D5.1

First EWA-BELT SI Assessment Framework

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DISCLAIMER

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EXECUTIVE SUMMARY

The overall objective of WP5 is to identify innovative and traditional practices oriented towards Sustainable Intensification (SI) of agricultural systems representative of different agroclimatic areas of the East (Ethiopia, Kenya and Tanzania) and of the West (Burkina Faso, Ghana, Sierra Leone) Africa, representing the best trade-off between productive, environmental, economic and social purposes. The evaluation of the technologies and practices tested within WP2 and WP3 will be carried out through the development of an operational framework based on SI indicators relying on already proposed frameworks (e.g., Musumba et al., 2017) but implemented and adapted according to the project needs with the integration of expert and lay knowledge, field measurements and modelling approaches.

The above described aims will be pursued through the following steps: i) identification of a set of indicators to evaluate the impact of the SI practices and technologies tested within the project; ii) quantification of the impacts of the implementation of the SI practices and technologies within the considered domains (productive, environmental, economic, social and human) through data collection; iii) development of a composite indicator of SI for each agricultural system studied in the range of study areas where innovative practices are implemented.

The purpose of this first deliverable of WP5 is, hence, to describe the first version of the SI indicators Assessment Framework adopted in EWA-BELT and the different phases of its development. After an introductory overview on the state of the art, the methodology used for the search and selection of SI indicators and the main results obtained are described. The lists of indicators elaborated in the different steps of the selection process and the consulted bibliography are reported in the ANNEXES.

The final version of the EWA-BELT SI Assessment Framework will be later presented in D5.2 and finally, a report on the innovative practices ensuring the best trade-off between productivity, economic, environmental and social purposes will be provided in D5.3.

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INTRODUCTION

Worldwide agriculture, and even more African agriculture, face the common challenge of guaranteeing food production while reducing the environmental impact of farming activities in the context of global climate change, greater unpredictability of water supply and increased land degradation (IPCC, 2019). "Sustainable intensification" (SI), defined as increasing or maintaining agricultural production, minimizing negative environmental impacts and promoting sustainable development, has been proposed by some authors as an answer to the aforementioned challenges (Pretty, 1997; Mahon et al., 2018). Nevertheless, depending on the considered scale and the specific environmental and socio-economic context of the agroecosystems analysed, the SI Assessment Framework can be conceptualized in different ways (Polge & Debolini, 2018).

The EWA-BELT project aims to develop the SI of agricultural production in different agricultural systems in six countries belonging to East (Ethiopia, Kenya and Tanzania) and West (Burkina Faso, Ghana, Sierra Leone) Africa by carrying out participatory research activities in Farmer Field Research Units (FFRU), including areas with marginalized and/or abandoned land and existing agricultural land to increase their yield potential. The project aims to improve current scientific knowledge on a wide range of practices including: i) the adaptation of new and improved traditional crops in different agroecosystems, ii) the impacts of traditional agricultural practices aimed to improve crop yields, soil health in terms of nutrients, water retention and organic matter content, iii) the improvement of agri-livestock integrated system of agricultural production whereby crop and livestock interact to create synergy with recycling allowing the use of available resources; and iv) the introduction of innovative and appropriate practices for pre and post-harvest integrated pest and disease management (IPDM).

The main objective of this preliminary investigation within WP5 was, thus, to identify a set of indicators to evaluate the impact of the SI practices and technologies tested within the EWA-BELT project in order to orient the analytical framework for the SI assessment of the tested technologies and practices on the basis of the local context of the project countries. The preliminary list of indicators will be revised along the project duration through an iterative process which will involve all the other WPs participants. The final list of indicators will be selected based on the following criteria: (i) availability of quantitative and robust data from different sources, (ii) data collection at the specific scale during the project in the study areas, (iii) relevance to the assessment of the results of sustainable intensification of the tested innovative practices as perceived by the stakeholders involved.

METHODOLOGY

The process of defining this first version of the SI indicators Assessment Framework took place through the following phases:

1. Desk study based on an in-depth analysis of literature data and development of a preliminary list of SI indicators
2. Online survey to mobilize the expert knowledge of project partners
3. Workshop on protocol harmonization
4. Definition of a minimum set of indicators related to the environmental, productivity, economic, human and social domains
5. Selection of the SI technologies to be assessed and customization and refinement of the set of indicators to be measured for each technology

1. Literature analysis and development of a preliminary list of SI indicators

An in-depth analysis of literature data and reports was conducted. Advanced search options were considered using the settings reported in Table 1.

