies on a community meeting of key informants including community leaders, religious leaders and representatives of local organizations. Separated meetings with women, men and youth are considered when appropriate.
Objectives: To build an historical timeline of the main events, achievements, and setbacks over the last 15/20 years related to environmental and social changes, to gain an understanding of the community mitigation and adaptability capacity to shocks and extreme events, and to map related key stakeholders.
Scale: Community
Stakeholders: Community elders, men and women from different wealth ranks, community and religious leaders, committee members, among others.

9. Wealth ranking and livelihood analysis

Description: Community meeting of key informants including community leaders, religious leaders and representatives of local organizations. Separated meetings with women, men, and youth may be considered.
Objectives: To identify the main socioeconomic groups in the community and their characteristics, to review the distribution of households among the groups, to identify any factors associated with migration between groups, and to discuss the causes and effects of poverty.
Scale: Community
Stakeholders: Women and/or men smallholders, community and religious leaders, committee members.

10. Focus group discussions

Description: Small group meetings (5 – 20 people) used to explore specific topics in-depth, conduct follow-up discussions, and enable people who may otherwise be overlooked in larger community meetings to express their point of view. Very useful to gather disaggregated data by age and sex. The composition of the focus group will depend on the topic under discussion.
Objectives: To collect information and to validate on specific topics such as land access and use, the community collective action and networks, traditional farming practices, land access, seeds use, crops and water management, soil erosion, inputs used, e.g., fertilizers, pests, gender equity, labour division, cultural rights, and access. When possible, focus group discussion will also support stakeholders mapping.
Scale: Community
Stakeholders: Women and/or men smallholders, community and religious leaders, committee members, farmers, among others.

11. Field walk

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Description: Observational field walks with key informants during which a community area(s) is explored and information is collected.
Objectives: To explore the field plots and conduct follow-up discussions to validate information provided during the semi-structured interviews.
Scale: Community
Stakeholders: Woman and/or men smallholders, community and religious leaders.

12. Household survey

Description: Questionnaire given to a sample of households (HHs) in each community to collect structured demographic and socioeconomic data. The survey is applied to the household head, defined as the person responsible for the main decisions regarding farming practices and management, resource uses, and land control.
Objectives: To characterize the HHs by collecting data about: 1. HH composition and education, 2. Housing characteristics, 3. HH consumption and expenditure, 4. HH and farm assets, 5. Land tenure, 6. Labour, revenue and expenses, 7. Social networking and collective action, 8. Women's access and power relations, 9. Migration periods, 10. Credits and cooperation formats, 11. Access to extension advisory Services and training 12. Other topics when needed.
Scale: Household
Stakeholders: Heads of the household of smallholder farmers

13. Minimum Dietary Diversity for Women (MDDW) survey

Description: Questionnaire recalling what was eaten in the previous 24 hours, adapted from FAO/USAID materials.
Objectives: To estimate women's diet quality.
Scale: Household
Stakeholders: Women in smallholder farmers households

14. Household Food Consumption Score + Food store survey

Description: Questionnaire recalling what food groups were consumed in the previous week, adapted from WFP materials.
Objectives: To assess the level of the household dietary's diversity.
Scale: Household
Stakeholders: Smallholder farmers

15. Semi-structured interviews

Description: This technique is based on asking selected open-ended questions face-to-face to key informants.
Objectives: To characterize the communities' farming systems by gathering information, opinions, and feedback and to collect detailed information about innovations, innovation needs, and adoption.
Scale: Farmer
Stakeholders: Key smallholder farmers, knowledgeable women and men, and innovators.

16. Soil sampling

Description: Collection of representative soil samples for lab analysis, based on procedures designed and implemented in collaboration with the Soils4Africa (https://www.soils4africa-h2020.eu/) project.
Objectives: To evaluate soil properties such as texture, soil pH, salinity, content of carbon and macro nutrients (total N, K, and P), among others.
Scale: Plot
Stakeholders: NA

17. Crop sampling

Description: Collection of physical crop samples in the field according to a determined sampling strategy.
Objectives: To determine annual yield and/or yield quality.
Scale: Plot
Stakeholders: NA

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18. Entomological sampling
Description: Collection of representative insect samples of main pests, beneficial organisms, and biodiversity. *Objectives*: To estimate the influence of selected agro-ecological practices on insect populations (pests, natural enemies, pollinators, and general biodiversity). *Scale:* Plot/farm (and surroundings) *Stakeholders*: NA

Note. Title coloured highlights refer to the scale of data collection using the same colour scheme as Figure 3 (National/Regional/AEZ: grey; Community/Landscape: brown; Household/Farmer: blue; Field/Plot: green).

For a generic guidance of implementation of each tool in the field, a flowchart of the toolbox is given depicting the data collection timeline for baseline assessments (Figure 3). As mentioned before, team conjoint efforts are in place to progress in the detailed definition of the selected tools to establish site-specific sampling strategies and other relevant details by completing the field protocols for each tool (Annex 4), and later adapted to each country and AEZ (when necessary), translated to local languages and tested according to task **T1.1.c: Preparing collection of primary data of African farming systems** (M08–14).

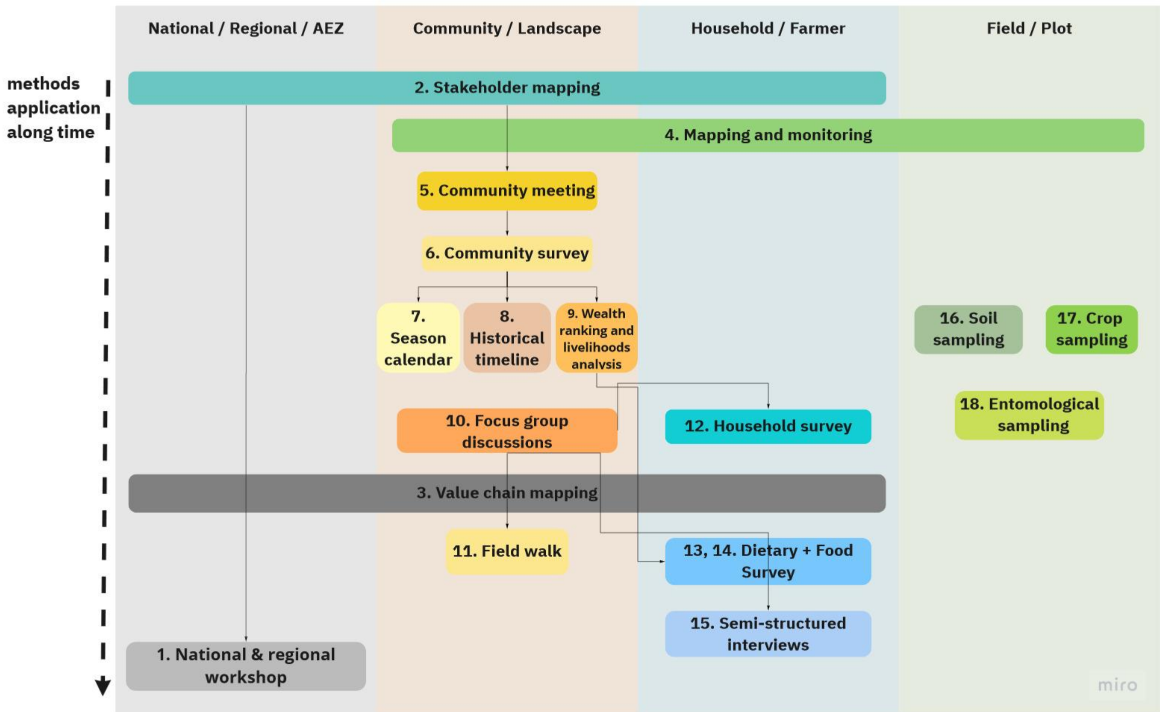

Figure 3. Flow chart for toolbox visualization and application to a generic SustInAfrica community for the period corresponding to baseline data collection. Field tools can be applied to one or more scales, i.e., national/regional/AEZ, community/landscape, household/farmer and/or field/plot. The number of each field tool corresponds to the number of the tools presented in Table 1.

Generically, toolbox implementation can be initiated by doing some desktop work and starting **mapping of key stakeholders** (tool #2) involved in the agro-food system of each country and selected communities. Simultaneously, it foresees the **mapping of the communities and surrounding landscape** (tool #4) to support field work organization and GIS and remote sensing data extraction (e.g., distances, land uses land cover) **and monitoring**. Before starting fieldwork data collection, it is

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appropriate to organize **community meetings** or general assemblies (tool #5) to present the project`s objectives and goals to the participating stakeholders. These meetings will also establish their interest in participating in the project and to collect informed consent about taking part in the research. After each meeting, all the other field tools can be initiated. First, a **community survey** (tool #6), with a local leader or representative, will be conducted for a complete characterization of the village, an activity initiated during the community selection (see deliverable D6.2). Based on this questionnaire and discussion with the local leader, stakeholders will be pointed at participating in the following activities: **season calendar** (tool #7), **historical timeline** (tool #8), and **wealth ranking and livelihood analysis** (tool #9). Based on the information collected during the previous phase, it will be possible to randomly select a sample of stratified households (by wealth and livelihood), to conduct the **household survey** (tool #12), an important step particularly in large communities with diverse livelihoods strategies. Similarly, **dietary and food-related surveys** will be conducted (tool #13 and #14) at the household level. Considering the information collected so far, it will be possible to organize several **thematic focus group discussions** (tool #10) that will be part of data collection and will also allow follow-up discussions of some of the topics addressed in the questionnaires. The following tools 7, 8, 9 and 10 will be organized in separated sex group discussions, and by youth when necessary, to collect different and independent opinions and perceptions. Based on the information collected in tool 10 and given by the community leader or representatives **semi-structured interviews** (tool #15) and **field walks** (tool #11) with key farmers will be conducted to complete data collection on the farming systems and to validate information, respectively. **Value chain mapping** (tool #3) will be possible by combining information obtained from other tools such as the household survey, focus groups discussions and semi-structured interviews. In parallel, natural sciences methodologies such as the **soil** (tool #16), **crops** (tool #17) and **entomological** (tool #18) **samplings** can be implemented in the field whenever planned human resources and transportation allows it.

The toolbox implementation requires prior enumerator and field team training, to ensure that everyone involved in their application has the required expertise. Likewise, it relies on the support and coordination of the local partners and straight engagement with the communities. Finally, as mentioned, the toolbox implementation represented in Figure 3 is meant to be flexible and adaptable to the unique local conditions and contexts, being only one of the several possible pathways of field tools implementation.

5. Baseline surveys

Based on the toolbox presented in section 4 WP1 will coordinate baseline assessment and four additional cross-cutting activities until March 2022 (Figure 4).

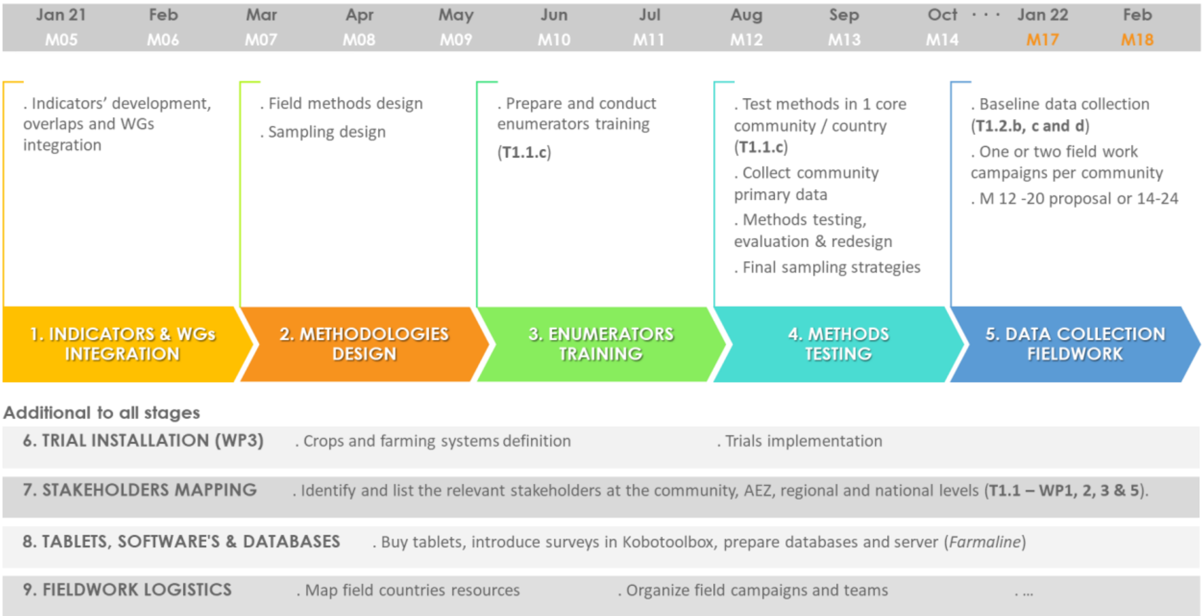

Figure 4. Stages and cross-cutting activities of the baseline data collection and their timeline.

WP1 is currently in M08 and still developing step **2. Methodologies design**. To complete this task, WP1 will design the final field methodologies and adapt them to each local context and country. This will be done through iterative information flow between WP1 and other WPs and also in close collaboration with the African local ***SustInAfrica*** teams. The subsequent steps are already being planned but will be further developed starting in M09. Steps **3. Enumerators' training** and **4. Methods testing** are within the proposal task **T1.1.c: Preparing collection of primary data of African farming systems** (M08–14). Step **5. Data collection fieldwork** corresponds to tasks **T1.2.b, c and d: Baseline data collection and analysis.**

Step **3. Training of enumerators** is under the WP1 spotlight. This task will be developed in close collaboration with all WPs and African local partners, given their knowledge and coordination for enumerators recruitment, essential to guarantee field work and data quality. Global institutions related to agro-food and development such as the FAO, the World Bank or OXFAM, have taken a role in contributing to the quality of rural data collection and further statistics by providing guidelines for field preparation and training (Fraval et al. 2019) particularly relevant to ***SustInAfrica***. Training is expected to tackle the following main topics: **an overview of the context of research, key concepts associated, methods objectives, implementation and stakeholder's approach, data quality and safety, and the relevance of the evaluation done pre-fieldwork**. It shall also cover the respective key roles, field protocols, survey instruments and the testing of tablets for data collection. The training program will be structured following the Training of Trainers (ToT) model aiming to build a pool of competent instructors among local partners who can train future collaborators. An in-person meeting with the ***SustInAfrica*** team is expected to take place in July in Lisbon, Portugal. This will be an opportunity to start training local teams, and later continue training online in collaboration with local partners and enumerators. In case Covid-19 does not allow face-to-face meetings, all the training will be conducted online. Illustrated materials and videos will be prepared to support training. Moreover, when considered necessary the current Covid-19 pandemic scenario will be

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approached to ensure field teams' safety, and guarantee data quality, following the standards and guidelines established by WP8.

Step **4. Methods testing** during a pilot field mission will be an important element of the enumerators and the whole field team training. This step will allow the redefinition of the methodologies, teams and materials applied in the field when necessary. In case of necessity, references to data collection materials guidelines such as those from UNSD, the World Bank and the UNESCO Institute for Statistics (World Bank 2020) on how to conduct Household Surveys under Covid -19 pandemic will be considered.

While phases 3 to 5 take place, tasks related to **6. Trial installation (WP3)**, **7. Stakeholders mapping** essential to fieldwork, **8. Tablet preparation with selected software and databases**, and **9. Baseline field work logistics**, will be defined. Once these tasks are completed, **5. Baseline data collection** phase will be initiated according to each country's context and considering the local crops (planting and harvesting) and weather seasons. Fieldwork will be coordinated by WP1 and local partners and assessed regularly, considering the project's objectives and the current Covid-19 pandemic situation. Therefore, all participants will be in straight communication during the whole time, to ensure personal safety and data quality collection.

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Annex 1. Screening of methods to apply in *SustInAfrica* state, monitoring, assessment & replication by working group

1. WG Crops

Team involved in the draft
Pierre Ellssel, Bernhard Freyer (BOKU, Vienna) Kwame Frimpong, Michael Adu (UCC, Ghana) Jenny Calabrese, Andi Mehmeti (CIHEAM, Italy) Boussadia Olfa (IO, Tunisia) Desire Lompo (Burkina Faso) Lawarnou Mahamane (Niger) Hamada Abdelrahman (Egypt) Paul Wagstaff (SHA)
Theme
[Description of the subject to be evaluated *e.g., Ecosystem services mapping and assessment*] **WG Crops** Cropping systems/farming systems assessment
Aim and links with the proposal objectives and tasks
[Description of the objectives of the proposed method and its links with the proposal *e.g., Ecosystem services (ES) mapping and assessment associated with the selected farming systems an AEZs will be done considering different analysis and scales. Specifically, the ES assessment will ….. together with WPs …. in T1.2c*] Introduced methods (interviews, focus groups/group discussion, transect/field walks, field sampling, remote sensing) will be employed for gathering data in WP1, WP3 and WP5: - **WP1.2b: Baseline data (primary data) on AEZ specific farming and cropping systems** - **WP3.1: Planning and implementing on-farm trials in 39 communities of the five partner countries; monitoring over 48 month via selected key indicators.** - **WP5.x: use of data from WP3.1 (sustainability/economic impact (gross margin, cost-benefit analysis))** The scales we consider are farm scale in the baseline assessment (WP1) and plot scale during the on-farm trials (WP3).
Indicators/metrics and scales

Indicators	Metrics	Scales (Farm; Plot; Household; Community / Landscape, Regional, National)	Method & number of measurements	Source
Seed source/quality	% 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)	Farm scale (baseline)	Interview / field walk 1 time Group discussion (validation)	
Planting date / timing		Farm scale (baseline)	Interview / field walk 1 time Group discussion	

			(validation)	
Planting type (broadcasting, row seeding)	Ha or % of farmers using improved practices	Farm scale (baseline)	Interview / field walk 1 time Group discussion (validation)	
Stocking density	Number per ha (determine yield of animals & products produced in the cropping system)	Farm scale (baseline)	Interview / field walk 1 time Group discussion (validation)	
Livestock management	Type of fodder Amount of fodder Hours of grazing Time in stable Free roaming Cut & carry	Farm scale (baseline)	Interview / field walk 1 time Group discussion (validation)	
Crop residue management	Ha or % (Burning, removal, incorporation, mulching)	Farm scale (baseline)	Interview / field walk 1 time Group discussion (validation)	
Compost/Manure management	Nutrient content g/kg, Ha, % or number of farmers with improved practice (preparation, storage)	Farm scale (baseline)	Interview / field walk 1 time Group discussion (validation)	
Tillage	Ha, % or number of farmers with improved technology. Type of plow Depth of plowing No. of crossings Use of minimum tillage/ no till/ Conservation Agriculture. Use of Zaï holes, Demi Lunes	Farm scale (baseline)	Interview / field walk 1 time Group discussion (validation)	
Crop diversity (species and varieties)	Crop type count & % Crop species richness	Farm scale (baseline)	Interview / field walk 1 time Group discussion (validation)	Smith et al. (2017)[1]
		plot scale (on-farm trials)	Interview/ protocol Yearly Group discussion (validation)	

[1] Smith, A., Snapp, S., Chikowo, R., Thorne, P., Bekunda, M., & Glover, J. (2017). Measuring sustainable intensification in smallholder agroecosystems: A review. Global Food Security, 12, 127-138.