Table 1 - Search options and keywords considered in the literature analysis

Search settings	
Search engine	Google scholar
Search field	Title
Keywords	"Sustainable intensification" AND (indicator OR indicators)" "Sustainable intensification" AND "framework" "Sustainable intensification AND (assessing OR assessment)" "Sustainable intensification" AND "review" "Sustainable intensification" AND "meta-analysis" "Sustainable intensification" AND "gender" "Sustainable intensification" AND "East Africa"; "Sustainable intensification" AND "Eastern Africa"; "Sustainable intensification" AND "West Africa"; "Sustainable intensification" AND "Western Africa"; "Sustainable intensification" AND "Sub-Saharan Africa"
Timespan	Anytime
Language	Any language

The items found were then examined and indicators of SI were extracted from the main relevant documents, avoiding replications, and gathered in a preliminary comprehensive list split by different domains (productivity, social, economic, environmental, human). The bibliographic research was constantly updated throughout the duration of the project up to the date of submission of this deliverable.

2. On-line survey among the project partners

A digital survey was developed by selecting a sub-group of 9 or 10 indicators for each domain (in case of human domain were 5) and circulated among the project partners with expertise in different disciplines such as agronomy, agro-ecology, soil science, plant breeding, plant pathology, agricultural economics etc. (the survey module is reported in Annex III). Within each domain, investigators ranked the proposed indicators from the most to the least relevant. Furthermore, for each indicator East and West African researchers were asked to express a measurability score on a 5-point scale from "very easy to measure" to "impossible to measure". Datasets were then extracted and analysed.

3. Workshop on protocol harmonization

On the 14th of May 2021, UNISS organized an internal project workshop on protocols harmonization where each participant presented the activities, field protocols and SI indicators that they considered most appropriate for the tested technologies and then the discussion was opened. The aim of the workshop was to promote spontaneous initiatives among project partners to collaborate and create synergies both within countries and across countries defining cross-cutting activities and common actions and strategies.

4. Definition of a minimum set of indicators

Following the results of the digital survey and the workshop, a "minimum set of indicators" was defined and circulated among the partners. The document, which was prepared in collaboration with all the WP and Task leaders, specifies a minimum set of 3-5 indicators to be assessed for each of the technologies tested within EWA-BELT also providing further suggestions for indicators related to specific tasks. Initially the document was focused only on the environmental, productivity and economic domains and then the social and human domains were integrated.

5. Selection of the SI technologies to be assessed and customization and refinement of the set of indicators to be measured for each technology

For the SI assessment, five technology groups were selected among the technologies tested by different partners in different agro-ecological zones of West and East Africa:

1. Neglected and Underutilized crop species
2. Organic fertilization
3. Bio-pesticides
4. Aflasafe
5. Water harvesting

The main selection criteria for identifying these 5 technology groups were:

- Technologies implemented in a wide range of agro-environmental and socio-economic situations
- Technologies which proved to be very promising across different contexts
- Technologies with high potential for expanding the "BELT" from West to East Africa and vice versa and beyond the Ewa-belt African countries

Ad hoc meetings with the partners involved were held for each technology group (15th-19th December 2022) and the relevant indicators (3 to 5 for each domain) to be measured were identified and discussed.

RESULTS

1. Literature analysis

The number of records found, excluded and included during the bibliographic search is reported in Table 2. The complete list of references found for each search string is given in Annex I.

Table 2 - Number of records found, excluded and included during the bibliographic search

Keywords	Number of records		
	Found	***Excluded***	***Included***
"Sustainable intensification" AND (indicator OR indicators)"	16	2	14
"Sustainable intensification" AND "framework"	24	9	15
"Sustainable intensification AND (assessing OR assessment)"	41	9	30
"Sustainable intensification" AND "review"	44	29	15
"Sustainable intensification" AND "meta-analysis"	3	0	3
"Sustainable intensification" AND "gender"	15	0	15
"Sustainable intensification" AND "East Africa";	8	1	7
"Sustainable intensification" AND "Eastern Africa";	36	27	9
"Sustainable intensification" AND "West Africa";	26	11	15
"Sustainable intensification" AND "Western Africa";	5	4	1
"Sustainable intensification" AND "Sub-Saharan Africa"	39	15	27
Total	**257**	**107**	**151**

The preliminary list of indicators extracted from the main relevant documents are reported in Annex II.

2. Survey outcomes

A total of 69 questionnaires were completed: 31 in Kenya (KALRO and UoN), 2 in Ethiopia (HU and JU), 8 in Tanzania (ICRAF, NM-AIST and TARI), 3 in Burkina Faso (ACRA, INERA and UNB), 5 in Ghana (CSIR-SARI and KDC), 3 in Italy (UNISS and OCCAM), 10 in Greece (AUTH), 1 in France (IRD) and 6 in the United Kingdom (CRAN).

Main results: ranking

Within the productivity domain, *crop yield* was considered as the first most relevant indicator among the majority of the researchers from both East Africa, West Africa and Europe. *Input use intensity* was indicated in second place in East Africa and West Africa, and in third place in Europe, where the second was instead *input use efficiency*. In third place, East Africa and West Africa indicated *post-harvest losses* (Figure 1).

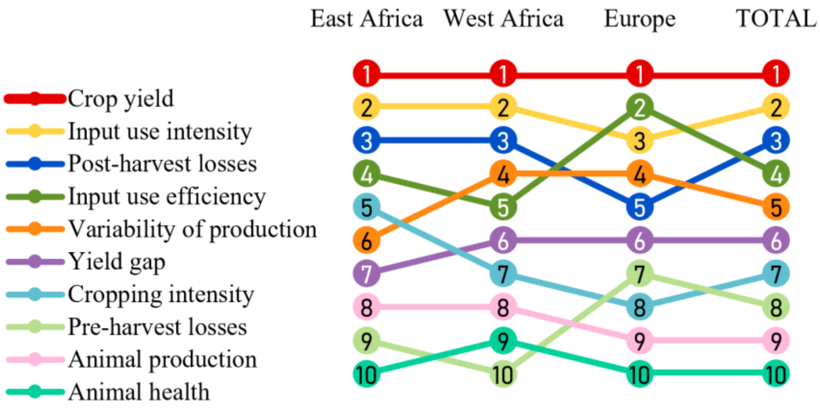

Figure 1 - Bump chart of the SI indicators' classification in the productivity domain as ranked by the researchers from East Africa, West Africa, Europe, and the Total.

As regards the environmental domain, *plant biodiversity*, *soil erosion* and *water quality* were considered as first in East Africa, West Africa and Europe, respectively. Among the second and third most relevant indicators were selected also: *soil nutrients* (second in East Africa and Europe and third in West Africa), *vegetation cover* (second in West Africa and third in East Africa) and again *soil erosion* (third in Europe) (Figure 2).

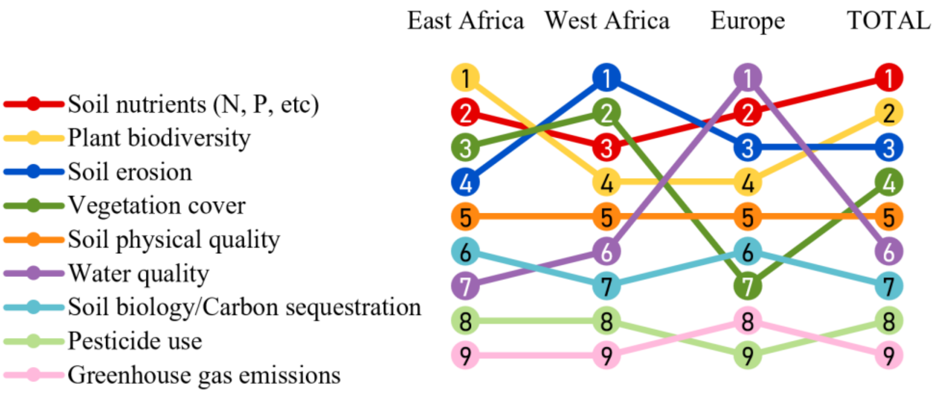

Figure 2 - Bump chart of the SI indicators' classification in the environmental domain as ranked by the researchers from East Africa, West Africa, Europe, and the Total.

Within the economic domain, *profitability* occupied the first position in both East Africa, West Africa and Europe, followed in second place by *variability of profitability* in Europe, *income diversification* in East Africa, and *returns to land, labour* and *capital* in West Africa. The latter was third in East Africa and Europe, whereas for West Africa researchers it was *poverty rates* (Figure 3).