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Pesticide use (chemicals, mechanicals, biologicals, etc.)	No of applications; kgha-1 / or lha-1 and crop	Farm scale (baseline)	Interview / field walk 1 time Group discussion (validation)	
		plot scale (on-farm trials)	Interview/ protocol Yearly Group discussion (validation)	
Input efficiency	Efficiency equivalent ratio of nutrients and water inputs; Efficiency equivalent ratio of water inputs Eco-efficiency score; all inputs; Partial factor productivity of nutrient inputs; Energy efficiency analysis; all inputs There is also potentially carbon input	Farm scale (baseline)	Interview/ Protocol 1 time Group discussion (validation)	Smith et al. (2017)
		plot scale (on-farm trials)	Interview/ protocol Yearly Group discussion (validation)	
Input intensity	Capital intensity in $/ha; Intensification index; Energy intensity in Mj/ha; Fertilizer rate in kg/ha & no. of applications (mineral/organic)	Farm scale (baseline)	Interview/ Protocol 1 time Group discussion (validation)	Smith et al. (2017)
		plot scale (on-farm trials)	Interview/ protocol Yearly Group discussion (validation)	
Pest pressure	Farmer reported pest pressure; # pests/plant or sample # pest species suppressed % crop plants damaged Weed infestation score	Farm scale (baseline)	Interview/ Protocol yearly	Smith et al. (2017)
		plot scale (on-farm trials)	Interview/ protocol Yearly Group discussion (validation)	
Crop growth stage	Use of industry standards for the different growth stages	Plot scale	Interview/ Protocol/field walks Remote sensing Yearly Group discussion (validation)	We found that crop growth stage was an important factor for predicting insect damage to maize from

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				satellite images (Paul Wagstaff)
Resilience (Paul Wagstaff – climate monitoring group)	Relative crop loss due to disaster Ability to maintain yield under a range of future scenarios, modelled	Farm scale (baseline) plot scale (on-farm trials)	Interview/ Protocol Yearly	Smith et al. (2017)
Crop yield	Output/area (kg/ha); disaggregated by crop, HH socioeconomic levels, gender of HH head.	Farm scale (baseline)	Interview 1 time	Smith et al. (2017)
		plot scale (on-farm trials)	Field sampling Yearly	
Biomass production above ground	Kg / ha	Farm scale (baseline)	Remote sensing or field sampling Interview 1 time	Smith et al. (2017)
		plot scale (on-farm trials)	Remote sensing or field sampling Yearly	
Biomass production below ground		Farm scale (baseline)		
		plot scale (on-farm trials)		
Yield / profit	$ product /ha;	Farm scale (baseline) plot scale (on-farm trials)	Interview/ Protocol Yearly	Smith et al. (2017)
Yield gap? Potential?	Attainable yield– actual yield;	Farm scale (baseline) plot scale (on-farm trials)	Interview/ Protocol Yearly	Smith et al. (2017)
Yield variability	Coefficient of variation	Farm scale (baseline) plot scale (on-farm trials)	Interview/ Protocol Yearly	Smith et al. (2017)
Field postharvest losses	Kg/ha	Farm scale (baseline) plot scale (on-farm trials)	Interview/ Protocol Yearly	

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Crop quality/physiological traits stomatal conductance performance index chlorophyll index leaf chlorophyll content ripening index oil content leaf area index (LAI) nitrogen status? → canopy water content	Ähnlich müsste das ja mit dem Futter sein , auch das was rein kommt , natürlich andere Indikatoren	Farm scale (baseline)? plot scale (on-farm trials)	Interview/ Protocol or remote sensing or laboratory Yearly	
Fodder quality	protein, Mg, Ca, K, P toxins;			
Alles was in eine verrechnung geht , ist ansich anders zu behandeln				
Links to other WGs				
Biomass → WG remote sensing		Plot scale		Smith et al. (2017)
Soil (SOC, nutrients, ? → WG soil				
Labor intensity, labor productivity → WG socio-cultural, economic…	$ product / person day or kg product / person day or Replacement of labor by technology	Plot scale / farm scale		Smith et al. (2017)
Capital productivity → WG socio-cultural, economic…	Benefit / cost Ratio or Total factor productivity	Plot scale / farm scale		Smith et al. (2017)
Methods and methodology description				

[Brief description of the methods and approach to be used. Inform if the method is already established or needs further work. If applied, distinguish between *__primary data collection__* *– field work and* *__secondary data collection__* *– e.g., from open databases, grey literature]*

Methods to be used: **semi-structured interviews, (focus) group discussions, transect/field walks, crop sampling**

- (Semi-)structured interviews: **For the baseline data collection in WP1 (Taks 1.2.b) we will use semi-**

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structured interviews which will be conducted to both man and women key informants in the community by same-sex researchers. - Focus groups or group discussion?!: **will be done in the local language mainly using open questions (and/or statements) and visual strategies by trained field teams leaded by the responsible per country for data collection and reception.** - Transect/field walks **can be conducted together with farmers when conducting the semi-structured interviews, but also in the monitoring phase. Transect/field walks are used for direct observations in the field.** - Crop sampling **in the field (yield, crop/fodder quality)** - Remote sensing
Justification of the methods proposed (sources)
[Justify your selection and indicate the literature that support it. If you need to conduct a literature review, please present a time plan] Exploratory study ! In the center are case studies – how many farmers per region?
Data collection phase(s)
[Indicate when do you foresee to collect the data and in what project phase(s) (baseline, monitoring, replicability, other), and if requires replication in time and space.] The data will be collected during the whole project period. - Baseline data collection: 2021 - Monitoring: 2022 - Monitoring: 2023 - Monitoring: 2024 (as in September 2025 the project is going to finish, no data will be collected in 2025 I suppose!?)
Data base
[Describe how do you envision the database for the data collected e.g. Excel, Access] - Excel for data collection and preparation - STATA or R for statistical analysis
Material and team necessary
[Indicate all the material necessary and team involved (including the team necessary on the field)] - Tablet for data collection - Who is collecting data? Do we have a local resource person who could fill protocol with farmers in case of illiteracy? - Local resource man/woman who contact farmers and arrange a meeting for the interview - Local guide/translator for the data collection
Others (e.g., potential risks, limitations)

2. WG Soil-Water

Team involved in the draft
WG Soil
Theme
Assessing, monitoring and validating soil fertility[1] and soil health[2] [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] Soil health is "the soil's fitness to support crop growth without becoming degraded or otherwise harming the environment" (Acton and Gregorich, 1995).
Aim and links with the proposal objectives and tasks
SustInAfrica`s specific objectives and expected outcomes are to: i) intensify and diversify nutritious food production in Ghana, Burkina Faso, Niger, Egypt, and Tunisia (Figure 1.3.c); ii) **increase productivity of partially degraded land and reintroduce severely degraded land into production**; iii) **increase water and nutrient**

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retention and storage of soil organic carbon in soils; and iv) **enhance delivery of targeted ecosystem services** (See in the proposal part B1-3 section 2.1 Expected Impacts; Table 2.1a).
How to measure, monitor and validate impact of agri-cultural practices on major objectives:

i) Increase productivity of partially degraded land and reintroduce severely degraded land into production

Productivity depends on multiple soil qualities (determined by soil properties) controlling plant performance, which include soil texture (nutrient and water retention), soil pH (nutrient availability; toxicity; biological nitrogen fixation; rootability), salinity (EC; water uptake, imbalanced nutrient content; rootability), content of macro nutrients (total N, exchangeable K, and extractable (available) P), content of micro nutrients (S, Zn, Cu, B), nutrient retention capacity (CEC), rootable and rooting depths (and coarse fragments content) in combination biomass (collaboration with WG Crop), and water infiltration capacity.

ii) Increase water and nutrient retention and storage of soil organic carbon in soils

The soils capacity to store carbon and water depends on pedological properties (texture, soil structure, Fe/Al hydro-oxides, water table). The soils capacity to hold water is simple (plant-available water holding capacity of the root zone depth), while assessing the soils capacity to store carbon is limited on two approaches: i) changing carbon stocks and ii) loss and gain. Assessing carbon stocks is based on simple soil analyses (bulk density, carbon concentration, thickness of soil layers, coarse fragments content) while loss and gain approaches are based on rather expensive flux measurements (e.g. soil respiration; net ecosystem exchange). The soil structure should be assessed in addition as aggregates support “stabilization” of organic carbon (and stickiness as a proxy). Additionally information on soil type (e.g. Ferralsol vs. Arenosol; Plinthosols vs Vertisols), water table and land use should be assessed in collaboration with other WGs.

iii) Enhance delivery of targeted ecosystem services

Targeted ecosystem services directly linked to soil are “nutrient delivery and cycle”, “carbon sequestration”, and “sediment retention (prevent erosion)” while soils will indirectly also affect “biological pest management” and “pollination” mainly addressed by WG Crops and Ecosystem services. Nutrient retention and cycle are determined by soil texture (including coarse fragments content), soil organic carbon, soil pH, cation exchange capacity and concentration of nutrients while carbon sequestration is controlled by soil texture, water content, soil pH, soil depth/rooting zone, and soil density. Soil texture, aggregation, soil organic matter and soil type (e.g. http://www.fao.org/3/t0733e/T0733E05.htm#ch4.2) explain at least partly soil erodibility. Aspects of land use and agricultural practices will be covered by WG Remote sensing and Crops.

Indicators/metrics and scales

Indicators **Bodenart und Bodentyp Gefälle?**	**Metrics**	**Scales is that at the pilot farms or in station? Or both?** (Plot ? Farm; Farmer/ Household; Community / Landscape, Regional, National) When and how often? What depth interval(s)?	**When to measure and how often to measure** (e.g. baseline; each year, two times [2021 and 2015])	**Relevance related to the project`s objectives and site conditions/resources** (existing data and resources)	**Authors/ source** **Below isn’t the author nor the source…**
Soil Organic Carbon (SOC)	mg kg^{-1}	Plot scale	2021 and 2025	highly relevant; we should measure at each site; analyses at the certified Soil4Africa lab in Africa	Element Analyzer; aligned with Soil4Africa approach

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Total nitrogen	mg kg^{-1}	Plot scale	2021 and 2025	highly relevant; we should measure at each site; analyses at the certified Soil4Africa lab in Africa	Element Analyzer; aligned with Soil4Africa approach
Soil pH	-/-	Plot scale	2021 and 2025 Each partner gets a probe allowing additional mesurments	we should measure at each site; analyses at the certified Soil4Africa lab in Africa	pH probe; aligned with Soil4Africa approach, what solution (KCl, $CaCl_2$, H_2O)?
Electrical conductivity	mS cm^{-1}	Plot scale	2021 and 2025 Each partner gets a probe allowing additional mesurments	Where is it relevant to assess?	EC probe; aligned with Soil4Africa approach
Bulk density (compaction)	g cm^{-3}	Plot scale	2021 (and 2025; Ellert and Bettany 1995) at each site we plan to determine stocks	highly relevant	soil rings; aligned with Soil4Africa approach
Soil texture	g per fraction (% sand, silt, clay fractions)	Plot scale	2021	highly relevant; check for already existing soil data (maps and local data); analyses at the certified Soil4Africa lab in Africa	Finger probe or lab method to be aligned with Soil4Africa approach
Soil aggregates Any indicator informing about erosion risk and workability??	Spade diagnosis why not the whole programme	Plot scale	2021 (maybe also 2025 as formation of soil aggregates takes time)	highly relevant	Guimaraes, R.M.L., Ball, B.C., Tormena, C.A. 2011. Improvements in the visual evaluation of soil structure. *Soil Use and Management*, **27**(3), 395-403
Total P and K own line	mg kg^{-1}	Plot scale	2021 and maybe in 2025	highly relevant; check if data are already available; analyses at the certified Soil4Africa lab in Africa	RFA or aqua regia; aligned with Soil4Africa approach
Soil respiration		Plot scale	Depends on the project; just at site of the core communities	relevant to assess the ecosystems capacity to sequestered carbon; rather sensitive compared to	Schiedung, H., Bauke, S., Bornemann, L., Welp, G., Borchard, N., and Amelung, W.

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			multiple SIA team will do research (soil, crop, insects, ecosystem services)	the stock-based approach	(2016). A simple method for in-situ assessment of soil respiration using alkali absorption. Appl. Soil Ecol. *106*, 33–36.
Earthworms					
Volumetric Water holding capacity of the soil fine earth fraction of the root zone, or rootable, depth	dm3/dm3 (l/l) (relative capacity), or: mm (in considered depth)	Plot scale	2021		??
Cation exchange capacity	mmolc kg^{-1}	Plot scale	2021 and maybe in 2025	highly relevant; analyses at the certified Soil4Africa lab in Africa	eff vs.pot? Soil4Africa approach
Soil color					Munsell?
Soil depths	cm	Plot scale	2021; repeating depends on the experimental design; e.g. deep-rooting to sequester C	Relevant and simple, but labor intense…	Rooting zone yes main rooting zone; ??
Soil type (WRB)			2021 based on soil maps; validation in 2021 (texture and soil depths)		??; Soil¤Africa?
Links to other WGs I would do that here in the table – I think later on all tables are merged and then this is obsolete anyway					
Cropping system (incl. management of carbon)	SOC, nutrients, biomass	Plot to farm scale			WG Crops; WG Climate/Weather
Biomass (AGB, BGB) or NEE/soil respiration	Carbon sink/source	Plot scale			WG Crops, WG Remote (LAI etc.), WG Climate; soil respiration: Schiedung, H., Bauke, S., Bornemann, L., Welp, G., Borchard, N., and Amelung, W. (2016). A simple method for in-situ assessment of soil respiration using

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					alkali absorption. Appl. Soil Ecol. *106*, 33–36.
Water supply and quality	EC, SAR, soil moisture, groundwater level	Plot to landscape scale			WG water, WG Climate/Weather

Methods and methodology description

Soil properties => Sampling in field and analyses in field/laboratory.
Soil groups => spatial data from ISRIC/FAO shape files; validation in field
May be this can be added in a column directly behind the drivers indicators.

Justification of the methods proposed (sources)

Again: do we need all these data? I am missing the real justification

SIA => focusing on chemical and physical soil properties; biological soil properties (e.g. carbon mineralization; soil respiration) just in addition (e.g. satellite experiments); See also: Wander, M.M., Cihacek, L.J., Coyne, M., Drijber, R.A., Grossman, J.M., Gutknecht, J.L.M., Horwath, W.R., Jagadamma, S., Olk, D.C., Ruark, M., et al. (2019). Developments in Agricultural Soil Quality and Health: Reflections by the Research Committee on Soil Organic Matter Management. Front. Environ. Sci. *7*, 1–9.

Data collection phase(s)

Baseline assessment in 2021
Mid-term check in 2023
Final sampling in early 2025
Sampling sites not clear yet, but intense sampling just on plots of the core communities

Data base

Preferably via Excel, but most likely added to the Soil4Africa data base.

Material and team necessary

Luke currently prepares purchase of equipment. Consumables have to be covered by local partners.
pH/EC probe

Others (e.g., potential risks, limitations)

Indicator aggregation not clear yet => how to combine to get a soil fertility indicator?
Kwame: **Indigenous knowledge**, also referred to as ethno-science, traditional, local, folk, and native knowledge refers to knowledge, skill and technology acquired by farmers based on their direct long-term use and interaction with the soil.
Farmer indicators of soil fertility. The key indicators mentioned by farmers include soil color, crop yield, soil workability, water holding capacity, presence of fresh worm casts, presence of soil macro-fauna, presence of indicator weeds, stoniness of soil, crop height and growth rate and level of deficiency symptoms on leaves (Dezbiez et al., 2004),
Farmer soil fertility indicators can be categorized into: i) Soil characteristic indicators: soil properties, which farmers use to describe soil as fertile or infertile, ii) Crop performance indicators: crop characteristics that depend on soil fertility status, iii) Topographical indicators: factors relating to the position of field along the top sequence and, iv) Biological indicators: plants (other than crops) or animals whose presence or growth give an indication of soil fertility status.
E.g. Fertile soils include dark soils, those that consistently produce high crop yields, have high water retention capacity, are easy to work, have numerous wet worm casts (70%), produce crops and plants with large green leaves and have ‘soil animals’ present. Infertile soils on the other hand are those that are difficult to work, give low yields, are pale or light colored, and have low moisture holding capacity.

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3. WG Ecosystem Services

Team involved in the draft			
Ecosystem services (FC.ID)			
Theme			
Ecosystem services (ES) – Provisioning of Biomass (food, fodder, fibres and others)			
Aim and links with the proposal objectives and tasks			
The service of **Biomass Provisioning** is one of the main metrics for the project, as Sustainable Intensification relates to an expected increase in production (see Others). The objective is to quantify the cultivated products. Besides the provision of the main products (food, feed or fibers) if other parts of the crops are also used by the farmer (mulch, firewood, construction materials, seeds for reseeding), then ES can be valued. **Ecosystem Services** (ES WP1.2c & WP3.3) mapping and assessment, in the selected **Farming Systems** (cultivated area), comparing the different **AEZ**.			
Indicators/metrics and scales			
Indicators	**Metrics**	**Scales** (Farm; Farmer/ Household; Community / Landscape, Regional, National)	**Authors/ source**
Crop (or animal) Yield	Relative amount of main crop/animal product (for food, feed and fiber materials) and of other by-products (crop residues) (e.g. kg/tree.ha)	**Cultivated area:** species and methods specified for SIA project (<0.0001 to 100 km^2 ?)	CICES v5.1, Egoh et al., 2012[2]
Methods and methodology description			
Yield: Primary Data collection (African partners): **1)** after each season, the farmer measures/estimates how many units (kg, litres, bushel, etc.) of the crop/animal product were produced (e.g. pineapples, cereal grain, corn grain, olives, cotton, leafy or bean legumes, leafy or fruity vegetables, root vegetables like cassava; or meat, milk, etc.), and reports to the local SIA partner. **2)** if possible, measures/estimates of amount of other plant parts used (crop residues? manure?). **3)** other information necessary to calculate the yield: cultivated area (e.g. m^2, ha), and seeding density or number of plants/area, reported by the farmer or, depending on the crop, **collected by UAV/satellite** (e.g. cultivated area, nº trees or shrubs All of these would be covered in the **Cropping systems indicators/metrics**. 4) Land cover, land-use/habitats base maps (cultivated areas, surroundings) and Cropping system detail maps (layout of crops). = **Cropping systems** & **Remote Sensing data/indicators/metrics** **ES data analysis (FC.ID):** - Assessment of the different components contributing for ES, secondary data collection related to available metrics. - Ecosystem Services, are mapped by combining maps of land cover with information about the measured attributes using geographic information systems (GIS). - Comparisons & estimates for the different cropping systems & AEZ are produced using (TBD) suited			

[2] Egoh B., Drakou E.G., Dunbar M.B., Maes J., Willemen L. (2012). Indicators for mapping ecosystem services: a review. JRC Scientific and Policy Report EUR 25456 EN, Luxembourg: Publications Office of the European Union

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applications or equations/indexes.
Justification of the methods proposed (sources)
Being a comparison between different cropping systems, detail is needed from each yield of production, rather than just gross estimates from the culture species, that don't capture the specifics of each system. May include: Yield of each crop used for food or animal feed; Yield of each crop used for fibres (e.g. cotton); Yield of each crop residues used for mulch, production of energy or seeds to replant; Biomass provisioning by animals (e.g. meat, milk, leather, manure). CICES v5.1, Egoh et al., 2012[3] see **Cropping systems indicators/metrics**
Data collection phase(s)
At the **end of the first crop season**, and afterwards seasonally* if possible, to account for yield differences due to external factors (e.g., climate), not due to farming system. *At least **two sets of data**: in the first and last season of the project, to compare before/after. Better if at each crop season, or annually. If possible, to have replicate farming systems & crops in each different AEZ. The metrics used for each crop should be similar among different sites or easily convertible.
Data base
EXCEL, GIS
Material and team necessary
see Cropping system, soil & water, and climate groups.
Others (e.g., potential risks, limitations)
Limitations: only the main crop product is quantified by the farmer, secondary products are used without keeping tabs. Total production is easier to calculate than yield, farmers may not know the number of seeds, plant density, etc. Sugestion - **EROI** - Biomass obtained through agricultural activities is not a mere product of natural ecosystems, but requires substantial human input to be obtained, so if possible, **another indicator related to Energy Resource Efficiency could be calculated**. Energy resource efficiency involved in the production process. Includes: Natural energy: Solar radiation, wind, rainfall, flowing water and groundwater (units/year) + soil erosion (per year) + purchased inputs (e.g. fertilisers, fencing, pesticides, seeds, irrigation, machinery, fuel, electricity, etc.) +Human resources (e.g. labour). Hall, 2011[4], Perez-Soba 2019[5], Pérez-Soba et al. 2015[6] The EROI[7] methodology is used in food and agricultural research as a key indicator of the sustainability of agricultural production systems (Schramski et al., 2013; Markussen and Østergård, 2013, Martinez-Alier, 2011, Moore, 2010). Also Perez-Soba 2019[8].

[3] Egoh B., Drakou E.G., Dunbar M.B., Maes J., Willemen L. (2012). Indicators for mapping ecosystem services: a review. JRC Scientific and Policy Report EUR 25456 EN, Luxembourg: Publications Office of the European Union

[4] Hall, C. A. S. (2011) "Introduction to Special Issue on New Studies in EROI (Energy Return on Investment) ". Sustainability 3(10): 1773-1777

[5] Pérez-Soba M., Elbersen B., Braat L., Kempen, M., van der Wijngaart R., Staritsky I., Rega C., Paracchini M.L., The emergy perspective: natural and anthropic energy flows in agricultural biomass production, EUR 29725 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76- 02057-8, doi:10.2760/526985, JRC116274

[6] Pérez-Soba M., Elbersen B., Kempen M., Braat L., Staristky I., Wijngaart R. van, Kaphengst T., Andersen E., Germer L., Smith L., Rega C., Paracchini M.L. (2015) Agricultural biomass as provisioning ecosystem service: quantification of energy flows. JRC Technical Report JRC97764. Publication Office of the European Union, Luxemburg

[7] Hall, C. A. S. (2011) "Introduction to Special Issue on New Studies in EROI (Energy Return on Investment) ". Sustainability 3(10): 1773-1777

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Links to **Cropping system, soil & water, and climate groups.**

Team involved in the draft			
Ecosystem services (FC.ID)			
Theme			
Ecosystem services (ES) – Provision of Water for irrigation			
Aim and links with the proposal objectives and tasks			
The service of **provision of irrigation from local water sources** in agroecosystems, can be related to the amount of irrigation water avaliable for the crops. Such as when the cropping system creates opportunities for the increase in surface water availability (reservoirs?) for irrigation. See also "maintenance of the hydrological cycle ES". Crops/systems that require less water use leave more of that capital in nature. This links to the **Water** (irrigation) & **Agriculture indicators/metrics** (cultivated area, crop species, cropping system). **Ecosystem Services** (ES WP1.2c & WP3.3) mapping and assessment, in the selected **Farming Systems** (cultivated area), comparing the different **AEZ**.			
Indicators/metrics and scales			
Indicators	**Metrics**	**Scales** (Farm; Farmer/ Household; Community / Landscape, Regional, National)	**Authors/ source**
Water (surface & ground) used for irrigation	Annual volumes of local water available & used for irrigation. Discriminated by water source (e.g. surface water, underground). Presence of Small Water Features.	**Cultivated area:** species and methods specified for SIA project (<0.0001 to 100 km^2 ?) + if relevant: surrounding area's water features; + data from other **AEZ**?	CICES v5.1 , Power 2010[9], Fleming 2014[10]
Methods and methodology description			
Primary Data collection (African partners): - estimates/measures of water used for irrigation and its sources. These would be covered in the **Water (hydrological model?)** or **Agriculture indicators/metrics**. - climatic data annual / seasonal / daily (**Climate group**) - cropping system details related to water features (**Remote sensing / Cropping systems groups**) **ES data analysis (FC.ID):** - Assessment of the different components contributing for ES (secondary data collection if needed for estimates) - Ecosystem Services, are mapped by combining maps of land cover with information about the measured attributes using geographic information systems (GIS). - Comparisons & estimates for the different cropping systems & AEZ are produced using (TBD) suited			

[8] Pérez-Soba M., Elbersen B., Braat L., Kempen, M., van der Wijngaart R., Staritsky I., Rega C., Paracchini M.L., The emergy perspective: natural and anthropic energy flows in agricultural biomass production, EUR 29725 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76- 02057-8, doi:10.2760/526985, JRC116274
[9] Power AG. Ecosystem services and agriculture: tradeoffs and synergies. Philos Trans R Soc Lond B Biol Sci. 2010;365(1554):2959-2971. doi:10.1098/rstb.2010.0143
[10] William M. Fleming, José A. Rivera, Amy Miller & Matt Piccarello (2014) Ecosystem services of traditional irrigation systems in northern New Mexico, USA, International Journal of Biodiversity Science, Ecosystem Services & Management, 10:4, 343-350, DOI: 10.1080/21513732.2014.977953

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applications (e.g. InVest) or equations/indexes.
Justification of the methods proposed (sources)
CICES v5.1 , Power 2010[11], Fleming 2014[12], Egoh 2008[13]
Data collection phase(s)
[Indicate when do you foresee to collect the data and in what project phase(s) (baseline, monitoring, replicability, other), and if requires replication in time and space.] **Baseline** (beginning) and **in the end. Annual data considering the annual variations in climate.** Species are a constant, but if any soil property changes with a new cropping system introduced, maybe by the end of the project the results are different. If possible, to have replicate farming systems & crops, and in different AEZ. The metrics used for each crop should be similar among different sites or easily convertible.
Data base
EXCEL, GIS
Material and team necessary
[Indicate all the material necessary and team involved (including the team necessary on the field)] **Data collection:** - details of irrigation in cropping systems in each field **(African partners)** **Water & cropping systems groups**
Others (e.g., potential risks, limitations)
Limitations: difficulties in evaluating water use and source?

Team involved in the draft
Ecosystem services (FC.ID)
Theme
Ecosystem services (ES) – Regulation & Maintenance of the hydrological cycle
Aim and links with the proposal objectives and tasks
The service of **maintenance of the hydrological cycle** in agroecosystems, can be related to the capacity to maintain soil humidity provided by some crop systems (e.g. mulching, shadowing). This links to the **Cropping systems indicators/metrics** and **Soils** (soil humidity). **Ecosystem Services** (ES WP1.2c & WP3.3) mapping and assessment, in the selected **Farming Systems** (cultivated area), comparing the different **AEZ**.
Indicators/metrics and scales

Indicators	**Metrics**	**Scales** (Farm; Farmer/ Household; Community / Landscape, Regional, National)	**Authors/ source**

[11] Power AG. Ecosystem services and agriculture: tradeoffs and synergies. Philos Trans R Soc Lond B Biol Sci. 2010;365(1554):2959-2971. doi:10.1098/rstb.2010.0143

[12] William M. Fleming, José A. Rivera, Amy Miller & Matt Piccarello (2014) Ecosystem services of traditional irrigation systems in northern New Mexico, USA, International Journal of Biodiversity Science, Ecosystem Services & Management, 10:4, 343-350, DOI: 10.1080/21513732.2014.977953

[13] Egoh, B., Reyers, B., Rouget, M., Richardson, D.M., Le Maitre, D.C., and van Jaarsveld, A.S. 2008. Mapping ecosystem services for planning and management. Agriculture, Ecosystems & Environment 127:135-140.

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Soil humidity	Measurements/estimates of soil humidity, in crop systems, either measured directly and/or estimated by Remote sensing metrics/hydrological models.	**Cultivated area:** species and methods specified for SIA project (<0.0001 to 100 km^2 ?)	CICES v5.1 Posthumusa 2010[14]
Nutrient leaching	soil or water chemical analysis is included in the project?		

Methods and methodology description

Primary Data collection (African partners):
- Measurements of soil humidity in crop systems and soil type.
All of these would be covered in the **Soil or Water or Agriculture indicators/metrics**.
- If available: Remote sensing estimates (**Remote sensing**).
- if available – chemical composition of agricultural leachates (soil/water analysis).
- climatic data daily (**Climate group**)
- Land cover, land-use/habitats base maps (cultivated areas) and Cropping system detail maps (layout of crops).

ES data analysis (FC.ID):
- Assessment of the different components contributing for ES (secondary data collection if needed)
- Ecosystem Services, are mapped by combining maps of land cover with information about the measured attributes using geographic information systems (GIS).
- Comparisons & estimates for the different cropping systems & AEZ are produced using (TBD) suited applications (e.g. InVest) or equations/indexes.

Justification of the methods proposed (sources)

Metrics, already used by other tasks, that provide an estimate of the soil moisture, a proxy for the capacity of the agroecosystem to retain water and prevent droughts.

Data collection phase(s)

Baseline (beginning) and **in the end.** Species are a constant, but if any soil property changes with a new cropping system introduced, maybe by the end of the project the results are different.
If possible, to have replicate farming systems & crops in different AEZ.
The metrics used for each crop should be similar among different sites or easily convertible.

Data base

EXCEL, GIS

Material and team necessary

Data collection:
- Relative humidity probe OR soil core collection and oven drying and weighting **(African partners)**
- Remote sensing of soil moisture

Others (e.g., potential risks, limitations)

Team involved in the draft

Ecosystem services (FC.ID)

[14] H. Posthumusa,⁎, J.R. Rouquetteb, J. Morrisa, D.J.G. Gowingb, T.M. Hess. 2010. A framework for the assessment of ecosystem goods and services; a case study onlowlandfloodplains in England. Ecological Economics 69 (2010) 1510–1523. DOI: 10.1016/j.ecolecon.2010.02.011

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Theme			
Ecosystem services (ES) – Regulation & Maintenance (control) of soil erosion			
Aim and links with the proposal objectives and tasks			
The service of **Control of Soil Erosion** in agroecosystems, can be related to **Soil Protection**, by cover crops. Living and dead biomass covering the soil, protect it from direct exposure to elements (rain, wind) that lead to erosion (soil loss). Factors affecting soil erosion: rainfall, wind, erodibility or soil type, absence of vegetation, slope and land management. This links to the groups: **Cropping systems and management + Landscape & Remote Sensing + Climate + Soil & Water**. **Ecosystem Services** (ES WP1.2c & WP3.3) mapping and assessment, in the selected **Farming Systems** (cultivated area), comparing the different **AEZ**.			
Indicators/metrics and scales			
Indicators	**Metrics**	**Scales** (Farm; Farmer/ Household; Community / Landscape, Regional, National)	**Authors/ source**
Capacity of agroecosystem to avoid soil erosion **+** **Soil retention**	# **Land use/land cover** (crops and cropping systems). # **Soil & climate data**: for RUSLE, RWEQ or INVEST models (see bellow) # **NDVI**	**Cultivated area:** species and methods specified for SIA project (<0.0001 to 100 km^2 ?) +Data from other **AEZ**?	Burkhard et al. 2017 (ES) Borrelli et al. 2017 (GIS-RWEQ)[15] Fryrear et al. 2000 (RWEQ) USDA-ARS 2014 (RUSLE) InVEST model[16]
Methods and methodology description			
Mapping of the **Land use/land cover** in each cultivated area (cropping system details). Determine amount of vegetation from **Remote sensing (NDVI)**. **Soil retention (tonns ha^{-1} year^{-1})** can be calculated as the difference between a model which calculates soil loss without vegetation cover (structural impact) and a model including the current land use cover pattern. Modellation using the Revised Universal Soil Loss Equation (**RUSLE**)[17]; or the Revised Wind Erosion Equation Model (**RWEQ**), which focus on erosion from precipitation or wind, respectively; or the **InVEST SDR** model, among others. **Primary Data collection:** - Land use/land cover, particular to each cropping system (species, patterns, crop cycles, timings) - *(Local African partners + Cropping systems and management group + Landscape & Remote Sensing group)* For **RUSLE**: **-** management practice (C) and conservation practice (P) *(Cropping systems and management group)* - slope steepness and length (LS) = digital elevation model; NDVI – *(Landscape & Remote Sensing group)* - rainfall erosivity (R) – *(Climate group + Soil & Water group)* - soil erodibility (K) - *(Soil & Water group)* OR for **RWEQ**:			

[15] DOI: 10.1002/ldr.2588
[16] http://releases.naturalcapitalproject.org/invest-userguide/latest/sdr.html#data-needs
[17] see: http://www.fao.org/land-water/land/land-governance/land-resources-planning-toolbox/category/details/en/c/1236444/ ; https://fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm ; https://www.ars.usda.gov/southeast-area/oxford-ms/national-sedimentation-laboratory/watershed-physical-processes-research/docs/revised-universal-soil-loss-equation-rusle-welcome-to-rusle-1-and-rusle-2/

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- WF, weather factor – *(Climate group)* - EF, wind-erodible fraction of soil; SCF, soil crust factor; K', soil roughness factor - *(Soil & Water group)* - COG, combined crop factors *(Cropping systems and management group)* OR for **InVEST**: - Digital elevation model (DEM); Land use/land cover including nearby Watersheds - *(Landscape & Remote Sensing group)* - Rainfall erosivity – *(Climate group + Soil & Water group)* - Soil erodibility (K); Topsoil particles finer than coarse sand (1000 µm; Vigiak et al. 2012) – *(Soil & Water group)* **ES data analysis (FC.ID):** - Assessment of the different components contributing for ES (secondary data collection if needed for estimates) - Ecosystem Services, are mapped by combining maps of land cover with information about the measured attributes using geographic information systems (GIS). - Comparisons & estimates for the different cropping systems & AEZ are produced using the suited applications or equations/indexes (e.g. **InVEST, RWEQ**, **RUSLE**).
Justification of the methods proposed (sources)
CICES v5.1, Burkhard et al. 2017
Data collection phase(s)
Baseline (beginning) and **in the end of the crop seasons** (minimum and maximum crop cover). Unless mulch is applied covering the cultivated soil completely, the plant cover may vary enormously during the growing season, thus knowing the values in the start and end of the growing season, an average value of soil protection can be estimated. The fate of crop residues may also be significant and should be described in the **cropping systems** data. Replicate farming systems & crops, and in different AEZ.
Data base
EXCEL, GIS
Material and team necessary
[Indicate all the material necessary and team involved (including the team necessary on the field)] **Data collection:** **Local African partners** – on-site data collection/ validation. **Cropping systems and management group** - Land use/land cover, particular to each cropping system. **Landscape & Remote Sensing group** – Digital elevation model (DEM), Land use/land cover maps, NDVI. **Climate group** – data on precipitation & wind. **Soil & Water group** – data on soil & water features.
Others (e.g., potential risks, limitations)

Team involved in the draft
Ecosystem services (FC.ID) +...
Theme
Ecosystem services (ES) – Regulation & Maintenance of microclimate (temperature & humidity, and Wind protection)
Aim and links with the proposal objectives and tasks
The service of **Microclimate regulation** in agroecosystems, can be related to the presence of plants that reduce the speed and movement of air, reducing the scale or frequency of wind damages (e.g. sand storms), maintain humidity and buffer temperature changes. The presence of trees forming barriers may protect from

windstorms and also affects erosion, humidity, microclimate, etc. This links to the **Soil, Climate & Cropping systems indicators/metrics** (cultivated area, crop species, cropping system). **Ecosystem Services** (ES WP1.2c & WP3.3) mapping and assessment, in the selected **Farming Systems** (cultivated area), comparing the different **AEZ**.			
Indicators/metrics and scales			
Indicators	**Metrics**	**Scales** (Farm; Farmer/ Household; Community / Landscape, Regional, National)	**Authors/ source**
Trees and shrubs **+Plant cover** **+Wind, temperature, humidity, radiation (microclimate)**	Fragmentation metrics for **trees & large shrubs** (hedgerows, green fences, etc.)= **small woody features** and their heights; soil cover (**NDVI**) + **climate data**	**Cultivated area:** species and methods specified for SIA project (<0.0001 to 100 km^2 ?) +Data from other **AEZ**?	CICES v5.1
Methods and methodology description			
Primary Data collection (African partners): - estimates/measures of "small woody features" in the **Agriculture indicators/metrics**. - Plant soil cover (NDVI) (**Remote sensing group + Cropping systems group**) - Wind direction & speed data, temperature, humidity (**climate group? Remote sensing group?**) **ES data analysis (FC.ID):** - Assessment of the different components contributing for ES (secondary data collection if needed for estimates) - Ecosystem Services, are mapped by combining maps of land cover with information about the measured attributes using geographic information systems (GIS). Model tool RWEQ? - Comparisons & estimates for the different cropping systems & AEZ are produced using (TBD) suited applications (e.g. InVest) or equations/indexes.			
Justification of the methods proposed (sources)			
CICES v5.1, Françoise Burel (1996)[18], Sivakumar M.V. (2005)[19], UNEP[20], USDA 2007[21]			
Data collection phase(s)			
Baseline (beginning) and **in the end of the season, or project**, depending on expected changes in volume of plants. **Daily to annual** microclimatic characterization of the area. If possible, to have replicate farming systems & crops in different AEZ. The metrics used for each crop should be similar among different sites or easily convertible.			
Data base			
EXCEL, GIS			

[18] Françoise Burel (1996) Hedgerows and Their Role in Agricultural Landscapes, Critical Reviews in Plant Sciences, 15:2, 169-190, DOI: 10.1080/07352689.1996.10393185.
[19] Sivakumar M.V. (2005) Impacts of Sand Storms/Dust Storms on Agriculture. In: Sivakumar M.V., Motha R.P., Das H.P. (eds) Natural Disasters and Extreme Events in Agriculture. Springer, Berlin, Heidelberg. https://doi.org/10.1007/3-540-28307-2_10
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Material and team necessary
[Indicate all the material necessary and team involved (including the team necessary on the field)] **Data collection:** - Details of soil cover in cropping systems in each field **(African partners)** - Remote sensing of plant cover (**Remote sensing group & Cropping systems group**) - microclimatic data (**Climate & Soils groups**)
Others (e.g., potential risks, limitations)
Limitations: crude estimates if based on species and cropping system only, without measurements. This may be separated into two ES (microclimate + wind protection) depending on data availability.

Team involved in the draft			
Ecosystem services (FC.ID)			
Theme			
Ecosystem services (ES) – Regulation & Maintenance of Soil quality			
Aim and links with the proposal objectives and tasks			
The service of **maintenance of soil quality** in agroecosystems, can be related to soil fertility. This links to the **Soil & Cropping systems indicators/metrics** (cultivated area, crop species, cropping system). **Ecosystem Services** (ES WP1.2c & WP3.3) mapping and assessment, in the selected **Farming Systems** (cultivated area), comparing the different **AEZ**.			
Indicators/metrics and scales			
Indicators	**Metrics**	**Scales** (Farm; Farmer/ Household; Community / Landscape, Regional, National)	**Authors/ source**
soil fertility **+ precipitation** **+ leguminous plants**	Soil type, basic soil properties: field capacity, capillary moisture, cation-exchange capacity and base saturation, organic matter, nitrogen, phosphorous, potassium, fertilisers. Species ID and legume cultivation area.	**Cultivated area:** species and methods specified for SIA project (<0.0001 to 100 km^2 ?) +Data from other **AEZ**?	CICES v5.1 , Burkhard2017
Methods and methodology description			
Primary Data collection (African partners): - estimates/measures of soil properties and soil map (**Soil** group & **African partners**). - climatic data annual / seasonal / daily (**Climate group**) - cropping system details (**Remote sensing / Cropping systems groups**) **ES data analysis (FC.ID):** - Assessment of the different components contributing for ES (secondary data collection if needed for estimates) - Ecosystem Services, are mapped by combining maps of land cover with information about the measured attributes using geographic information systems (GIS). - Comparisons & estimates for the different cropping systems & AEZ are produced using (TBD) suited applications (e.g. InVest) or equations/indexes.			

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Justification of the methods proposed (sources)
CICES v5.1 , Burkhard2017
Data collection phase(s)
[Indicate when do you foresee to collect the data and in what project phase(s) (baseline, monitoring, replicability, other), and if requires replication in time and space.] **Baseline** (beginning) and **in the end.** If possible, to have replicate farming systems & crops, and in different AEZ. The metrics used for each crop should be similar among different sites or easily convertible.
Data base
EXCEL, GIS
Material and team necessary
Data collection: - soil collection for analysis in each field **(African partners)** **-** data on soil types (**soil group**) - precipitation data (**climate group**) - plant species – leguminous (**Cropping system group**)
Others (e.g., potential risks, limitations)

Team involved in the draft			
Ecosystem services (FC.ID)			
Theme			
Ecosystem services (ES) – Regulation & Maintenance of Climate (carbon storage)			
Aim and links with the proposal objectives and tasks			
The service of **climate regulation,** links ultimately to regulation of the concentrations of gases in the atmosphere, like greenhouse gases. This links to the soil (carbon) & cropping systems indicators/metrics (cultivated area, crop species, cropping system). **Ecosystem Services** (ES WP1.2c & WP3.3) mapping and assessment, in the selected **Farming Systems** (cultivated area), comparing the different **AEZ**.			
Indicators/metrics and scales			
Indicators	**Metrics**	**Scales** (Farm; Farmer/ Household; Community / Landscape, Regional, National)	**Authors/ source**
Carbon sequestration/storage	Above ground biomass (photogammetry?**)** + below ground biomass (estimates from species) +soil carbon	**Cultivated area:** species and methods specified for SIA project (<0.0001 to 100 km^2 ?)	CICES v5.1 Burkhard2017
Methods and methodology description			
Primary Data collection (African partners): - estimates/measures of soil carbon (soil group). - climatic data annual / seasonal / daily (**Climate group**) - plant biomass estimates (**Remote sensing / Cropping systems groups**) **ES data analysis (FC.ID):**			

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- Assessment of the different components contributing for ES (secondary data collection if needed for estimates) - Ecosystem Services, are mapped by combining maps of land cover with information about the measured attributes using geographic information systems (GIS). - Comparisons & estimates for the different cropping systems & AEZ are produced using (TBD) suited applications (e.g. InVest) or equations/indexes.
Justification of the methods proposed (sources)
CICES v5.1
Data collection phase(s)
Baseline (beginning) and **in the end. Annual data considering the annual variations in climate.** Species are a constant, but if any soil property changes with a new cropping system introduced, maybe by the end of the project the results are different. If possible, to have replicate farming systems & crops, and in different AEZ. The metrics used for each crop should be similar among different sites or easily convertible.
Data base
EXCEL, GIS
Material and team necessary
Data collection: - soil for analysis **(African partners)** **-** remote sensing plant biomass estimates
Others (e.g., potential risks, limitations)
Is the use of fire one component of any SIA cropping systems?

Team involved in the draft
Ecosystem services (FC.ID+LUKE)
Theme
Ecosystem services (ES) – Regulation & Maintenance of Habitats/Life cycle
Aim and links with the proposal objectives and tasks
The service of **maintenance of Habitats/Life cycle** in agroecosystems, is related to the **number of different habitats and food sources present in the cultivated fields, available to the surrounding natural biodiversity, that contribute to a more complex local food web, and to a lower impact of crop pests.** This links to the Agriculture indicators/metrics (cultivated area and structure, crop species, cropping system). **Ecosystem Services** (ES WP1.2c & WP3.3) mapping and assessment, in the selected **Farming Systems** (cultivated area), comparing the different **AEZ**.
Indicators/metrics and scales

Indicators	**Metrics**	**Scales** (Farm; Farmer/ Household; Community / Landscape, Regional, National)	**Authors/ source**
Plant biodiversity (taxonomic & functional)	Listing of species cultivated, their distribution patterns (time & space) and strata (e.g. trees, shrubs, herbaceous, young and	**Cultivated area:** species and methods specified for SIA project (<0.0001 to 100 km^2 ?)	CICES v5.1

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	old trees). AND Remote sensing vegetation structure metrics, if available.		
Habitats	Habitats local cartography + habitat fragmentation & connectivity	Cultivated area and surroundings + other AEZ	
Insect Biodiversity	**InsectaMon** (total biomass, functional groups abundance and diversity, taxonomic richness and diversity)	Cultivated area and surroundings	

Methods and methodology description

Primary Data collection (African partners):
- List of the species cultivated in each cropping system, distribution pattern in time (e.g. annual, rotation of cultures) and space (monoculture, agroforestry, etc.).

All of these would be covered in the **Agriculture indicators/metrics**.
- If available: Remote sensing of vegetation structure (**Remote sensing**).
- Land cover, land-use/habitats base maps (cultivated areas, surroundings) and Cropping system detail maps (layout of crops).