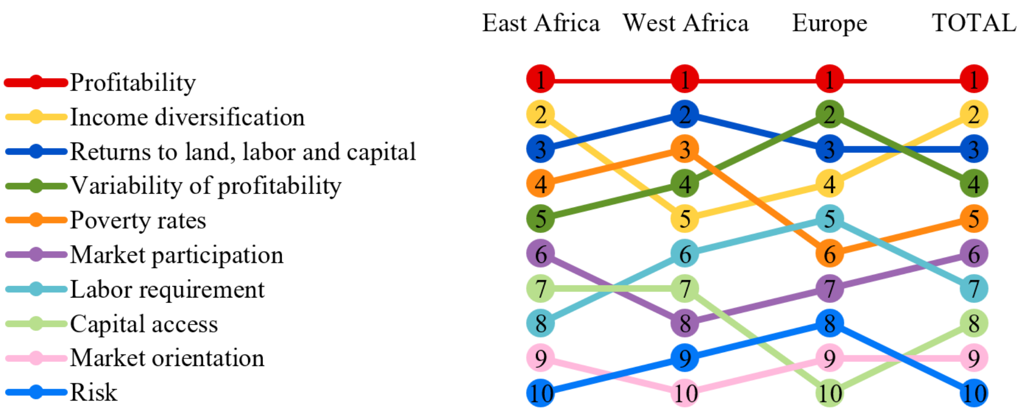

Figure 3 - Bump chart of the SI indicators' classification in the economic domain as ranked by the researchers from East Africa, West Africa, Europe, and the Total.

As concern the social domain, *gender equity* was regarded as the first most relevant indicator of social sustainability in East Africa and Europe and as third in West Africa, where the first was c*onflicts over resources*. *Level of collective action* was considered as second in West Africa and third in Europe. Among the most relevant indicators within social domain, *educational level of farmers* (second in Europe), *food self-sufficiency* and *age equity* (second and third in East Africa) were also mentioned (Figure 4).

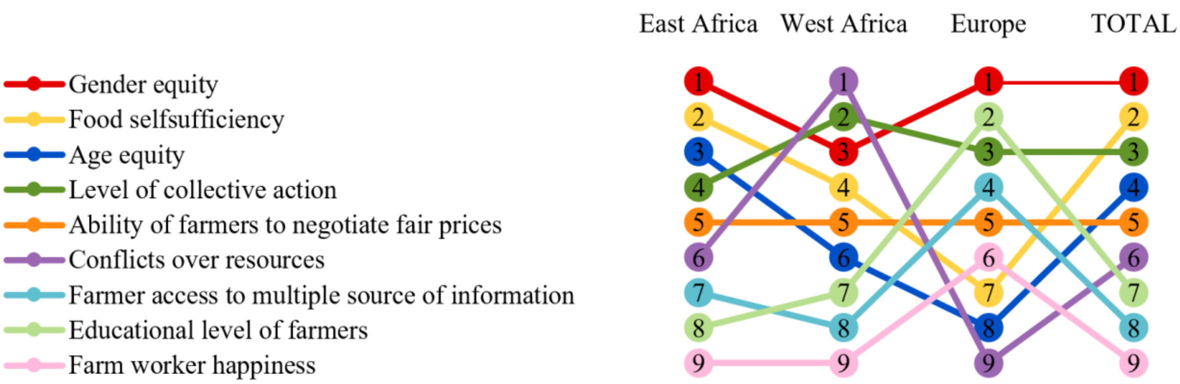

Figure 4 - Bump chart of the SI indicators' classification in the social domain as ranked by the researchers from East Africa, West Africa, Europe, and the Total.

Regarding the human domain, *food security* was considered as the first most relevant indicator from both East Africa, West Africa and Europe researchers. Other relevant indicators were *nutritional status* (second in East Africa and West Africa), *food safety* (second in Europe and third in East Africa), *nutrition awareness* (third in West Africa) and *human health* (third in Europe) (Figure 5).