ES data analysis (FC.ID):
- Assessment of the different components contributing for ES (secondary data collection if needed)
- Ecosystem Services, are mapped by combining maps of land cover with information about the measured attributes using geographic information systems (GIS).
- Comparisons & estimates for the different cropping systems & AEZ are produced using (TBD) suited applications (e.g. InVest) or equations/indexes

Justification of the methods proposed (sources)

Metrics, some already used by other tasks, that provide an estimate of the complexity of the cultivated area regarding microhabitats and food sources for different species, contributing for a balanced and resilient ecosystem.
e.g. :
http://www.fao.org/3/b-i7374e.pdf; https://doi.org/10.1016/j.foreco.2018.10.064;
https://doi.org/10.1029/2008JG000883

Data collection phase(s)

Baseline (species are a constant, structure may differ, if that is the case other final sampling is required). **annual/seasonal sampling** (maximum productivity).
If possible, to have replicate farming systems & crops in different AEZ.
The metrics used for each crop should be similar among different sites or easily convertible.

Data base

EXCEL, GIS

Material and team necessary

Data collection:
- list of species and details of cropping systems in each field and tree height **(African partners)**
- Remote sensing of vegetation structure (**Remote sensing**)

Others (e.g., potential risks, limitations)

Limitations: basic vegetation structure data.

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Team involved in the draft			
Ecosystem services (FC.ID+LUKE)			
Theme			
Ecosystem services (ES) – Regulation & Maintenance of pollination & seed dispersal			
Aim and links with the proposal objectives and tasks			
The service of **regulation and maintenance of pollination & seed dispersal** by insects or similar requires the quantification of species links and pollinators identification. This links to the soil (biodiversity) & cropping system indicators/metrics (cultivated area, crop species, cropping system). **Ecosystem Services** (ES WP1.2c & WP3.3) mapping and assessment, in the selected **Farming Systems** (cultivated area), comparing the different **AEZ**.			
Indicators/metrics and scales			
Indicators	**Metrics**	**Scales** (Farm; Farmer/ Household; Community / Landscape, Regional, National)	**Authors/ source**
Birds & insects functional groups	Number and abundance of pollinator species (number/m2) OR biomass of functional groups (insectaMOn)	**Cultivated area:** species and methods specified for SIA project (<0.0001 to 100 km^2 ?) + surrounding area's biodiversity	CICES v5.1
Methods and methodology description			
Data collection: - InsectaMon, lists of potential insects and other groups **(African partners)** - cropping system details related to plant fucntions or plant list/map (**Remote sensing / Cropping systems groups**) **ES data analysis (FC.ID):** - Assessment of the different components contributing for ES (secondary data collection if needed for estimates) - Ecosystem Services, are mapped by combining maps of land cover with information about the measured attributes using geographic information systems (GIS). - Comparisons & estimates for the different cropping systems & AEZ are produced using (TBD) suited applications (e.g. InVest) or equations/indexes.			
Justification of the methods proposed (sources)			
CICES v5.1			
Data collection phase(s)			
Baseline (beginning) and **in the end. Annual data considering the annual variations in climate.** Species are a constant, but if any soil property changes with a new cropping system introduced, maybe by the end of the project the results are different. If possible, to have replicate farming systems & crops, and in different AEZ. The metrics used for each crop should be similar among different sites or easily convertible.			
Data base			
EXCEL, GIS			
Material and team necessary			

Data collection: - details of seasonal visits in cropping systems in each field **(African partners)** - ID of insects, birds, etc. (**Insect partners**)
Others (e.g., potential risks, limitations)
Limitations: underestimation of biodiversity

Team involved in the draft
Ecosystem services (FC.ID+LUKE)
Theme
Ecosystem services (ES) – Regulation & Maintenance of Pests & Diseases
Aim and links with the proposal objectives and tasks
The service of **regulation of** pests and diseases in agroecosystems can be related to the presence of specific biocontrol agents and to biodiversity. **Ecosystem Services** (ES WP1.2c & WP3.3) mapping and assessment, in the selected **Farming Systems** (cultivated area), comparing the different **AEZ**.
Indicators/metrics and scales

Indicators	Metrics	Scales (Farm; Farmer/ Household; Community / Landscape, Regional, National)	Authors/ source
Insect abundance and funtions + NDVI	Abundance, diversity and function of insect species +reflectance indexes (plant health and diseases)	**Cultivated area:** species and methods specified for SIA project (<0.0001 to 100 km^2 ?) + if relevant: surrounding area's water features	CICES v5.1

Methods and methodology description
Primary Data collection (African partners): - InsectaMon, lists of potential insects and other groups **(African partners)** - cropping system details (**Remote sensing / Cropping systems groups**) - remote sensing plant health **ES data analysis (FC.ID):** - Assessment of the different components contributing for ES (secondary data collection if needed for estimates) - Ecosystem Services, are mapped by combining maps of land cover with information about the measured attributes using geographic information systems (GIS). - Comparisons & estimates for the different cropping systems & AEZ are produced using (TBD) suited applications (e.g. InVest) or equations/indexes.
Justification of the methods proposed (sources)
CICES v5.1 ,
Data collection phase(s)
Baseline (beginning) and **in the end. Annual data considering the annual variations in climate.** Species are a constant. maybe by the end of the project the results are different. If possible, to have replicate farming systems & crops, and in different AEZ. The metrics used for each crop should be similar among different sites or easily convertible.
Data base
EXCEL, GIS

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Material and team necessary
Data collection: - details of species **(African partners)** **- other partners for data prcessing**
Others (e.g., potential risks, limitations)
Limitations: difficulties in evaluating insects

Team involved in the draft
Ecosystem services (FC.ID+ISEG)
Theme
Ecosystem services (ES) – Cultural heritage & Spiritual or symbolic meaning
Aim and links with the proposal objectives and tasks
The **Cultural** ES in agroecosystems, can be related to the **traditional value** of the cropping system/crop to the local communities. **Ecosystem Services** (ES WP1.2c & WP3.3) mapping and assessment, in the selected **Farming Systems** (cultivated area), comparing the different **AEZ**.
Indicators/metrics and scales

Indicators	**Metrics**	**Scales** (Farm; Farmer/ Household; Community / Landscape, Regional, National)	**Authors/ source**
Traditional cropping systems used **+ traditional crops used**	Peoples's perceptions, inquires about tradtional methods and folk species	**Cultivated area:** species and methods specified for SIA project (<0.0001 to 100 km^2 ?)	CICES v5.1 ,

Methods and methodology description
Primary Data collection (African partners): - inquires for local communities (**Socioecon group?**) - cropping system details related to cropping systems and species (**Cropping systems groups**) **ES data analysis (FC.ID):** - Assessment of the different components contributing for ES (secondary data collection if needed for estimates) - Ecosystem Services, are mapped by combining maps of land cover with information about the measured attributes using geographic information systems (GIS). - Comparisons & estimates for the different cropping systems & AEZ are produced using (TBD) suited applications (e.g. InVest) or equations/indexes.
Justification of the methods proposed (sources)
CICES v5.1
Data collection phase(s)
Baseline (beginning). If possible, to have replicate farming systems & crops, and in different AEZ. The metrics used for each crop should be similar among different sites or easily convertible.
Data base
EXCEL, GIS

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Material and team necessary
Others (e.g., potential risks, limitations)

4. WG Remote Sensing

Team involved in the draft				
Remote Sensing/GIS/Data group				
Theme				
Remote sensing for ecosystem services and crop productivity assessment				
Aim and links with the proposal objectives and tasks				
Remote sensing as well as additional data will support WPs 1 and 3 with additional spatial information required to ensure monitoring of ecosystem service monitoring, e.g., greening infrastructures such as bushes and hedges within smallholder farming communities, disclose potential pathways of ecosystem services that are beneficial for biological pest management and utilisation of targeted ecosystem services. Another task should be the generating mapping information from UAV and satellite imagery for relevant agronomic parameters to timely deliver data about yield prediction and crop protection, e.g. biomass, drought, stress, plant diseases or nutrient deficiencies.				
Indicators/metrics and scales				
Indicators	**Metrics**	**Scales**	**Relevance** (high, Medium, Low)	**Methodology/ Sampling – Ground Truthing Effort/ Available data/ Literature**
Land use (Ecosystem services)	Classification providing information on land cover.	Regional scale; Baseline assessment (one time)		Can be achieved by supervised classification using various classifier (pixel based/object based, Maximum Likelihood Classifier; Random Forest, Deep Learning). Needs knowledge of real land cover best by sampling (e.g. locating the areas by GNSS) for calibration and testing. Effort high if large areas should be covered. Quality can be increased by using time series imagery. Land cover map available for Africa: ESA CCI LAND COVER http://2016africalandcover20m.esrin.esa.int/viewer.php High resolution land cover mapping could also be conducted from UAV imagery directly via vectorization of the areas (Effort high, drone use over large areas needed, might conflict with legal requirements). Example of land use classification with Sentinel 2 data: https://doi.org/10.1117/1.JRS.13.014530

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Vegetation indices (VI) (Ecosystem services)	Spectral indices specifically aimed on plant reflectance, e.g., NDVI, SAVI, RedEdge NDVI etc.	Regional / local		Sentinel 2 data is suitable for estimating many different vegetation indices. SNAP tool available. Effort easy. However, this is highly indirect information and may only correlate to a certain degree with the desired target (crop vitality, plant stress, biomass) High resolution VI mapping could also be conducted from UAV imagery with multispectral camera (Effort high, drone use over large areas needed, might conflict with legal requirements).
Various terrain attributes (Ecosystem services)	Slope, Exposition, Watershed, Topographic wetness index, etc.	Watershed, Landscape scale		SRTM elevation data freely available (30 m). SAGA-GIS provides a good front-end to derive many different primary and secondary terrain attributes, partly integrated in QGIS. Effort easy-medium. UAV photogrammetry may provide high resolution elevation data assuming undisturbed view on ground and accurate ground truthing (Effort high). Example of landform classification with SRTM: https://doi.org/10.1007/s40808-015-0055-9
Crop type (Ecosystem services, WG Innovation and replicability)	Classification of crop types	Regional Seasonal assessment		GT: Survey RS: From UAV imagery can be directly vectorized with highly accurate field boundaries and direct assessment of crop type (Effort high: drone use over large areas needed, might conflict with legal requirements) From Copernicus with time series data with Sentinel 2 possible within experimental plugin in SNAP – Sen2Agri (Linux version available) (GT Validation strongly needed); Effort high: 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 (e.g. Vuolo et al., 2018, Griffiths et al., 2018) Sen2Agri Validation https://doi.org/10.1016/j.rse.2018.11.007 Watkins: https://doi.org/10.1016/j.compag.2019.02.009 Griffiths: https://doi.org/10.1016/j.rse.2018.10.031
Small woody features (Ecosystem services) Object delineation of hedges, bushes, tree rows, or isolated trees	Scalability: Communities level (UAV) regional level (Sentinel, highly uncertain, only larger structures)		May relate to shadowing, wind erosion etc. e.g. effects of height of hedgerows on crop yield determined (Van Vooren et al., 2017)	Ground truthing: Survey, height measurements 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) Aksoy et al. https://doi.org/10.1109/TGRS.2009.2027702 Hobart et al. https://doi.org/10.3390/rs12101656 Van Vooren et al.

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				https://doi.org/10.1016/j.agee.2017.04.015
Evapo-transpiration (Ecosystem services)	Combined water flux of evaporation from soil, plant and water surfaces as well as transpiration from plants. [mm/m²/time]		Microclimate	Estimated from biophysical parameters derived from Sentinel data with SNAP Toolbox (Pasqualotto et al., 2019) Thermal camera UAV can provide additional information e.g., evapotranspiration (Qwater model, Ellsäßer et al., 2020). Ground truthing of evapotranspiration involves sensors or devices (e.g., lysimeter, LAI meter), effort high. Pasqualotto et al https://doi.org/10.3390/agronomy9100663
Fruit and flower counting (Ecosystem services, Crop productivity)				Very high resolution UAV imagery. Object classification/detection. Convolution Neural Networks Machine vision Chen et al. https://doi.org/10.1109/LRA.2017.2651944 Qureshi et al. https://doi.org/10.1007/s11119-016-9458-5
Above ground biomass (AGB)	[kg/m²] All living biomass above the soil including stem, stump, branches, bark, seeds and foliage (FAO). Usually measured as fresh and dry biomass	Scalable from crop to regional level (but needs calibration)	An important indicator of agro-ecosystems is usually used as a key factor in predicting crop production and estimating water use 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	GT: involves the manual removal of all plant material within a specific crop canopy area (e.g., in wheat usually 1x1m²) 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. Niu et al. 2019 https://doi.org/10.3390/rs11111261 Schirrmann et al., 2016 https://doi.org/10.3390/rs8090706 More sophisticated modelling with crop growth models thinkable (e.g. SAFY) with LAI or crop cover as RS input but many secondary parameters necessary (weather, soil etc.) Song et al. 2020 https://doi.org/10.3390/rs12152378

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			practices [9,10], to research agro-ecosystem processes [11], and to estimate global market risk [12] (see Niu et al. 2019)	
Crop yield (Crop productivity)	(kg/ha);	Farm/ Household	FAO; SGD 2.4.1	Empirical relationships specifically for VI similar AGB, best to include multiple Vis (e.g. with random forest), time series 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 https://doi.org/10.1016/j.rse.2018.06.036 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 https://doi.org/10.1016/j.rse.2019.111599 For upscaling crop type specific information layer needed.
Yield potential (Crop productivity)	Relative measure High yielding and low yielding zones within a field.			Using time-series VI data from satellite imagery to estimate potential yield. https://www.gfz-potsdam.de/en/section/remote-sensing-and-geoinformatics/projects/closed-projects/agrifusion/
Leaf Area Index (LAI) (Crop productivity, Ecosystem Services)	Dimension-less or [m^2/m^2] Total one sided leaf area per unit ground area Scalable from crop to regional level (e.g. with Copernicus data)	Scalable		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 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)

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Leaf chlorophyll content (Cab) (Crop productivity)		Crop canopy level	Cab is strongly related to leaf nitrogen content.	Best estimated with hyperspectral data, but multispectral or even visual index VI good empirical relationships were established. Vegetation biophysical parameter (Cab) can be derived from each Sentinel level 2A product using the ESA-SL2P integrated in the Sentinel-2 SNAP toolbox.
Nitrogen status (Crop productivity)	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
Canopy water content (CWC) (Crop productivity)	g m^{-2} Scalable (validation needed) Refers to the mass of water within the canopy for a unit ground area (Pasqualotto et al., 2018).			GT: Determined with drying biomass or leaves. Calculated by difference dry and wet biomass. Latter can be upscaled with LAI to CWC (e.g. Cernicharo et al. 2013). RS: 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)
Crop Pests (Crop productivity)	Classification / object detection	Field scale	**Pest control**	With remote sensing detection of crop pests (insect, diseases) are mainly indirect and secondary through the damage the pest causes. Due to the effect of crop diseases normally photosynthesis is reduced which have a strong influence on many Vis. From high resolution imagery (UAV), potential disease nests (e.g., formed by stripe rust) can be characterized. The small symptoms however would require a spatial resolution capable of characterizing the within variability of leaves (sub cm – sub – mm). Often, symptoms may derive in the lower part of the canopy (fungal diseases) with no visibility from above.
Methods and methodology description				
Specific methods have been mentioned in the table above. General methodology: 1. <u>Remote sensing systems</u> **UAV copter system: DJI Matrice 300**				

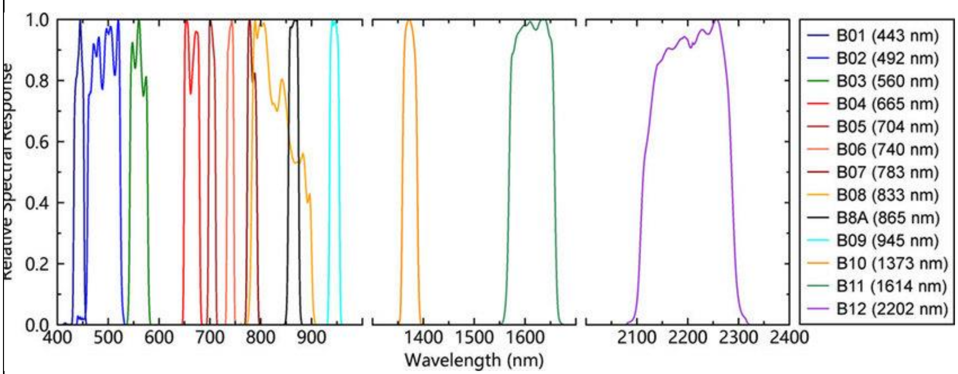
The DJI matrice 300 RTK is a quad copter system of the latest generation.
It has a maximum take off weight of 9 kg (2,7 kg maximum payload weight), with a max speed of 23 m/s. The system is quite robust. It resists wind velocities of up to 15 m/s and is water and dust proof for particles with a diameter larger than 1 mm (IP protection class: IP 45).
Further it comes with powerful batteries, which are sufficient for measurement flights of about 45 min with the aimed sensor payload (Micasense Altum). There is the possibility to connect a second sensor in ground direction if needed.
The GPS RTK system onboard in combination with the vision sensors deliver a sufficient accuracy of ±0.1m vertically and ±0.3m horizontally. As an as is system by DJI it delivers sufficient flexibility for our aimed flight campaigns but is still easy to handle when planning flights.

UAV camera system: Altum
The camera Altum by Micasense combines a Vis (RGB), VisNIR (multispectral) and thermal camera in one system designed for the needs of a UAV platform. It comes with a good price-performance- and weight-performance ratio. For the camera system, a payload of only 400 g needs to be accounted, which is why a long flight duration can be maintained. Further data from the sensors achieved from a combined system should be easier to bring into alignment.
The multispectral/RGB sensor captures the following wavelength

- Blue: 475 nm center, 32 nm bandwidth;
- Green: 560 nm center, 27 nm bandwidth;
- Red: 668 nm center, 16 nm bandwidth;
- Red Edge: 717 nm center, 12 nm bandwidth;
- Near IR: 842 nm center, 57 nm bandwidth

with a ground sample distance of 5.2 cm/pixel at 120 m above ground level (which corresponds to a spatial resolution of about 0.43 cm/pixel at 10 m flight altitude). The thermal infrared sensor takes pictures with : 81 cm/pixel ground sample distance at 120 m above ground level (which corresponds to a resolution of 6.75 cm/pixel at 10 m flight altitude). All bands are captured once every second.

<u>Satellite data: Sentinel 2 imagery</u>



Spectral response curves of spectral bands of Sentinel 2A sensor.
(aus: DOI: 10.1109/JSTARS.2018.2835823)

Spatial resolution: 10 m (B02, B03, B04, B08), 20 m (B05, B06, B07, B08a, B11, B12), 60 m (B01, B09, B10).
Temporal resolution: Revisit time of 5 d at the equator.
Radiometric resolution: 12 bit

Specifically, the RedEdge bands gives the Sentinel 2 system an advantage for crop biophysical variable retrieval.

2. <u>Photogrammetry</u>

Photogrammetry is a method to delineate three dimensional structures from the overlap of two dimensional photographs. In a first step characteristic key points in an image are defined. These are matched over

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different images and their position to each other is compared. From this information the depth of each pixel in the photograph is estimated. In that way a three dimensional structure of the captured area is calculated. Today, the process will be accomplished by structure-from-motion and is capable of calculating thousands of images to generate 3D point clouds or ortho-photos. Even though this methodology offers great analysis potential, especially for the derivation of spatial parameters, the obtained data have a lower resolution than the original photos and there are often data gaps in poorly depicted areas. 3. Spectral indices A spectral index is a function applied to different spectral bands of an imaging sensor to enhance certain spectral features and reduce interfering influences such as shadowing pixel by pixel on an RS image. Most commonly, vegetation indices (VIs) are used to build empirical relations between RS image and vegetation cover, vigour, density or stress. A typical example is the NDVI defined as the normalized difference between the near infrared (NIR) and the red (RED) spectral range reflectance: NDVI = (NIR – RED)/(NIR + RED). 4. Retrieval of biophysical parameters Leaf area index (LAI), chlorophyll content (Cab) and canopy water content (CWC) are examples of vital biophysical parameters for crop growth. Remote sensing provides methods for retrieving those parameters from imagery, including empirical methods such as regression based on VIs as co-variables, physically based models based on inversion with look up tables or machine learning. The SNAP tool box offers the Biophysical Processor, which uses a built in neural network that was trained with the radiative transfer model PROSAIL, to obtain various biophysical parameters from Sentinel 2 imagery (e.g., LAI). 5. Image classification Image classification is the process of assigning all pixels of an RS image into specific classes that describe certain surface features, e.g. land cover, vegetation differences. As input for the classifier serve band values, spectral indices, textural and/or object features. Can be enhanced by using multi-date imagery. Unsupervised classification uses cluster method to find without user defined samples distinguishable classes (e.g., K-means). Supervised classification uses training areas defined by user to find class differentiation (e.g., maximum likelihood classification). Object based classification uses image segmentation and object shape statistics to generate classification. Machine-learning such as random forests and deep learning can be used as a more advanced classifier.
Justification of the methods proposed (sources)
Remote sensing assessment is explicitly mentioned in Task 2.3. However, overall it is a minor part of the SustInAfrica project and methods should be discussed in terms of implementation resources.
Data collection phase(s)
Data base
GIS
Material and team necessary
ATB and Dex Africa are currently organizing the purchase of two UAVs. Sentinel data freely available from Copernicus Expertise of Remote Sensing group, additional input from WP1 and WP3 needed as well as working group Ecosystem Services. Mainly free software: QGIS, Sentinel Application Platform (SNAP), SAGA-GIS, Photogrammetry will be conducted in Agisoft Metashape Higher performance computer tech needed (especially RAM, >100GB) Storage (5TB and higher)
Others (e.g., potential risks, limitations)
Limitations regarding resources and expertise for RS -> should be carefully discussed in RS group -> what is possible and what is only wishful thinking. Assessment can become quite resourceful depending on the spatial coverage, scale and frequency wished. Legal requirements (drone use in countries): especially drone use over populated area might become very complicated as it may needed for full ES assessment of communities.