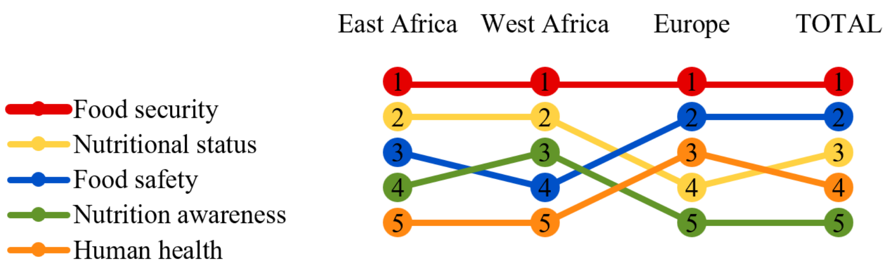

Figure 5 - Bump chart of the SI indicators' classification in the human domain as ranked by the researchers from East Africa, West Africa, Europe, and the Total.

Main results: measurability score

The measurability scores of the SI indicators assigned by the East and West African researchers, and the Total, within the five domains (productivity, environmental, economic, social and human) are showed in Figures 6-10.

Within the productivity domain, more than 90% of African researchers considered the *crop yield* indicator easy or very easy to measure with substantial agreement between researchers from West (100%) and East Africa (89%) (Figure 6). Also the *cropping intensity* was considered easy or very easy to measure by 75% of the total of the researchers with about 86% in West Africa and about 72% in East Africa. The other indicators for which the overall share of researchers who answered easy or very easy to measure exceeded 50% were: *animal health* (62%), *animal production* (61%), *yield gap* (60%) and *post-harvest loss* (55%). In all of these cases, the majority of the remaining respondents (50% to 80%) rated these indicators as somewhat hard to measure. The *input use intensity* was easy or very easy to measure according to 50% of West African researcher and 49% of the researcher from East Africa, with a percentage, out of the total of the remaining respondents, of those who answered somewhat hard to measure equal to 65%. As regards the *variability of production*, *pre-harvest losses* and *input use efficiency* indicators, only about 25-30% of all African researchers answered easy or very easy to measure, around 40-50% responded somewhat hard to measure while and another 20-35% hard or very hard to measure.

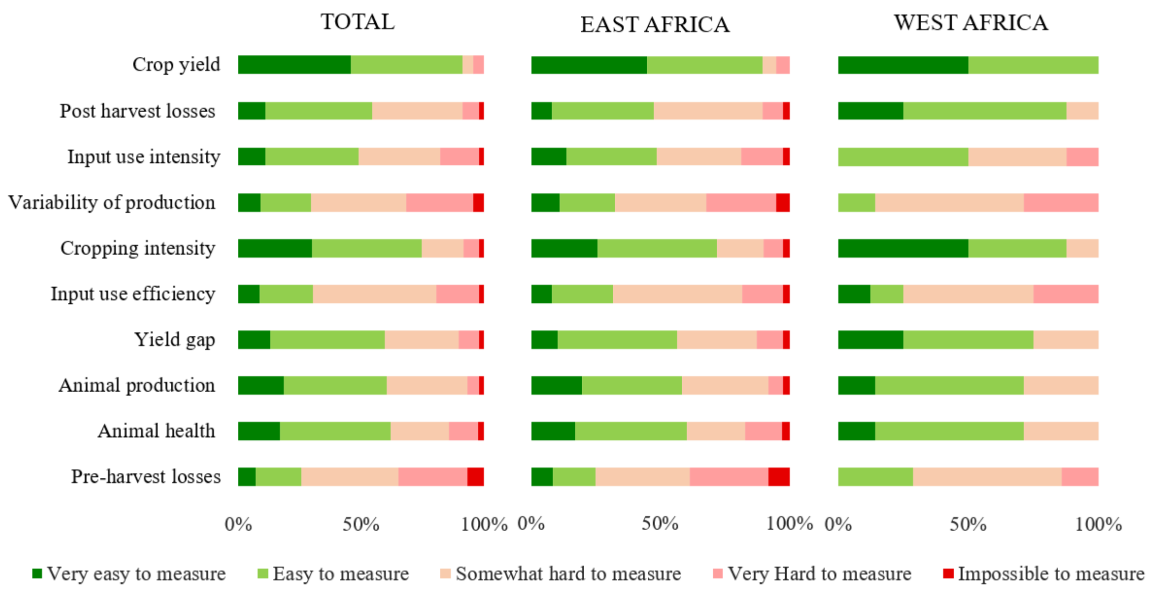

Figure 6 - Measurability score of the SI indicators in the productivity domain as assigned by the East and West African researchers and the Total.