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The success of monitoring vegetation with remote sensing is strongly depending on the sensor and platform characteristics (e.g., spatial, temporal and spectral resolution, spatial coverage) and external conditions (e.g., size, shape, aggregation, extent of distribution and phenology of individual observed plant/crop species; canopy structural characteristics, etc.). Some limitations for Sentinel 2: - Restricted to clear sky conditions - Spatial resolution (10/20m): Within field variability can be partly discovered only. Monitoring of individual trees or plants impossible. - Sentinel 2 constellation has a revisit time of 5 d at the equator. - Features to be discovered need to be distinct in the reflectance from each other. Limitation UAV Flight duration (Captured area vs. Resolution) Per battery set (at this moment 1 set) a flight duration of about 45 min can be realized. This period can be used for nadir flights with high flight altitudes (e.g. 100 m above ground level). In that way, each photograph captures large areas and the UAV can have a high velocity, while maintaining a good image overlap (e.g. 95%). These campaigns will lack in resolution quality. To enhance the resolution the flight altitude can be minimised (5.2 cm/pixel at 120 m above ground level or about 0.43 cm/pixel at 10 m for the RGB/Multispectral bands; 81 cm/pixel at 120 m above ground level or 6.75 cm/pixel at 10 m for the thermal sensor). Yet, this comes with drawbacks regarding the captured area and other influences may disturb photogrammetry such as movement of plant constituents or increased parallax effect. More sophisticated viewing angles that might enhance the structural data quality, can minimise the captured area.

5. WG Clima

Team involved in the draft
Paul Wagstaff (SHA), Nicola Houlihan (SHA), Nils Borchard (LUKE)
Theme
Suitability of SustinAfrica outputs for current and future climates and resilience to climatic shocks and stresses
Aim and links with the proposal objectives and tasks
The overall goal of *SustInAfrica* is to empower West and North African smallholder farmers and small- and medium-sized enterprises (SMEs) to facilitate sustainable intensification of African farming systems, and to develop and deploy a reference framework on best agricultural practices and technologies, based on a systems approach, and successfully verified for their efficacy to intensify primary production in a self-sufficient, sustainable and resilient manner. Most of the agroecological zones covered by **SustInAfrica** are subhumid, semi-arid or arid and so experience frequent and extended droughts. Traditional farming and pastoral systems in these areas are well-adapted to droughts and all the outputs from **SustInAfrica** must further increase the resilience of farming systems to droughts in order to **intensify primary production in a self-sufficient, sustainable and resilient manner** and contribution to **SDG 13.1: Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries**. WP5 proposes to use the **Climate Smart Agriculture** framework developed by FAO to assess the potential of each output to build resilience to climatic shocks and stresses. FAO defines **Climate-Smart Agriculture** as agricultural practices (FAO CSA Sourcebook 2013) that: 1. Sustainably increase agricultural productivity and incomes (Assets) 2. Adapt and build resilience to climate change (Vulnerability, Adaptation and Resilience) 3. Reduce and/or remove greenhouse gas emissions where possible (Mitigation) **CSA 1 Sustainably increase agricultural productivity and incomes** will be assessed using standard agronomic

and economic metrics which are covered in detail in

CSA 2 Adapt and build resilience to climate change (Vulnerability, Adaptation and Resilience) will be assessed in two stages:
CSA 2.1 Exposure to current and future climate shocks and stresses
SustinAfrica WP5 will use historic temperature and rainfall data and the output of GCMs to predict the climates of the project areas until 2040.

CSA 2.2 Sensitivity to current and future climate shocks and stresses
All crops have optimum temperature and water requirement thresholds, above or below which production declines, and maximum and minimum thresholds, which define the climatic limits of the each crop. These thresholds vary with the crop growth stage, but plants are typically most sensitive during germination, flowering and grain filling. Several crops have critical night-time temperatures and can survive high daytime temperatures as long as the nights remain cool. SustinAfrica WP5 will assess if the optimum and max/min thresholds of each crop are likely to be reached before 2040, which would have a critical impact on the sustainability of primary production.

CSA 3: Reduce and/or remove greenhouse gas emissions where possible (Mitigation)
Assessing **Reduction and/or remove greenhouse gas emissions** is both complicated, controversial and expensive. Though many of the practices tested in SustinAfrica will reduce greenhouse gas emissions and help sequester carbon, most of the farmers in the project have very small carbon footprints compared to farmers in Europe and so should not be expected to focus on reducing greenhouse gas emissions on their farms.

Due to the cost of the analysis required to assess greenhouse gas emissions from crops and livestock WP5 proposes that the third Pillar of CSA should not be directly assessed. Instead this pillar will use indicators proxy indicators developed by:
- **Soil Organic Matter (developed by the Soil Working Group)**
- **Below Ground Biomass (developed by the Cropping Working Group).**

The following crops have been proposed for the project:
Amaranthus sp., Chilli Pepper (Capsicum sp), Lettuce (Lactuca sativa), Yam (Colocasia esculenta and Disocorea sp.), Cowpea (Vigna unguiculata), Soybean (Glycine max), Okra (Abelmoschus esculentus), Eggplant (Solanum melongena), cabbage (Brassica oleracea), Maize (Zea mais), pineapples (Ananas comosus), cotton (Gossypium sp.), groundnut (Arachis hypogaea), tomato (Solanum lycopersicum), Onion (Allium cepa), watermelon (Citrullus lanatus), cassava (Manihot esculenta), Pigeon Pea (Cajanus cajans), Drumstick Tree (Moringa oliefera), hibiscus (Hibiscus sabdariffa), millet (Pennisetum glaucum), clover (Trifolium sp.), wheat (Triticum aestivum), olive (Olea europaea), Fava beans (Vicia faba), Sulla (Hedysarum coronarium).

Indicators/metrics and scales

Indicators	Metrics	Scales (Plot, Farm; Farmer/Household; Community / Landscape, Regional, National)	Authors/ source
FAO CSA Pillar 1: Sustainably increase agricultural productivity and incomes	Crop yield data, Gross margin analysis. Returns to Family Labour	Farm	FAO. 2013. Climate-smart agriculture sourcebook. Rome, Italy: Food and Agriculture Organization of the United Nations (FAO). See Crop Indicator menu

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FAO CSA Pillar 2: Adapt and build resilience to climate change	**Exposure** to climate shocks and Stresses **Sensitivity** to Climate Shocks and Stresses.	Landscape Farm (crop)	FAO. 2013. Climate-smart agriculture sourcebook. Rome, Italy: Food and Agriculture Organization of the United Nations (FAO). Pillar 2 will be assessed using the concepts of **Exposure** and **Sensitivity** from Simpson, Brent M. 2016. Preparing smallholder farm families to adapt to climate change.
CSA2.1 Exposure to current and future climate shocks and Stresses	Assessment of historic trends and future predictions for Changes in rainfall and rainfall patterns and changes in temperature extremes, especially high night-time temperatures in project areas	Landscape	Simpson, Brent M. 2016. Preparing smallholder farm families to adapt to climate change.
CSA2.2 Assessment of the **sensitivity** of research outputs to current and future shocks and stresses	Assessment optimum, maximum and minimum temperature and water requirements for each crop in the project.	Landscape	Simpson, Brent M. 2016. Preparing smallholder farm families to adapt to climate change. Pocket Guide 1: Extension practice for agricultural adaptation. Catholic Relief Services: Baltimore, MD, USA. Crop parameters Alfonso del Rio1 and Brent M. Simpson. *Agricultural Adaptation to Climate Change in The Sahel: a Review of Fifteen Crops Cultivated in the Sahel*. USAID. August 2014. Casas, N. M. (2017). *Crop Weather and Climate Vulnerability Profiles* (1st ed.; P. Wagstaff, ed.). (Option: Crop modelling software like DSSAT if there is interest within SustinAfrica)
FAO CSA Pillar 3: Reduction and/or remove greenhouse gas emissions	Below Ground Biomass Soil Organic Matter Soil Organic Carbon	Plot/ Farm	FAO. 2013. Climate-smart agriculture sourcebook. Rome, Italy: Food and Agriculture Organization of the United Nations (FAO).
Methods and methodology description			

CSA 1: Sustainably increase agricultural productivity and incomes:

Sustainable increases in agricultural productivity will be assessed using the metrics identified by the **WG Crop** (Cropping systems and management). These key metrics are:

Crop Yield

Units: Kg/ha (kg ha^{-1})
There are many definitions of **Crop Yield**, so the exact crop yield measurement will be agreed for each crop. For most crops (cereals and legumes) **Crop Yield** will be the weight of dried and shelled/threshed grain per hectare (**Actual Yield**). For cassava and yams the wet weight of the tubers will be used. Wet weight will also be used for pineapples and vegetables. Groundnuts will be weighted unshelled and a shelling factor applied to avoid damaging the testa and to reduce post-harvest aflatoxin risks. The weight of unstained cotton bolls will be used for cotton. Some experiments may also assess **Attainable Yield**, the yield without the negative effects of yield-reducing factors (especially pests and diseases), limited only by yield defining factors (radiation, temperature,

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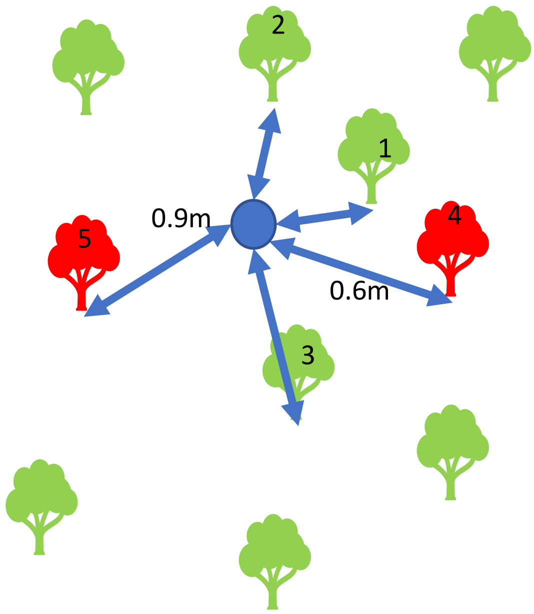
crop phenology, and physiology) and limiting factors (water and soil nutrients) or **Potential Yield,** the yield of a crop free from water and nutrient stress, or damage by pests and diseases. The **Yield Gap** is the difference between the Actual Yield and the Potential Yield.

The most accurate method for smallholder agriculture is to demarcate quadrates in the fields 1-2 months before harvest. Farmers can harvest crops outside the quadrates at any time (green maize harvest for example) to reduce the risk of a negative impact of the research on household food security but the farmers will be asked to refrain from harvesting the quadrates until the researcher is present. Yield measurements based on Farmer recall are inherently erroneous, especially in areas that regularly receive food aid. The errors mainly come from estimates of field size.

The size and number of quadrates will depend on:

- **The size of the field**: for most cereals quadrates will be 10m x 10m however where fields are small the size will have to be reduced to avoid including too much of the farmers crop in the quadrates or placing the quadrates too close to the edge of the field (edge effects).
- **The plant density**: the quadrates should be large enough to contain sufficient plants to achieve the statistical power required for the experiments.
- **The heterogeneity of the field**: Where the field shows significant heterogeneity due to water and nutrient stress more quadrates will be required for each field to capture the variability in crop yields.
- **The resolution of the satellite imagery and GNSS equipment IF the data will be required for remote sensing ground truthing**. With 3m resolution imagery a 5m x 5m quadrate will be far too few pixels (<4) for a reliable analysis of the quadrate, however at 0.30m resolution a 5m x 5m quadrate may be adequate. With a standard hand-held GNSS device without a correction service or smart phone the inherent 2-3m error will make the data from a 5m x 5m quadrat useless for remote sensing and a high precision, corrected, GNSS device will be needed.

For tree crops and cassava the Point to Plant method should be used.



- Place a stick amongst cassava plants that are representative of the crop, i.e. not damaged by wildlife, shaded or already part-harvested.
- Count the five plants nearest to the stick.
- Measure distances from the stick to the 4th and 5th plants (red), in this example 0.6 and 0.9 metres.
- Add distances together and divide by 2= 0.75 metres.

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- Area taken up by 4 plants is $\pi r^2 = 1.76\ m^2$
- Area taken up by one plant is $\pi r^2 /4$ sq m= $0.44\ m^2$
- Number of plants per ha is 10,000/0.44 = 22,635 plants per ha.
- Harvest cassava plants 1,3,5.
- Cut, clean and weight the tubers (wet weight).
- Divide by 3 to get the average weight of tubers per plant.
- Multiply the average weight by the number of plants per ha, in this case 22,635, to get the yield per ha.

A video of how to use Point to Plant for cassava can be found here: https://youtu.be/BJt4g6zHX3c

Land Equivalent Ratio (LER)

Units: ratio

SustinAfrica will test intercropping in many of the field experiments, which complicates the measurement of crop yield per ha. For intercropping and agroforestry the LER will be calculated. LER is the amount of land that would be required to produce the same quantity of crops in an intercropping system that would be produced under a monocropping system. Calculating **LER** will require intercropping trials to include sole crop plots.

LER is calculated as: $\frac{Yield\ per\ ha\ of\ crop\ a\ as\ an\ intercrop}{Yield\ of\ crop\ a\ per\ ha\ as\ a\ sole\ crop} + \frac{Yield\ per\ ha\ of\ crop\ b\ as\ an\ intercrop}{Yield\ of\ crop\ b\ per\ ha\ as\ a\ sole\ crop}$

Where the LER > 1 more land is required to produce the same yields under monocropping than under intercropping, indicating that the crops have a synergistic relationship when intercropped. Where the LER<1 intercropping has depressed the yield of one of the crops.

Yield data will be collected as part of the field experiments, with treatment plots compared to control plots. If the control plot will require no treatment the investigators should consider providing the farmers with an equivalent amount of grain to the grains lost as a consequence of not treating the plot. Baseline data will not be required.

Gross margin analysis

Units: Euro per unit of production for a defined enterprise

Gross Margins for smallholder agricultural enterprises traditionally do not account for family labour, capital expenditure or depreciation and is simply: **Total variable costs per unit of production – total cash revenue per unit of production**.

The field trials will record the area, costs of inputs, labour hours and costs, yield, and the average price for the harvest for each enterprise to calculate the Gross Margins. An electronic tool will be developed to track Costs and Revenues on the tablets.

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	Lira district			
Labor costs	Traditional	Low input	High input	Conservation tillage
Land clearing	56,038	50,038	46,038	40,000
First ploughing	35,600	35,800	35,856	0
Second ploughing	36,167	35,600	38,650	0
Herbicide use	0	5,600	7,450	6,000
Digging holes, add fertilizer and planting	25,000	32,800	33,400	60,000
1st weeding / Spot weeding	52,500	40,250	45,000	45,600
Application of fertilizer	0	0	30,000	0
2nd weeding	0	50,000	50,234	42,500
Pesticide application	0	12,340	24,000	6,000
Harvesting	8,000	12,000	15,600	10,000
Transporting home/ store	6,000	16,000	24,800	7,500
Drying	8,500	12,000	15,000	12,000
Shelling	6,000	9,000	20,800	4,500
Cleaning, sorting Grading, bagging	5,600	11,580	22,460	20,000
Total Labor Cost	**239,405**	**323,008**	**409,288**	**254,100**
Costs of inputs				
Hired land	0	66,900	74,500	73,705
Seed	0	40,000	40,000	43,560
Fertilizers	0	0	254,600	120,000
Herbicides	0	27,840	28,450	25,000
Inorganic insecticides	0	15,600	18,600	15,800
Bags	4,500	10,000	15,640	15,000
Total Input cost	**4,500**	**160,340**	**431,790**	**293,065**
Total Variable cost	**243,905**	**483,348**	**841,078**	**547,165**
Total Yield (TY)	524	956.87	2,456	1,456
Average price (Ug shs/kg)	350	450	450	450
Total Revenue (TR)	183,400	430,592	1,105,200	655,200
Gross margin (TR-TVC)	**-60,505**	**-52,757**	**264,122**	**108,035**
Benefit-cost ratio (TR/TVC)	0.75	0.89	1.31	1.20
Returns to investment based on total cost of production (TVC/TY)	465.47	505.13	342.46	375.80
Marginal returns on investment (Unit price-Unit cost of production)	(115.47)	(55.13)	107.54	74.20

Figure 5: Example of Gross Margin Analysis for maize in Lira District, Uganda, under three production practices per acre per season, showing the metrics that need to be recorded at the field level

Data Collection: the data will be collected as an integral part of each field experiment. No baseline data is required however indicative Gross Margins produced annually by the Ministry of Agricultures Economics Division would be helpful.

Returns to Family Labour

Units: Euro per person-day for a defined enterprise

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This is a measure of the economic returns from investing time and labour in a farm enterprise, record as the net income per person hour (or day). **Returns to Family Labour** enables farm enterprises to be compared based on the amount of labour required and the opportunity costs of time spent on the enterprise. This is critical indictor for smallholder farmers and is important for predicting the adoption of SustInAfrica research output in labour-scarce households. The field trials will record the time spent on field operations by the farmer and her family, disaggregated by gender:

Area under the crop
Person-days required for:
Field clearing
Field preparation: 1st ploughing/ ridging/ mounding
Field preparation: 2nd ploughing
Field preparation: Harrowing
Planting
Fertilizing/ mulching
Gap filling
1st Weeding
2nd weeding
3rd weeding
Top dressing
Irrigation
Rogueing
Earthing-up
Pest control
Bird scaring
Harvesting

Returns to family labour for each enterprise will be calculated as: $\frac{Gross\ Margin\ per\ ha\ for\ a\ defined\ enterprise}{Total\ Persondays\ per\ ha\ for\ a\ defined\ enterprise}$

CSA 2: Adapt and build resilience to climate change:
Pillar 2 will be assessed using the concepts of **Exposure** and **Sensitivity**, as developed by Simpson, Brent M. 2016.

This approach will track **Current tends and use future predictions for r**ainfall, PET, max and minimum day and night temp to determine which crops/ varieties can be grown without irrigation, how yields can be expected to change in the future and the "life expectancy" of SustInAfrica outputs.

CSA 2.1 Exposure to current and future climate shocks and stresses:
Units: N/A
WP5 will analysis the current and future **exposure** for each project AEZ by combining farmers observations of the climate with historic data sources. Future exposure will be based on 20-year predictions (2020-2040) for an ensemble of GCMs, downscaled for the project AEZ. Key sources for climate data include:

- World Bank Climate Portal **https://climateknowledgeportal.worldbank.org/**
- CGIAR CCAFS: Downscaled GCM datasets **http://www.ccafs-climate.org/**; **http://www.ccafs-climate.org/climatewizard/** ; CCAFS Climate Analogues Model
- WorldClim: **https://www.worldclim.org/**
- National Meteorological Databases.
- World Bank Climate Portal https://climateknowledgeportal.worldbank.org/
- CGIAR CCAFS: Downscaled GCM datasets www.ccafs-climate.org/; www.ccafs-climate.org/climatewizard/ ;
- CCAFS Climate Analogues Model
- WorldClim www.worldclim.org/
- FAO Cropping Calendars www.fao.org/agriculture/seed/cropcalendar/welcome.do
- FAO NewLocClim software

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- USAID. Background Paper for the ARCC West Africa Regional Climate Change Vulnerability Assessment February 25, 2013
- USAID Background Paper on The Status and Possible Evolution Of Climate Projections In West Africa October 2013
- National Climate Adaption Plans, e.g. Burkina Faso National Climate Change Adaptation Plan 2015

Farmers observations of climate risks will be collected during the baseline through focus group discussion. The facilitator will assist farmers to draw a seasonal timeline on a flipchart – or even on the sand (which can be photographed at the end of the session). Farmers will be asked to mark on the timeline when each field activity takes place (if drawn on the sand these can be represented by stones, beans, etc.). Using the timeline as a promote the facilitator will ask farmers about when they experience climate shocks (dry spells, floods, hail, high temperatures, etc) and if the farmers have observed any changes or trends in the frequency of these events.

checklist of questions for the facilitators:

Temperature		Rainfall	
Measure	**Insight**	**Measure**	**Insight**
Change in average annual temperature	Are temperatures increasing?	Change in average annual rainfall	Is rainfall increasing or decreasing?
Change in average monthly high temperature	Are days getting hotter and, if so, how quickly?	Change in average monthly rainfall	Is there a shift in when rainfall is occurring durir the year?
Change in average monthly low temperature	Are nights warming and, if so, how quickly?	Change in timing of start of rainy season	Are rains starting soone later?
Change in number of days above high-temperature threshold	Is more of the growing season experiencing critically high temperatures that could affect crop yield?	Change in number of dry spells at the start of rainy season	Are false starts to the growing season increasi
Change in number of days above low-temperature threshold	Are hot nights becoming more common?	Change in length of rainy season	Is the growing season getting longer or shorte
Change in number of extremely-high-temperature days	Are hot days or heat waves becoming more frequent?	Change in amount of rainfall within rainy season	Is the amount of rainfall available during the rain season changing?
		Change in number of days between rainfalls	Are dry spells becoming more frequent and/or longer?
		Change in number of rainfalls above threshold	Is more rainfall being los runoff?

Cropping Calendar

Key crops	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Cotton (irrigated)				■	■	■	■	■				
Vegetables (irrigated)	■	■	■							■	■	■
Maize (rainfed)						■	■	■	■	■		
Beans (rainfed)						■	■	■	■			
Rice (irrigated)				■	■	■	■					

Farmers observations

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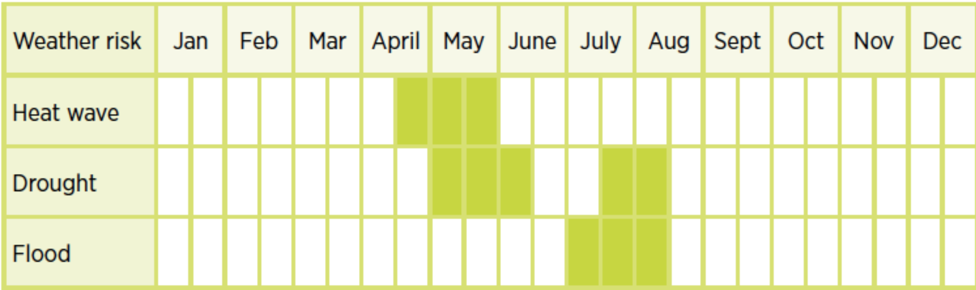
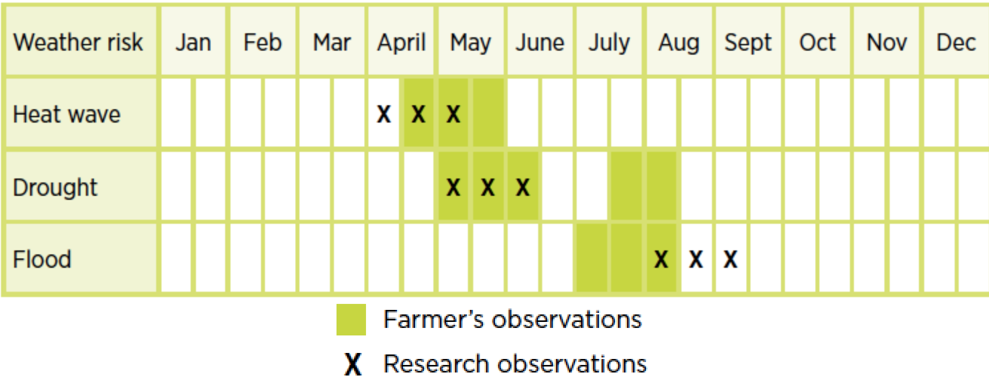


The results of the farmers observations are then combined with formal meteorological data and model predictions:



CSA 2.2 Assessment of the sensitivity of outputs to current and future climate shocks and stresses:
The optimum, maximum and minimum temperature and water requirements for each crop in the project will be assessed from a review of the literature (Casas, 2017). The crop requirements will be assessed against current and future climatic conditions to estimate the suitability of the technologies for future climates. The effects of climate trends on pest and disease risks will also be assessed for each crop. Though less well understood the impact of CO2 levels on the nutritional value of crops will be estimated.

The Sensitivity assessments will take into account Crop Diversity (Crop diversity, Crop rotation, Intercropping, Multi-storey cropping and Agroforestry), and livestock. Crop diversity should, in theory, increase resilience to climate shocks. Farmers can hedge their risks by planting a mixture of varieties and crops. intercropping may ameliorate high temperatures for temperature-sensitive crops and soil functions, and reduce PET but this will depend on the appropriate mixtures of crops and their water requirements. Climate change will impact on Livestock, either directly, though heat stress, or indirectly through changes in disease vector behaviour and changes in fodder species and nutritional value of fodder. Heat stress, water requirements and susceptibility to vector borne disease is largely determine by the breed.

Data on crop temperature and water requirements for Project Crops
Alfonso del Rio1 and Brent M. Simpson. *Agricultural Adaptation to Climate Change in The Sahel: a Review of Fifteen Crops Cultivated in the Sahel*. USAID. August 2014.
Casas, N. M. (2017). *Crop Weather and Climate Vulnerability Profiles* (1st ed.; P. Wagstaff, ed.).

Pest, diseases and vectors
USAID, Climate Change in Mali: Expected Impacts on Pests and Diseases Afflicting Selected Crops, August 2014

CO_2 and nutrition:
Smith, M. R., & Myers, S. S. (2018). Impact of anthropogenic CO2 emissions on global human nutrition. *Nature Climate Change*, *8*(9), 834–839.

CSA 3: Reduction and/or remove greenhouse gas emissions:
As it is unlikely that SustinAfrica can afford to measure gas emissions directly the project will use the proxy indicators:
Underground Biomass, Soil organic matter and soil organic carbon. With the exception of the root and tuber crops the below ground biomass for most of the proposed crops is not harvested and will contribute to soil organic matter if it is not removed during field tillage, which in turn will contribute to soil organic carbon. A proportion of Soil Organic Matter will remain in the soil, acting as a sink for atmospheric carbon. The cultivation practices tested in SustinAfrica will be reviewed for their potential to increase carbon sequestration in the soil.

The protocols for measuring Underground Biomass, Soil organic matter and soil organic carbon are under development by the Cropping WG and Soils WG.

Justification of the methods proposed (sources)

CSA
WP5 proposes to use the **Climate Smart Agriculture** framework developed by FAO. FAO defines **Climate-Smart Agriculture** as agricultural practices (FAO CSA Sourcebook 2013) that:

- • Sustainably increase agricultural productivity and incomes (Assets).
- • Adapt and build resilience to climate change (Vulnerability, Adaptation and Resilience).
- • Reduce and/or remove greenhouse gas emissions, where possible (Mitigation).

To determine if the outputs solutions are Climate Smart, WP5 will review the outputs against FAOs definition of Climate Smart Agriculture. WP5 acknowledges that there is ideological disagreement over the use of the term **Climate Smart Agriculture** (Pimbert, 2015, CIDSE 2014) however the FAO definition of CSA is clear and succinct and so is ideal for screening the SustInAfrica outputs. It should also be noted that there is very little disagreement between those for and against CSA over which agricultural interventions are appropriate for increasing resilience to climate shocks and stresses.

FAO CSA Pillar 1: Sustainably increase agricultural productivity and incomes
This will be measured through standard indicators that are familiar to all agronomists and extension workers. Crop yield, Gross margin analysis, Returns to Family Labour. SustinAfrica, through the Cropping WG will agree on which Crop Yield to use: actual yield, attainable yield, potential yield, and the specific protocols for measuring the yield of each crop. Where ever possible the yield measurement protocols should be in-line with industry and national standards to reflect the value of the yield as a safe and nutritious food crop or a source of income. For example, cotton yields should be calculated based on the grade of bolls (fibre length, uniformity, strength, micronaire, color, trash).

CSA 2: Adapt and build resilience to climate change
SHA has been working with Brent Simpson to further develop the approach initially developed for CRS (Simpson, Brent M. 2016. Preparing smallholder farm families to adapt to climate change). CRS's approach combines farmers knowledge with formal meteorological data and the predictions of CGMs to assess Exposure to current and future climate shocks and stresses and the sensitivity of outputs to current and future climate shocks and stresses.

Clearly crop modelling using software like DSSAT (https://dssat.net/) with met data and CGM model outputs would produce more specific recommendations and could be considered as an additional research project for a MSc student. SustinAfrica WP4 could consider running a DSSAT training workshop for partners if there is enough interest.

FAO CSA Pillar 3: Reduction and/or remove greenhouse gas emissions.
Measuring greenhouse gas emissions and sequestration is expensive – and almost a separate research project. Unless any of the partners have a specific research interest in greenhouse gas emissions and sequestration, and access to approprtaiet equipment WP5 proposes to use proxy "cost effective" indicators that will be used across several research domains

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Data collection phase(s)
FAO CSA Pillar 1: Sustainably increase agricultural productivity and incomes Crop yields: collected for each experiment at the end of each crop cycle for each treatment and control. Gross margin analysis: data collected during the cropping cycle for each experiment and control. Returns to Family Labour: data collected during the cropping cycle for each experiment and control. **CSA 2: Adapt and build resilience to climate change** **CSA 2.1 Exposure to current and future climate shocks and stresses:** **Farmers observations:** these should be collected through Participatory Rural Appraisal (PRA) sessions with the farmers. These sessions are probably best held during quiet periods in the growing season or during the dry season (unless farmers migrate in search of off-farm employment in the dry season). **Meteorological Data:** Access to national meteorological data is uneven, with some countries providing the data free online while others requiring permission from the Director of Meteorology to release the data, and a fee may be charged. Partners will be requested to use their contacts to obtain the required data. **CSA 2.2 Assessment of the sensitivity of outputs to current and future climate shocks and stresses:** This does not require field data collection. **FAO CSA 3: Reduction and/or remove greenhouse gas emissions.** The data for Below Ground Biomass, Soil Organic Matter and Soil Organic Carbon will collected for each experiment at the beginning and end of each crop cycle for each treatment and control.
Data base
Material and team necessary
Others (e.g., potential risks, limitations)

6. WG Nutre

Team involved in the draft			
Mary Corbett (SHA), Yacouba Bologo (SHA), Nicola Houlihan (SHA)			
Theme			
Health and Nutrition			
Aim and links with the proposal objectives and tasks			
SustinAfrica is not designed as a nutrition project, or even as a Nutrition Sensitive Agriculture project (Agriculture to Nutrition Project, A2N), however the outputs of the project should ideally improve the nutritional status of women and children or, at the very least **Do No Harm**, i.e., not undermine international efforts to improve nutrition enshrined in **SDG 2: Zero Hunger**.			
Indicators/metrics and scales			
Indicators	**Metrics**	**Scales** (Farm; Farmer/ Household; Community / Landscape, Regional, National)	**Authors/ source**

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Minimum Dietary Diversity for Women (MDDW)	Individual women in a Household, community of reproductive age 15-49years – a recall of what was eaten in the previous 24hrs and then this is calculated in terms of food groups consumed.	The metric measures the number of food groups consumed by women of reproductive age, 15-49 years, in the past 24 hours. There are 10 standard food groups and a score of at least 5 food groups is required for a minimum acceptable diet	FAO/USAID
Household Food Consumption Score (HFCS)	FCS gives different levels of dietary diversity at Household level Score • <20 poor diversity • 21-34 – borderline • 25-49 – acceptable • 50+ - good dietary diversity	A seven day recall of foods from the different food groups eaten in the Household in the previous week. The food groups are weighted depending on their nutritional value. The score indicates whether dietary diversity is poor, borderline, adequate or adequate +	Adapted from the WFP FCS
Stunting rates	• Percentage of stunting levels in the community in children <5years – normally random selection -clusters	Stunting is measured in children 0-59months using height for age metrics. There are international cut-offs of acceptable levels of stunting- in country stunting levels of 20-30% considered high and levels .30% very high - available through the National DHS (Demographic Health Surveys and UNICEF country profiles	WHO/UNICEF
Severe Acute Malnutrition (SAM) and Global Acute Malnutrition (GAM) Rates	Children 0-59months weight and height measurements together with mid upper arm circumference (MUAC) • Levels of SAM • Levels of MAM • Levels of GAM	Measured in children <5years in general -standard. Through health systems in clinics and can be done nationally through the DHS and UNICEF country surveys. May be collected in emergency settings where there are high levels of food insecurity/volatility	WHO/UNICEF standards
Food calendars/ seasonal availability	Community groups and focus groups Identify which foods are available within each food group throughout the year and if there are gaps where food is not available within some food groups	Community – Focus group discussions, verify through markets etc. – get understanding of what foods available in different seasons especially perishable foods – help in deciding how to address seasonal gaps in dietary diversity	Bioversity International /CIAT and CGIAR
Micronutrient deficiencies/ hidden hunger	Micro-nutrient studies done at local or national level – once off. Some micro-nutrient data collected during regular Country DHS studies. Invasive and can be costly, needs laboratory for results	UNICEF studies Specific groups within the community • Pregnant/lactating women • School age children • Children 0-59mths **19.** (anaemia in certain groups within population)	WHO

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Food production at household level	•Holding size •Farming System Analysis •Land area •Harvested Yield, Yield Gap •Livestock productivity •Crop diversity.	Household and community level	
Food safety	• Farming System Analysis • Yield quality • Storage • Water: Heavy metals, fluorine & Microbial contamination	Household and community level, could be a production level also	
Agricultural Income and Food expenditure		Household	
Methods and methodology description			

MDDW: The data will be disaggregated by Farming System and will be measured during the baseline and periodically throughout the programme and cross checked with secondary data from UNICEF and DHS. Seasonality needs to be factored in – food availability may vary in different seasons. Analysis needs to compare data from the same seasons year on year to see if change and also between seasons. The data is a 24hr recall of what was consumed in the previous day and is based on 10 standard food groups. The person needs to have consumed at least 5 out of the 10 standard food groups in the previous 24hrs to have a minimum acceptable diet. The groups include 1) Grains, white roots, tubers and plantains 2) Pulses (beans, pes, lentils) 3) Nuts and seeds 4) Dairy 5) Meat, poultry and fish 6) Eggs 7) Dark green leafy vegetables, 8) Other vitamin A rich fruit and vegetables 9) Other fruit and 10) Other vegetables.

HFCS: Household data will be collected at the baseline and then seasonally using SHAs digital tool, which is based on a WFP food consumption score card. This data will give an understanding of what the household dietary diversity was, prior to start of the intervention period and how dietary diversity changes with seasons and over time of intervention.

Stunting rates: WP5 will not collect data but will review secondary data to build a picture of risks within the farming systems, disaggregated by AEZ/ farming system from UNICEF and DHS.

SAM and GAM Rates: SustInAfrica does not propose to collect anthropometric data but rely on secondary data to build a picture of risks within the farming systems from UNICEF and DHS.

Food calendars/ seasonal availability: The survey will be conducted during the baseline using SHAs digital tool. Bioversity International and others have developed a methodology guideline on the process of conducting a Seasonal food availability study within a community.

Micronutrient deficiencies/ hidden hunger: Secondary data collection using IFPRI's Global Hunger Index, research from UNICEF and DHS.

Food production at household level:

Food safety: This will be a desk study based on the Farming Systems Analysis and secondary data.

Yield Quality: These are parameters that the SustinAfrica investigators routinely measure and, with the possible exception, of aflatoxin testing equipment, own the required equipment (grain spears, moisture meters, hand lenses). These should be national or international standards: Ghana National Bureau of Standards, World Food Program, IFOAM, etc.

Food storage: The baseline will assess current storage facilities and track the quality of the crop harvested against national, international and trade standards, like the WFP standards. Food storage will be assessed using the WP1 & WP3 metric **Water quality:** WP5 will conduct a literature review to identify risks in the project areas and conduct interviews with key staff of National Geology/ Mineral Resources/ Water Depts. Water samples will be tested for arsenic and other heavy metals using WHO testing protocol. **Water sources:** biological tests, Chemical contamination (heavy metals, fluoride) WP5 does not intend to conduct water testing of all water sources but will use water sources types as a proxy Indication of exposure to water borne diseases that can impact on nutrition. Agricultural Income and Food expenditure: Will the technology increase income sufficiently to enable households to buy foods from the market to diversify diets and purchase foods not available locally? This will be assessed from the **Gross Margin Analysis**.
Justification of the methods proposed (sources)
MDDW: (minimum dietary diversity for women) This metric (previously known as the Women's Dietary Diversity Score, WDDS) was developed by FAO/USAID to measure impact of interventions from a nutrition perspective. The metric measures the number of food groups consumed by women of reproductive age, 15-49 years, in the past 24 hours. As the timeframe is short dietary recall is very accurate. Changes in WDDS is generally reflective in changes in diet in the household. It can also look at different age groups such as adolescent nutrition and other age groups if of specific interest. There is a standard of 10 food groups and for minimum dietary diversity the recall needs to include at least consumption of five of these food groups in the previous 24hrs. The list of food groups above is what has been developed as the standard food group as it has a stronger relationship to micronutrient adequacy compared to other food groupings (Martin-Preval et al.,2015) **HFCS:** WP5 proposes to use SHAs adaptation of the standard WFP score based on 7-day recall of 7 weighted food groups: Starch staples, pulses, vegetables, fruit, fats, sugars, meat/fish/eggs, and milk/dairy. The sum of the weighted food group values is the HFCS. More nutritious foods high in protein get a higher score and increases the food consumption score. There are different categories of scoring: borderline Poor dietary diversity score = 0-21, Borderline 22-34 Borderline and a score of 35 is required for a minimum acceptable diversified diet. SHA has introduced an extra category of a dietary diversity score of 50+ which nis considered a acceptable + score and what would be ideally more acceptable as a diverse diet. **Stunting rates:** Stunting rates, measured as **Height for Age scores** is the standard international indicators of long-term malnutrition caused by inadequate diet and feeding practices, poor sanitation, micronutrient deficiencies, unsafe food, presence of nutrition inhibitors in the diet, repeated gastro-intestinal infections and high parasite burdens. Stunting rates are described as Z-scores. Following recent research new prevalence thresholds have been agreed in terms of the level of stunting within the under five population as low, medium, high and very high(de Onis et al., 2019). **SAM and GAM Rates**: Acute malnutrition is an indicator of short-term acute deficiencies in food intake and or acute illness and is measured using Weight and Height -calculation weight for height against international standards. Mid Upper Arm Circumference (MUAC) is also a measurement for acute malnutrition and a low MUAC is a strong predictor of increased risk of mortality. MUAC is conducted in children 1-5years and there are international standard cut-offs in terms of SAM and MAM. **Food calendars/ seasonal availability:** The seasonal food availability calendar will identify what foods from each food group are available throughout the year. It can be a combination of what is produced, processed and purchased from local markets. The results from the seasonal food calendar can identify when there are food gaps (lean/ hunger season) especially looking at access to perishable goods such as fruit and vegetables. To maximise impact on nutrition SustInAfrica outputs should increase food availability during periods during the year where there are the food gaps within food groups, either through the off-season production of crops or

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through improving the yield and storage of main season crops. Many countries have developed tools to collect data on seasonal food availability(Lochetti & Meldrum G kennedy, 2020).

Micronutrient deficiencies/ hidden hunger: Micronutrient deficiencies in the diet (Iodine, zinc, iron, vitamin A, calcium, selenium) are common in Africa and have a significant impact on maternal and child growth and development. WP5 will identify potential micro-nutrient deficiencies through secondary data available which is geographically (regional/district) and/or country specific using various resource material such as IFPRI's Global Hunger Index, research from UNICEF and DHS. Where crops have particular limiting nutrients this needs to be factored in and understood.

Food production at household level: Crop diversity is a useful proxy indicator for dietary diversity (Kumar et al, 2015).

Food safety: WP5 will identify potential food safety risks in each of the farming systems that may impact on nutrition. The best-known examples are the risk of inhibition of iodine uptake in poorly processed cassava and the high levels of arsenic in rice grown in the Ganges Valley, however other risks involve contamination of the food in the field, during harvesting and during storage by mycotoxins, and biological contamination due to dirty water and unsafe handling.

Yield Quality: The harvests will be assessed against appropriate quality standards as this will provide a standardised indication of quality, marketability and safety. (Ghana National Bureau of Standards, World Food Program, IFOAM, etc.)

Food storage:

Water quality: Some water sources for drinking and irrigation will be tested for biological and chemical contamination as part of the environmental indicators. Arsenic in irrigation and drinking water pumped from shallow wells in the Ganges Valley has created a public health crisis and all donor funded irrigation and potable water 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, causing irreversible damage to teeth and bones. 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. Crypto testing is expensive and E coli testing can be used as a proxy indicator of contamination (Marshak, Young and Radday, 2015).

Data collection phase(s)

MDDW: Baseline and ideally annually at a similar time/season to the baseline – for accuracy in data analysis (comparing like with like)

HFCS: at baseline and seasonally (should be done at least twice per year)

Stunting rates: this data should be taken from secondary sources as available.

SAM and GAM Rates: as above – secondary data as available

Food calendars/ seasonal availability: Baseline to help with decision making process of what to produce and when – depending on seasonal calendar results – mid-line and end line.

Micronutrient deficiencies/ hidden hunger: from secondary data as available

Food production at household level: seasonally and especially at harvest time

Food safety: At harvest time, periodically during storage and during processing depending on the food

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Food storage: Baseline **Water sources: The baseline** will collect data on the type of water sources in the target communities.
Data base
Standardized questionnaires ideally on handheld electronic devices with data cleaned and sent to central platform for analysis etc.
Material and team necessary
Some should be routinely collected by project staff, baselines may be conducted as part of a baseline study, similarly midline and endline surveys may be collected y project team or an external consultant.
Others (e.g., potential risks, limitations)

7. WG Socio-economic

Team involved in the draft
Idalina Dias Sardinha (ISEG) **Ana Luz (ISEG)** **Daniela Craveiro(ISEG)** **Rita Queiroga (ISEG)**
Theme
WG Socioeconomic Data collection and analysis of West and North African farming system's cultural, institutional, economic, and policy settings.
Aim and links with the proposal objectives and tasks
To reach SustInAfrica's main aims, all relevant issues specific to each AEZ in the 5 countries are to be studied, mapped, and analysed, in order to ensure *context-specific and demand-driven* interventions. To do so, WP1 conducts a **baseline analysis & monitoring system's design** of West & North African farming systems, by: - collecting baseline data/information of targeted agro-food systems to characterise AEZ's farming systems, ecological, socio-economic, cultural and political former and current states related to specifically their agro-ecological features and determinants - conducting stakeholder mapping of agro-food sector of targeted AEZ and African regions - identifying interrelations between agricultural sector, social system, and norms (e.g., role of women and youth), public policy (policy support/barriers), and private sector (value and supply chains) WP1 T1.1.a instructs us to conduct a systematic literature review on diagnosis and evaluation methods and tools specific and adequate for farming systems and their agro-ecological, socio-economic and institutional environments, with special attention to W. and N. Africa, and specific needs of WPs 2 to 5. A **set of criteria/indicators and appropriateness to the specific needs of each WP of SustInAfrica will be the base of selection of the analytical methods to data collection and evaluation, resulting from the literature's review** from databases ISI Web of Science, Scopus, and key institutional international sources (grey literature) all concerned with *sustainable intensification agriculture* (SIA). Additional literature analysis on local, regional and specified matters, selected by local partners has to be further integrated. To support this process, partners were divided regarding their expertise in thematic working groups (WG) to propose the most appropriate methodologies and indicators. **WG Socioecon** concerns the **socio-economic, cultural and political characterization of the AEZ**. To assess the data required for the assessment of these domains, a systematic literature review protocol was set (details in ***the Justification of the methods proposed section***).

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The first finding from this systematic literature review is that there are striking low levels of consistency in addressing the topic across SIA literature.
Due to the state of the art, the **WG Socioecon** is therefore preparing a multi-step indicator selection process relying first on critical assessment of indicators, drawn from the literature, and then expert consultation.

The indicators below, and metrics presented when available, were extracted from the consulted scientific and grey literature. Their designations resulted from the need to aggregate the findings and are not final, as the systematization of the information extracted is in process of validation.
Some themes identified under the socio, economic, and political domains refer directly to "physical" farming system analysis (farming system features and practices, agricultural production and productivity, resource efficiency), and therefore are not addressed in detail since the selection of these indicators and metrics should respond to other WGs criteria and data requirements (a note in Author/source column signals these cases).

Sub-theme / Indicators	Metrics	Scales (Farm; Farmer/ Household; Community / Landscape, Regional, National)	Authors/ source
Household (HH) structure			
HH head		HH	*First selection from literature review*
HH size & composition		HH	*First selection from literature review*
HH members ages		HH	*First selection from literature review*
Education	. level of the household head . level of all members	HH	*First selection from literature review*
Access to sanitation facilities		HH	*First selection from literature review*
Housing quality		HH	*First selection from literature review*
HH vulnerability		HH	*First selection from literature review*
Farming experience	. number of years spent on farming	HH	*First selection from literature review*
Community infrastructure access	. church, community centre, school, health centre, etc	COMMUNITY	*First selection from literature review*
Farm & practices characteristics		FARM FIELD, HH	***WG Crops***
Cultural			
Recreational, spiritual/cultural, sacred grounds, natural heritage **[Some are cultural ES: WG ES]**	. Perceptions . Number of sacred grounds . Recreational value of the SES . Number of cultural events . Income from recreation and tourism ($ year -1) . Sports and leisure	FARMER, HH, COMMUNITY	*First selection from literature review* ***+ WG ES***
Human-environment connections		FARMER, HH	*First selection from literature review*
Value system towards food, crop & environment	. Farmers' preferences . Cooking characteristics and landraces passed over generations together with recipes . Satisfaction of knowing that a specific or ecosystems exists . Satisfaction of knowing that future generations will have access to nature benefits . Attitudes towards climate change	FARMER, HH	*First selection from literature review*

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Traditional ecological knowledge	. Local knowledge . Intergenerational continuity in agriculture	FARMER, HH	*First selection from literature review* ***+ WG Crops***
Marriage and dowry culture		HH	*First selection from literature review*
Succession plan	. Egalitarian base partible inheritance principles	HH	*First selection from literature review*
Knowledge & Information access			
Information access	. Access to extension services . Connectivity to farmer knowledge network . % farmers receiving agricultural information from other farmers	HH, COMMUNITY	*First selection from literature review*
Knowledge integration	. Use of farmers' criteria for evaluation of SI efforts . % farmers reporting knowledge of an SI practice . Test on SI practices	FARMER, HH, COMMUNITY	*First selection from literature review*
Training		FARMER, HH, COMMUNITY	*First selection from literature review*
Research participation		FARMER, HH, COMMUNITY	*First selection from literature review*
Collective action			
Group membership & engagement	. # groups member and level activity . frequency (and presence of collective action) . number of times HH members interacted with private or public research institutions during the last 12 months	FARMER, HH	*First selection from literature review*
Social movements & groups	. #, type and functions of groups	COMMUNITY	*First selection from literature review*
Trust and cooperation	. Level of trust in the community . Level of involvement in communal activities	COMMUNITY	*First selection from literature review*
Conflicts	. Incidence of conflicts related to collective action . Effectiveness of conflict resolution measures	HH, COMMUNITY	*First selection from literature review*
Collective Resilience	. Risk sharing . Farmers and consumers can organize into grassroots networks and institutions, such as coops, farmer's markets, community sustainability associations, community gardens, and advisory networks	COMMUNITY	*First selection from literature review*
Technology			
Farmer preference	. Evaluation of agricultural technologies based on farmers' criteria . Attitudes towards technology . Multi-category scoring of technology . % farmers favouring a technology	FARMER, COMMUNITY	*First selection from literature review*
Openness to innovation	. ordinal scale (1–7)	FARMER, COMMUNITY	*First selection from literature review*
Number of technologies promoted	. count	FARMER, COMMUNITY	*First selection from literature review*

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Number of technologies tested	. count	FARMER, COMMUNITY	*First selection from literature review*
Equity / gender			
[Women] Empowerment	. Women's Empowerment in Agriculture Index . Attitudes towards empowerment . Women's literacy and empowerment	HH, COMMUNITY	*First selection from literature review*
Agency / leadership roles / distribution of tasks	. Time allocation by gender . Variability and distributions resources, agency, and achievements . Distribution of labour between men and women . Distribution of tasks across members of the family . Level of mutual decision making . Differences in social network connectivity	FIELD FARM, HH, COMMUNITY	*First selection from literature review*
Access to resources (land and livestock ownership)		FIELD FARM, HH	*First selection from literature review*
Access to information	. Women's access to agricultural information	FIELD FARM, HH, COMMUNITY	*First selection from literature review*
Achievements (income, wealth, nutrition, food security, health, well-being)	. By gender	FIELD FARM, HH	*First selection from literature review*
Cross-cutting / technologies	. Rating of technologies by gender	FIELD FARM, HH, COMMUNITY	*First selection from literature review*
Market participation by gender		FIELD FARM, HH	*First selection from literature review*
Equity / youth			
Creation and distribution of income on the farm	. Revaluation of agricultural activities . Inter-generational	FARM	*First selection from literature review*
Employment / activity	. % of young people working in the agricultural production of the system assessed . % of young people in education or training . % of young people working outside but currently living in the system assessed . % of young people not in education, nor working in agricultural nor in other activities	FARM	*First selection from literature review*
Emigration	. % of young people who want to continue the agricultural activity of their parents . % of young people who would emigrate, if they had the chance . % of young people who already left the community for lack of opportunities		*First selection from literature review*
Economic capital			

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Capital/credit access	. Availability of capital . Farmer report access to credit . % of households reporting access to credit . Existence of reliable allowance for borrowing	HH	*First selection from literature review*
Financial balance	. Financial support . Whether the household has financial savings . Evolution of trading accounts . Liquidity . Stability . Savings	HH	*First selection from literature review*
Assets	. Number of productive assets owned . Asset index . Existence of accumulated non-financial savings . Cars and trucks value in local country currency . Infrastructure age . Total value of infrastructure	HH	*First selection from literature review*
Land	. Economic valuation of land . Land area . Area of private land accessible . Land holdings	HH	*First selection from literature review*
Debt	. Debt	HH	*First selection from literature review*
Wealth	. Asset wealth categorization . Attitudes towards wealth . Proxies of user wealth . Food stores	HH	*First selection from literature review*
Labour			
Labour requirement	. Employment needs . Farmer rating of labour . Jobs created . Labour requirement (hours). . Labour requirement (hours/ha)	FIELD	*First selection from literature review*
Labour productivity	. Income per unpaid labour unit EUR/labour unit . Profit/person day of labour . $ product / person day . kg product / person day . Replacement of labour by technology	FIELD	*First selection from literature review*
Labour conditions	. Working time . Workload	HH	*First selection from literature review*
Management and workflow		HH	
Market orientation			

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Market access	. Degree of market access for selling . Whether products were sold and which types . Whether items are sold/ traded directly to producers . Whether items are bought/ traded directly from producers . Distance to nearest market . Travel time to market . Walking distance to main markets	HH	*First selection from literature review*
Sales	. Output derived From the market % . Total sales . Proportion sold	HH	*First selection from literature review*
Market orientation	. Market orientation index . Marketing	HH	*First selection from literature review*
Profitability			
Economic returns	.Income per hectare and per worker, added value per ha and per worker . Market based gross margin per hectare EUR/hectare . Profit/unit area/unit of labour used . Monetary value of output/input used . Profit . Profitable farm income	*HH, FIELD*	*First selection from literature review* + ***WG Nutri.*** ***WG Inno.*** ***WG Crops.***
Crop value	. Farm output value per person . Value of the yield of agricultural product . Farm output value per hectare (in local currency and converted to PPP$. Crop economic value USD/ha·yr . $ product/ha	*HH, FIELD*	*First selection from literature review* + ***WG Nutri.*** ***WG Inno.*** ***WG Crops.***
Net income	. Net income from farming . Net income +rents +taxes +interests – subsidies . Net income (total net income for all farm activities) . Net income ($/crop/ha/season)	*HH, FIELD*	*First selection from literature review* + ***WG Nutri.*** ***WG Inno.*** ***WG Crops.***
Gross margin	.	*HH, FIELD*	*First selection from literature review* + ***WG Nutri.*** ***WG Inno.*** ***WG Crops.***
Benefit / cost ratio	.	*HH, FIELD*	*First selection from literature review* + ***WG Nutri.*** ***WG Inno.*** ***WG Crops.***

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Value chains	.	*HH, FIELD*	*First selection from literature review* + ***WG Nutri.*** ***WG Inno.*** ***WG Crops.***
Economic resilience			
Living wage	. Income level against poverty threshold (total household income/ country poverty threshold) . Likelihood above $1.90 poverty line . Farmer welfare	HH	*First selection from literature review*
Autonomy	. Independence from CAP	HH	*First selection from literature review*
Insurance	. Whether livestock and crops are protected by insurance . Crop insurance system	HH	*First selection from literature review*
Losses to disaster		HH	*First selection from literature review*
Number of non-economic failures		HH	*First selection from literature review*
Probability of low profitability	. Probability that income>expenses . Probability of low profitability	HH	*First selection from literature review*
Economic viability	. Farm is economically viable	HH	*First selection from literature review*
Income stability		HH	*First selection from literature review*
Income			
Income	. $ product - $ expenses . Outputs - inputs - operating expenses – depreciation + other income . Crop income . Farm income . Household income . Disposable income	HH	*First selection from literature review* ***WG Nutri.*** ***WG Inno.*** ***WG Crops***
Income distribution		HH	
Income diversification	. Coefficient of variability of net income. . The trade volume of medicinal species ($ ha -1) . Quantity of raw materials harvested (kg ha -1 year -1) . Quantity of products prepared (quantity year -1) . Income from pottery and handicrafts ($ year -1) . Off farm income (USD/hh/yr) . Contribution of off-farm income to total household income	HH	*First selection from literature review*
Household expenditures	. Distribution of household expenditure among food groups . Household consumption . Per capita expenditure . Major costs to the household	HH	*First selection from literature review*
Economic context			

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Living conditions	. Cost of living index (COLI) related to food expenditures: cereals, fruit, vegetables, fish and meat . Income per capita . Per capita hh consumption expenditure . Poverty headcount ratio . Salaries	NATIONAL; REGIONAL	*First selection from literature review*
Prices	. Whether selling prices are too high, too low, stable or unpredictable . Output prices . Input prices . Crop price flutuations	NATIONAL; REGIONAL	*First selection from literature review*
Consumer characteristics	. Consumer characteristics . Consumer standards	NATIONAL; REGIONAL	*First selection from literature review*
Labour availability		NATIONAL; REGIONAL	*First selection from literature review*
Agriculture expansion	. Agricultural competitiveness . Agricultural employment; contribution to regional or national GDP . Gross domestic product in agriculture . Agricultural Intensification . Regional mean income from agriculture . National mean income from agriculture	NATIONAL; REGIONAL	*First selection from literature review*
Energy sources	. Lack of alternative energy sources . Feed conversion efficiency	NATIONAL; REGIONAL	*First selection from literature review*
Food supply/demand		NATIONAL; REGIONAL	*First selection from literature review*
Transportation	. Number of routes, passengers and boats	NATIONAL; REGIONAL	*First selection from literature review*
Demography	. Population density . Population growth	NATIONAL; REGIONAL	*First selection from literature review*
Farmland scarcity		NATIONAL; REGIONAL	*First selection from literature review*
Livelihood strategies		NATIONAL; REGIONAL	*First selection from literature review*
Efficiency			***WG Inno.*** ***WG Crops***
Intensification			***WG Inno.*** ***WG Crops***
Input costs			***WG Inno.*** ***WG Crops***
Farming productivity			***WG Inno.*** ***WG Crops***
Community Structure			
Key governance mechanisms	Democratic or traditional institutions	COMMUNITY	*First selection from literature review*
Key socio-economic infrastructure	Public services	COMMUNITY	*First selection from literature review*

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Governance and social equity	. Rights in relation to land/water and other natural resource management . Community-based landscape/seascape governance . Social capital in the form of cooperation across the landscapes	COMMUNITY	*First selection from literature review*
Land tenure	. Customary tenure system . Existence of formal document and presence of name on it . Existence of legal recognition of access to land (mobility for pastoralists) . Existence of the right to sell, bequeath, and inherit land, always disaggregated by gender . Perception of security of access to land	COMMUNITY	*First selection from literature review*
Inheritance local practices	Egalitarian base partible inheritance principles; Inherent rights protection	COMMUNITY	*First selection from literature review*
Governance Policy			
Government support programmes	. Agricultural subsidies . Subsidies & taxes to encourage SI practices . Removal of subsidies to encourage SI practices . Financial Incentives (taxes, payments and subsidies, trading schemes) . Supporting access to equipment and other inputs . Payment for environmental services . SDGs	NATIONAL; REGIONAL	*First selection from literature review*
Regulatory environment	. Land tenure . Farming practices . Seeds . Air quality . Crop protection chemicals . Water quality . Territorial development . Grouped resettlements programs . Agricultural advisory services . Infrastructures development projects and urbanization . Corporate social responsibility . Fair and green policies	NATIONAL; REGIONAL	*First selection from literature review*

Methods and methodology description
Overall, it is expected that part of data collection will rely on **secondary data (from international, national & regional data sets and reports)**, and from **primary data** collected through **interviews, surveys and community discussion groups**. However, *the final data collection methodologies need further work.*
Justification of the methods proposed (sources)
To ensure a comprehensive understanding of the options available for the assessment of SIA socio-economic domains, we opted to perform a **systematic literature review targeting peer-reviewed papers** and **grey literature** on monitoring social, economic, and institutional dimensions regarding sustainable intensification agriculture. Although we have not detailed the methodologies to collect date, the description bellow of the

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literature review was essential to identify indicators.

As protocolled, the review is based on a set of keywords. The keywords selection process was informed by a preliminary consultation of the literature on SIA concept (e.g. Jain et al. 2020; Vanlauwe et al. 2019; Jiao et al. 2019; Dawson et al. 2019; Taveira et al. 2019; Franke et al. 2018; Weltin et al. 2018; Grassini et al. 2017; Mahon et al. 2017; Sims & Kienzle 2015; Vanlauwe et al. 2014; Charles et al. 2014; Tittonet & Giller 2013; Rudel, 2020; Nassary et al. 2020; Xie et al. 2019; Thomson et al. 2019; Jayne et al 2019; Pretty, 2018; Liao & Brown, 2018; Struik & Kuyper, 2017; Smith et al. 2017; Wezel et al. 2015; Prett & Bharucha 2014; Tittonell, 2014; Flavell, 2010) that advised to:

(1) include different formulations for the "sustainable intensification agriculture" term, since there are other close conceptual terms (such ecological/agroecological/sustainable)
(2) include different formulations for the "assessment" term, since there are multiple methodological approaches
(3) include different formulations concerning the "socio-economic" domain, since there is not a consist term for it across the literature (socio, social, cultural, political)

The preliminary literature review also supported the definition on the criteria of inclusion and exclusion of the papers in the revision concerning: (1) the time limitation (from 1997, when the term SIA is first published); (2) the publications type (only revisions, given the high level of systematization of the literature). Additionally, according with the team available language skills, only papers in English, Spanish and French were considered.

The following keywords were considered:
(sustainab* AND intensification AND agricult*) OR (ecologic* AND intensification AND agricult*) OR (agroecolog* AND agricult*)
AND (method* OR tool* OR indicator* OR assessment OR evaluation OR monitor*)
AND (well-being OR soci* OR econom* OR governance OR policy OR institutional) OR (training OR education) OR innovation).

The strategy to find relevant grey literature was done searching targeted websites of notable international, bilateral and multilateral agencies and organizations identified in the areas of agriculture, development and sustainability. Those included FAO, UNDP, UNESCO, World Bank, African Bank, OCDE, European Union – Africa, Oxfam, USAID, GIZ, USDA National Library, GYGA - Global Yield Gap Atlas and CGIAR - Global Agricultural Research Data Innovation Acceleration Network.
These key websites showed a wide diversity in search functionalities, ranging from a simple search box to an advanced search with filters and additional queries. As such, researchers adapted the search phrase to fit each search engine's options. Indeed, as opposed to the academic database search where one search strategy was used combining all search terms, the grey literature search required creating different search strategies with multiple combinations of the search terms. In some instances, document searches resulted in thousands of hits. In such cases, the first 100 links were searched.

A total of 343 papers were extracted and 86 were selected for information extraction. Additionally, 10 resources were identified as relevant from the grey literature.

Data collection phase(s)

The full set of indicators is to be collected during baseline assessment.
After data analyses and consultation with other WGs, a subset of indicators will be selected to be included as part of the monitoring process and toolbox, as previewed in the WP1 T1.3 (see below), as well as, transferred for the replicability WP when necessary in the replication.

WG Socioecon Time Frame *according to GANTT review at WP1. Structure & Timeline from 23 Oct20*
T1.1.a: Literature review on methodologies and tools (ISEG) – Set20 (M1) to Feb21 (M6)
T1.1.b: Evaluation and co-selection of methodologies and tools (ISEG) – Jan21 (M5) to Jul21 (M11)

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T1.2.d: Baseline data collection and analysis of society, economy, & policy in field (ISEG) – Oct21 (M14) to Ago22 (M24) T1.2.e: Data verification and first assessment (BOKU) – Apr22 (M20) to Dec22 (M28) T1.3: Design long-term monitoring toolbox (ISEG) – Aug 22 (M25) to Aug 24 (M48)
Data base
Most indicators are to be processed in a quantitative form, suitable to be stored in database format (excel, access, or other). Links between different aggregation scales (field, farmer/household, community, society) must be predicted (and properly coded for). Qualitative data is to be processed by the team, and through the process of categorization, part of the information is expected to be integrated into the database (using ordinal scales for example).
Material and team necessary
After the final selection of indicators, data collection instruments are to be developed and pre-tested (**T1.2.e: Verification of collected data and first assessment** (M20–M28)). Data collection material and team requirements include mostly tablets, and enumerators to fulfil the need to interview stakeholders, organizing community groups discussion, do farmers surveys, and the integration of self-report monitoring by farmers (monitoring phase). Qualitative data processing can be made by the team (based on the translation of material collected) or by local partners (e.g., by filling a report form).
Others (e.g., potential risks, limitations)
The broadness of this multi-theme domain (socio, economic, political) advises for the identification of overlaps across working groups data requirements, to ensure data format more suitable to all teams' needs, avoid double efforts and conceptual mismatches.

8. WG Innove

Team involved in the draft
WG Innovation and replicability **[1] Generosa Jenny Calabrese (CIHEAM)** **[2] Andi Mehmeti (CIHEAM)** **[3] Nils Borchard (LUKE)** **[4] Daniela Cravero (ISEG)** **[5] Mladen Todorovic (CIHEAM)** **[6] Hamada Abdelrahman**
Theme
Replicability and Innovation
Aim and links with the proposed objectives and tasks
SustInAfrica will apply multi- and transdisciplinary, participatory, and multi-actor approaches to ensure maximum applicability and replicability of the project beyond its duration. Technologies (e.g. BLUELEAF, InsectaMon, Low-cost assessment tools) that have passed the screening processes and the proof of concept trials will be assessed for replicability to denote the capability of a system for being duplicated within another network, location, or time. Based on an agreed methodological framework, replicability analysis will monitor the implementation of the innovations in the AEZs and systematically define which innovations are sustainable and replicable. It will also identify the main factors that determine effective implementation, enabling partners and project to overcome possible stumbling blocks or constraints to a wider implementation (scaling up or transfer). The analysis is based on the following objectives: a) Define the innovations, the system, contexts, and involved actors. b) Define and quantify measurable indicators to screen replication potential.

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c) Assessing replication potential of new technologies/innovations through an indicator-based framework.

The NEW contests where innovations are transferred will be monitored to check and identify critical/key elements/issues that could hamper in the medium/long term sustainability (social, economic, environmental, governance aspects)
To achieve such objectives an indicator set is proposed and hereafter reported.

Indicators/metrics and scales

Indicators	Metrics	Scales (Farm; Farmer/ Household; Community / Landscape, Regional, National)	Authors/ source
Crop Yield per AEZ	($kg*ha^{-1}$)	Farm; Farmer/ Household	FAO; SGD 2.4.1
Amount of yield losses from pests	($kg*ha^{-1}$)	Farm; Farmer/ Household	CICES v 5.1 - Pest control (including invasive species) - 2.2.3.1
Share of cropland under integrated Pest management	(%)	Farm; Farmer/ Household	
Increase in production from the adoption of NEW agro-ecological practices	(%)	Farm; Farmer/ Household	FAO; SGD 2.4.1
Increase in production from adoption innovations	(%)	Farm; Farmer/ Household	FAO; SGD 2.4.1
Water use efficiency (WUE) – Crop yield per unit of water supplied	kg/m^3	Farm; AEZ	CICES v 5.1 4.2.1.2; Abi Saab et al. (2019)
Water Productivity (WP)	kg/m^3	Farm; AEZ	CICES v 5.1 4.2.1.2; Abi Saab et al. (2019)
Change in water-use efficiency (and water productivity) over time	(%)	Farm; AEZ	FAO; SGD 6.4.1
Level of water stress: Freshwater withdrawal as a proportion of available freshwater resources	(%)	Farm; AEZ	FAO; SGD 6.4.2
Water delivery performance	(%)	Farm; AEZ	Malano, H. M., & Burton, M. (2001). Guidelines for benchmarking performance in the irrigation and drainage sector (No. 5). Food & Agriculture Org..
Annual water supply	(-)	Farm; AEZ	Malano, H. M., & Burton, M. (2001). Guidelines for benchmarking performance in the irrigation and drainage sector (No. 5). Food & Agriculture Org..
Pollutant loadings (fertilizer, manure)	(mg/l)	Farm; AEZ	FAO – Integrated Food Energy system (2014)

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The proportion of agricultural area under productive and sustainable agriculture	(%)	Farm; AEZ	SDG 2.4.1 and
No. of farmers applying NEW practices and innovations	(Numerical value)	AEZ	FAO – Integrated Food Energy system (2014)
Good practices applied on farm to improve resilience	(Numerical value)	AEZ	FAO – Integrated Food Energy system (2014)
Food loss/increment index	($kg*ha^{-1}$)	Farm; AEZ	SDG 12.3.1
Time to recover from production loss (monetary or in terms of weight)	(years)	Farm; Farmer/ Household	FAO – Integrated Food Energy system (2014)
Maximum of yield per average, wet and dry year	($kg*ha^{-1}$)	Farm; Farmer/ Household	FAO – Integrated Food Energy system (2014)
Degree of integrated water resources management implementation	(0–100)	Farm; Farmer/ Household	FAO; SGD 6.5.1
Proportion of youth and adults with information and communications technology (ICT) skills, by type of skill	(%)	Farm; Farmer/ Household/ Community	FAO; SGD 4.4.1
Value of production	($/ha, $/farm)	Farm; Farmer/ Household	FAO – Integrated Food Energy system (2014)
Benefit/Cost ratio	(-)	Farm; Farmer/ Household	FAO – Integrated Food Energy system (2014)
Economic viability (the period for return of capital)	(years)	Farm; Farmer/ Household	
% Increase in income of producers from adoption practices and innovations	(% or Local currency/hectare)	Farm; Farmer/ Household	FAO – Integrated Food Energy system (2014)
Managers/ farmers satisfied with agricultural services as a percentage of all managers/farmers	(%)	Farm; Farmer/ Household/ Community	FAO – Integrated Food Energy system (2014)
Day of training provided	(days)	Farm; Farmer/ Household/	FAO – Integrated Food Energy system (2014)

Crop Yield ($kg*ha^{-1}$) per crop per AEZ - It is the **average** production achieved per crop in each AEZ. This is very basic information and it is needed to assess the productivity of agricultural areas in the AEZs and to have a benchmark for any future improvement induced by the project actions. The definition of crop yield refers to the definition of actual yield, that is consistent in the most important literature on crop losses, and so is also accepted in this research: the actual yield is the site-specific yield achieved using the available resources and current practices (labor and inputs) of the farmer, generally affected by pests and diseases (Nutter et al., 1993; Savary et al., 2006; Savary and Willocquet, 2014). In this research, it is considered that each field crop has its actual yield.

Amount of yield losses from pests ($kg*ha^{-1}$) (per crop and AEZ) - The indicator can be used to characterise farms and AEZ. Crop loss is the reduction in quantity and/or quality of the crop yield (yield loss) due to biotic or abiotic factors, which can occur in the field (pre-harvest) or the storage (post-harvest) (Oerke, 2006). Such reductions are also known as crop damage (Savary et al., 2012). For others, crop loss also includes a reduction in value and/or financial returns due to yield loss (Nutter et al., 1993).

Yield loss ($kg*ha^{-1}$) is the quantitative decrease of the crop yield caused by a single injury or by an injury profile. The yield loss is the difference between attainable yield and actual yield and can be expressed in terms

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of weight or volume or as relative yield loss (%) concerning the attainable yield (Nutter et al., 1993; Savary et al., 2006).

Attainable yield (kg*ha^{-1}) is the yield without the negative effects of yield-reducing factors (especially pests and diseases), limited only by yield defining factors (radiation, temperature, crop phenology, and physiology) and limiting factors (water and soil nutrients) (Zadoks and Schein, 1979; Rabbinge, 1993; Savary and Willocquet, 2014). Under this broad definition, we consider attainable yield as the site-specific yield achieved under the environmental conditions of the site and with the best available production techniques to avoid biotic stress caused by pests (Nutter et al., 1993; Oerke et al., 1994). The definitions of attainable yield given by Nutter et al. (1993) and Oerke et al. (1994), have two important similitudes: both consider that attainable yield is site-specific and is achieved with the local production techniques, and both consider that it should be achieved in absence of pests. These definitions are considered the most suitable for the approaches and objectives of our project and of the innovations we are proposing that include BlueLeaf and InsectaMon. An attainable yield can involve high costs to control any pest or disease, and thus, would not be always the best economic yield; that is why this yield is considered to be theoretically independent of economic factors (Avelino et al., 2011). Therefore other indicators have been introduced to track this aspect in time:

- Value of production (Euro/ha, Euro/farm)
- % Increase in income (Euro) of producers from adoption practices and innovations (INSECTAMON – BlueLeaf).

Water use efficiency (WUE) - WUE is usually calculated based on the grain yield or total biomass produced per unit of water supplied to a field (including both precipitation and irrigation). WUE assesses the adequacy, equity, and efficiency of water utilization in a field. Water efficiency in irrigated/rainfed agriculture is calculated as the agricultural value added per agricultural (net) water withdrawn, expressed in USD/m^3.

Water productivity (WP) represents the yield or biomass produced per unit of water effectively consumed by crop in a field – which refers to crop evapotranspiration. WP assesses the adequacy of applied agronomic practices (including the use of different cultivars) and it is directly linked with the crop response to the amount of water used.

Change in water-use efficiency and water productivity over time (%) - The change in the ratio of the value added to the volume of water use, over time.

Freshwater withdrawal as a proportion of available freshwater resources (%) – Ratio between total freshwater withdrawn by all major sectors and total renewable freshwater resources, after taking into account environmental flow requirements.

Water delivery performance (%) - Water delivery performance is generally defined as the amount of actual water. delivered by the system compared to the target amount.

Annual water supply – It is the ratio between total annual volume of water supply and total annual volume of crop water demand.

The proportion of agricultural area under productive and sustainable agriculture (%) - This indicator is defined as the percentage of "agricultural area" that is "area under productive and sustainable agriculture”.

Time to recover from production loss (monetary or in terms of weight) - Time to recover from production loss from catastrophic events such as crop loss, forest fire or flooding in years.

Maximum of yield per average, wet and dry year - Minimum, maximum and average yield in driest years.

Degree of integrated water resources management implementation (0–100): a process which promotes the coordinated development and management of water, land and related resources in order to maximise economic and social welfare in an equitable manner without compromising the sustainability of vital

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ecosystems.

Proportion of youth and adults with information and communications technology (ICT) skills, by type of skill (%) - Proportion of youth and adults with information and communications technology (ICT) skills, by type of skill.

Pollutant loadings (fertilizer, manure) - Nitrate (or phosphorus) concentration in water: the proportion of surface water and groundwater above a national threshold value of nitrate concentration (NO_3 mg/l) or phosphorus (P total mg/l).

Good practices applied on farm to improve resilience - Number of good practices applied on farm to improve resilience.

Benefit/cost ratio - A benefit-cost ratio (BCR) is an indicator showing the relationship between the relative costs and benefits of a proposed project, expressed in monetary or qualitative terms.

Value of production - Value of production measures production in monetary terms at the farm gate level at the time they are produced. It can be compiled by multiplying gross production in physical terms by output prices at farm gate. Value of gross production is provided in both current and constant terms and is expressed in Euro and Standard Local Currency (SLC).

Additionally some Agro-environmental indicators are proposed in order to characterize the AEZs and the related cropping systems as well as to track the impacts of implemented innovations also on the AEZs' structure, information about structural characteristics of cropping systems are needed (Table 1).
The "structure" of the AEZ derives from the structure of the field crops belonging to the area of land. The structure of a farm derives from the spatialization of crops and cultivation techniques and their change over time (cropping system). The structural characteristics will be used to describe the AEZ and will be referred at the AEZ level but they need to be collected at the farm level or field level and then be aggregated for each AEZ.

Table 2: Proposed indicators to describe the structure of AEZs.

Agro-environmental indicators		Acronym	Unit of measure	References
Structure of AEZ	Plot Size (Crop Field Size = patch area)	CFS	Ha	Calabrese, 2009; Migliorini e Vazzana, 2007
	Field density	FD	Number * ha^{-1}	Migliorini e Vazzana, 2007
	Duration of Rotation (average)	DCR	Number	Pacini et al., 2003
	Crop Rotation	CR	Crops*yrs^{-1}	Calabrese, 2009
	Crop diversity	CD	Number	Calabrese, 2009
	Permanent crop density (field)	PCD	Number * ha^{-1}	Calabrese, 2009; Caporali et al., 2003
	Herbaceous crop density	HCD	Number * ha^{-1}	Calabrese, 2009; Caporali et al., 2003

In each AEZ one or more demonstration fields/plot will be activated, in that case, data about the following parameters should be collected using a mix of participatory methods: Total farm surface (Ha); Utilised Agricultural Area (UAA) (Ha); Crops per farm (n); Crop per field (n); Rotations for each field (number of crops*$year^{-1}$ and/or number of years in case of herbaceous crops); Cultivated varieties (number of different varieties per crop). Maps and cartographies and GIS can be of great support in describing AEZs and also the farming and cropping systems.

Methods and methodology description

To be able to screen all innovative options provided by the project in a systematic way and to define which

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innovations, once adopted by the AEZ, are sustainable and replicable, we will follow the IFES Analytical Framework set by FAO as a guidance document (FAO 2014). The Analytical Framework (AF) includes a set of criteria, indicators and measures to assess the sustainability and replicability of each technology. For the purpose of this study, the framework will be adjusted to local circumstances. The first phase of the replicability analytical framework aims to define the system and its context. Then, to assess the baseline and track the changes induced by the project implementation in upcoming years some essential indicators are proposed. Indicators will be the impact (quantitative) or performance (process or qualitative) in nature. The analysis will account for different relevant aspects, including technical, environmental and economic boundary conditions, regulation, and the behavior and interaction of involved stakeholders. The methodology to be used in combination with a data collection tool. The data will be collected using a mix of quantitative and qualitative methods. We will gather primary data from individual interviews, key informant interviews, focus group discussions and questionnaires. Secondary data will be derived from modelling and analysis of secondary sources (maps, aerial photographs, satellite imagery and documents). Results of the other working groups will be taken into account in the model for replication potential. After data have been identified and obtained they are transformed into useful information to facilitate decision making and subsequent action. Finally, potential for replication for new technologies/innovations or any combination thereof is assessed within its specific supply chains or production processes. These specific areas of interest and requested actions will be further detailed and assessed against specific production systems. A clear commitment among all the stakeholders that are going to participate is necessary.
Justification of the methods proposed (sources)
Up to now, there is not a very consistent and strictly defined methodology for the Replicability Analysis. Mostly, replicability is conducted for energy-based systems focusing mainly on technical, the economic, the regulatory and the acceptance of stakeholders. FAO has developed a scientifically –valid r framework/ guidance approach to assess the sustainability and replicability of existing integrated food-energy systems the will be adopted as conceptual framework to develop the project own approach.
Data collection phase(s)
• M01– M18– Development of methodology for replicability analysis • M07–M39 - Define and describe agri-food system, context, and actors involved • M13–M48 - Assess replicability
Data base
An Excel-based comprehensive database will be developed for storing and filtering relevant information. The database will be updated whenever new information relevant is acquired. The information will NOT be forwarded to any party outside the project consortium without prior permission by the project partners involved.
Material and team necessary
NA or to be agreed
Others (e.g., potential risks, limitations)
The validity and robustness of RA results depends on the representability and suitability of data to quantify the selected indicators and replication potential. In order to ensure the quality of SRA, it is necessary to have enough data available to correctly perform the analysis.

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Annex 2. *SustInAfrica* working groups integration

Highlights from the produced Excel file:

SHEET 1

Working groups	Coordinators
WG Crops. Cropping systems and management	Pierre Ellßel & Bernhard Freyer (BOKU), Kwame Frimpong (UCC)
WG Soil-Water. Soils and water	Nils Borchard (LUKE) and Mladen Todorovic (CIHEAM)
WG ES. Ecosystem services (ES)	Helena Serrano (FC.ID)
WG Insects	Stephanie Saussure (LUKE)
WG RS. Landscape & Remote Sensing	Michael Schirrmann(ATB)
WG Clima. Climate	Nicola Houlihan (SHA)
WG Nutre. Health and Nutrition	Nicola Houlihan (SHA)
WG SE. Socio-cultural, institutional, economic & policy	Ana Luz, Daniela Craveiro and Idalina Dias Sardinha (ISEG)
WG Innove. Innovation and replicability	Jenny Calabrese (CIHEAM)

Working phases and timeline

Stage	Description	Coordination & participants	Deadline
1 -- COMPLETE --	Prepare a first draft of field methods (or procedures, techniques, tools) by WG	WG coordinators with all partners inputs	End of January 2021
2 -- COMPLETE --	Integrate indicators & methods and discussion among WGs.	WG coordinators with all partners inputs	End of February
3 -- COMPLETE --	Redefine indicators clusters and further develop methods	WG coordinators with all partners inputs	End of March
4 -- IN PROGRESS --	Evaluate and co-select the most appropriate research methods and customize them to each country. **Integration with African partners**	ISEG with all partners input; Task 1.1b	April / May
5	**Plan baseline assessment** & enumerators **training**. Travel to African countries.	BOKU, FC.ID, ISEG with all partners input; Task 1.1c -> Tasks 1.2b, c, d	May / July

SHEET 2

Indicators' systematization and integration task	
Aims	**1. List the indicators necessary to accomplish SIA objects by WGs - "your wish list"** **2. Indicate and validate WGs correspondences /links (column "WGs Overlaps")** **3. When there are indicators overlaps, comment if the indicators from other WGs can fill your WG data requirement in column "Notes".** **Example: "Crop yield by WG Crops adequate"; "similar to Crop yield by WG Crops, but would prefer a different metric (specify)"**
Work description	**Each WG has a dedicated sheet.** The information presented in that sheet <u>**is not complete**</u> regarding what you sent in the draft. **At this stage each WG must:** **i. Validate and complete the information for your WG (exclusively on the corresponding sheet)** **ii. Codify the collumns when possible according to the classes proposed** **iii. In your indicators list, identity correspondences/overlaps with other WGs and point out the group related in the column "WGs Overlaps".** For this step please read the WGs drafts (available in Tiimeri) and <u>do not rely on the other WGs sheets of this Excel</u>. Also, you can look at the first integration attempt documented at 20210205_SIA_WGs matching topics for discussion_4Feb_NB.docx (available in Tiimeri). **iv. When necessary contact other WGs to clarify indicators, metrics and measurement aims.** **NOTE:** The use of the terms *indicator and metric* is not consistent across groups. In time, we will to unify these concepts.
Supporting materials	**1.** All the drafts' final version developed by each WP are available at Tiimeri -> Documents -> Working groups -> Stage 1_methods&indicators screening **2.** First integration draft documented in 20210205_SIA_WGs matching topics for discussion_4Feb_NB.docx is availabe at Tiimeri -> Documents -> Working groups -> Stage 2_integration **3.** This Excel (SIA WGs_indicators integration) is under folders Tiimeri -> Documents -> Working groups -> Stage 2_integration
Deadline	End of February

SHEETS 3 to 11 /one sheet by WG

WGs OVERLAPS	INDICATOR	METRICS	SCALE P [plot], F [farm], HH [household], C [community], L [landscape], R [regional], N [national], other (specify)	REPEATED MEASUREMENTS B [Baseline (2021)], Pre-Post [Baseline (2021) and final (2025)], Multiple [specify timing]	RELEVANCE to the project`s objectives and site conditions/resources (existing data and resources) Highly relevant, Relevant, Nice to have	NOTES

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Annex 3. Pre-list of field tools for data collection

List of field tools for data collection, obtained directly or indirectly from the previously shared materials from the Working Groups.
Please validate this list. You can edit directly on Tiimeri or send to the ISEG team. Also, if you find the name of the method / tool inadequate, please suggest a new one in the latest column.

Note: *The table below shows the original list sent to validation to the WGs. The final list of methods approved by the WGs and its designation is shown in Table 1 of this document.*

	METHOD / TOOL	SCALE	WG REQUEST	MAIN RESPONSIBILITY	APPROVED (OR NOT) Please add comments if necessary
1	**Soil sampling and analyses**	Plot	WG Soil	**WG Soil**	
2	**Crop sampling and analyses**	Plot	WG Crops	**WG Crops**	
3	**Crop-water system sampling and analyses**	Plot	WG ES	**WG ES**	
4	**Entomological sampling and analyses**	Plot/farm (and surroundings)	WG Insects	**WG Insects**	
5	**Tree / forest/ habitat sampling?**	Plot/farm (and surroundings)	WG Insects / ES	**WG Insects**	
6	**Interviews and/or technical form?**	Farmer	WG Crops	**WG Crops**	
7	**Household head survey**	Farmer / HH	WG Crops / ES / Nutre / Insects / SE	**WG SE**	
8	**Minimum Dietary Diversity for Women survey**	Farmer	WG Nutre	**WG Nutre**	
9	**Household Food Consumption Score + Food storage survey**	Farmer	WG Nutre	**WG Nutre**	
10	**Community meeting / workshop**	Community	WG SE	**WG SE**	
11	**Community leader survey**	Community	WG SE	**WG SE**	
12	**Trend analysis**	Community	WG Clima	**WG Clima / SE**	
13	**Field walk**	Community	WG Crops	**WG Crops / SE**	
14	**Experts interview**	Community	WG Crops	**WG Crops**	
15	**Season calendar**	Community	WG Crops / Clima	**WG Clima / SE**	
16	**Wealth ranking and livelihoods analysis**	Community	WG SE	**WG SE**	
17	**Stakeholder analysis**	Community	WG SE	**WG SE**	
18	**Targeted focus group**	Community	WG SE / Crops	**WG SE**	
19	**Bird sampling ?**	Community / landscape	WG ES	**WG ES**	
20	**Mapping and monitoring**	Community / landscape	WG Crops / ES / RS / SE / Insects	**WG RS / ES ?**	
21	**Micro / climatic data**	Community / landscape	WG Clima / ES / Insects	**WG Clima**	
22	**Value chain analysis**	Community / AEZ/Region/Country	WG SE	**WG SE**	
23	**Mapping GIS / RS / modelling**	AEZ/Region/Country	All	**WG RS / ES ?**	
24	**Stakeholders workshops (e.g., value chain product/sector, policy, academy)**	AEZ/Region/Country	WG SE	**WG SE**	

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Annex 4. Field protocol template

FIELD PROTOCOL

[Name / generic description]

AIMS

[Generic statement on what the data collection methodology is about]

FIELD METHODS

[Specify scale(s), sample size, sampling strategy and selection criteria if needed, and describe the specific procedures and material/equipment used in each procedure step]

FIELD FORM

[Registry of data to collect, e.g., field measurement sheet, interview guide, questionnaire, etc. Indicate if the form is going to be adapted to a phone, tablet, other platform, or used in paper]

PERSONNEL REQUIREMENTS

[#people, roles and responsibilities, qualifications needed, other (specify)]

# people	Role & responsibility	Qualifications needed
E.g., 3	*Enumerator – conduct independently household survey, translate focus groups and workshops*	*Speak local language, understand about the local agricultural context (agronomy, biology student), ability to collect the data independently*

MATERIAL & EQUIPMENT NEEDED

[List of material and equipment. Add information if acquired in the field country or brought from Europe or another African country]

Material / Equipment	Acquired at [country] / Return to [country]	Responsibility
E.g., Insect traps	*Finland / Finland*	*LUKE will be responsible to take and return the traps to each African country*

DATA MANAGEMENT & CONSENT

[Database, data management and consent/ethics requirements – if applicable]

TRAINING

[Schedule, Coordination, Staff time, etc.]

MONITORING PHASE APPLICATION

[State if relevant, adaptation of the method in the monitoring phase]

SUPPORTING MATERIAL

[If necessary, add name of documentation necessary to support this field protocol and is location in Tiimeri]

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