Considering the environmental domain, the indicators for which at least 50% of all researchers answered easy or very easy to measure were: *soil nutrients* (78%), *soil physical quality* (71%), *water quality* (66%), *plant biodiversity* (57%), *vegetation cover* (53%) and *pesticides use* (50%) (Figure 7). However, in West Africa *plant biodiversity* and *pesticides use* did not reach 50%, hovering around 38% and 43%, respectively. *Soil biology/Carbon sequestration* was considered easy or very easy to measure by 46% of all researchers with a certain difference between East (50%) and West Africa (25%). About 60% of the remaining researchers considered this indicator somewhat hard to measure and the remaining 40% very hard to measure. Only 24% of African researchers considered *soil erosion* easy to measure, while about 45% considered it somewhat hard to measure and the remaining 31% very hard to measure. *Greenhouse gas emissions* was the indicator that obtained the lowest percentage of easy or very easy to measure responses (about 16% in total, 17% in East Africa and 13% in West Africa) while the remaining researchers considered this indicator somewhat hard to measure (39%), very hard to measure (34%) or impossible to measure (11%).

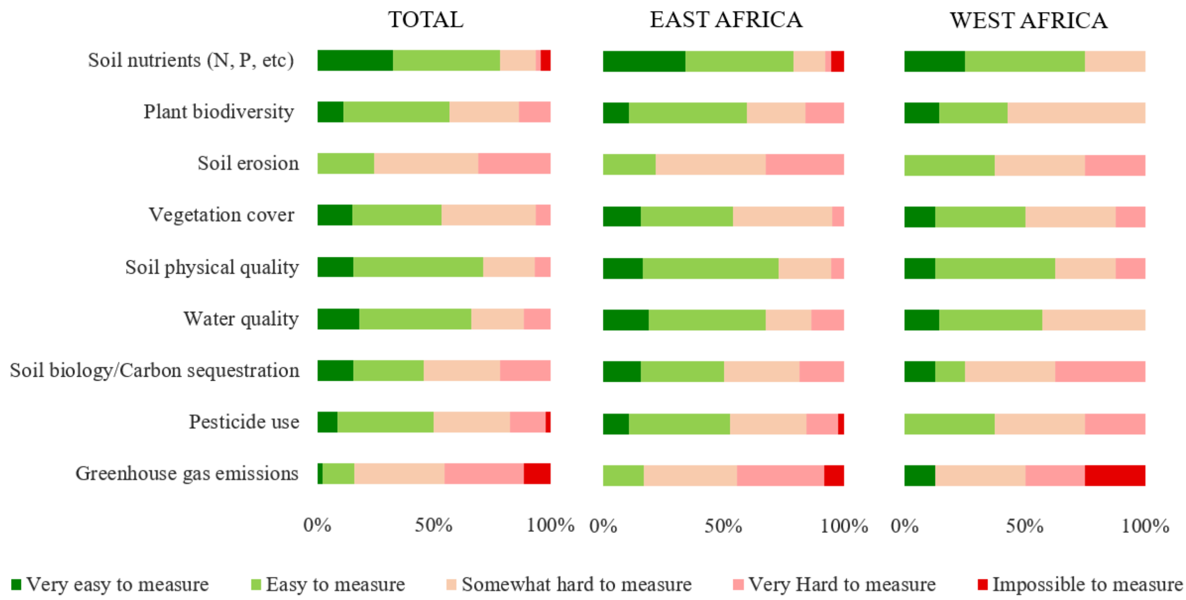

Figure 7 - Measurability score of the SI indicators in the environmental domain as assigned by the East and West African researchers and the Total.

Considering the economic domain, for most of the indicators 50% or more of all researchers answered easy or very easy to measure (*profitability* 64%, *capital access* 64%, *market participation* 58%, *labour requirement* 56%, *risk* 56%, *market orientation* 54%, *returns to land, labour and capital* 53%, *income diversification* 51%) while a percentage between 20 and 40% answered somewhat hard to measure

(Figure 8). As regards variability of profitability and poverty rates, only about 30% of the researchers found these indicators easy or very easy to measure, a remaining 45-50% found them somewhat hard to measure, 15-20% hard to measure and the remaining 5% impossible to measure.

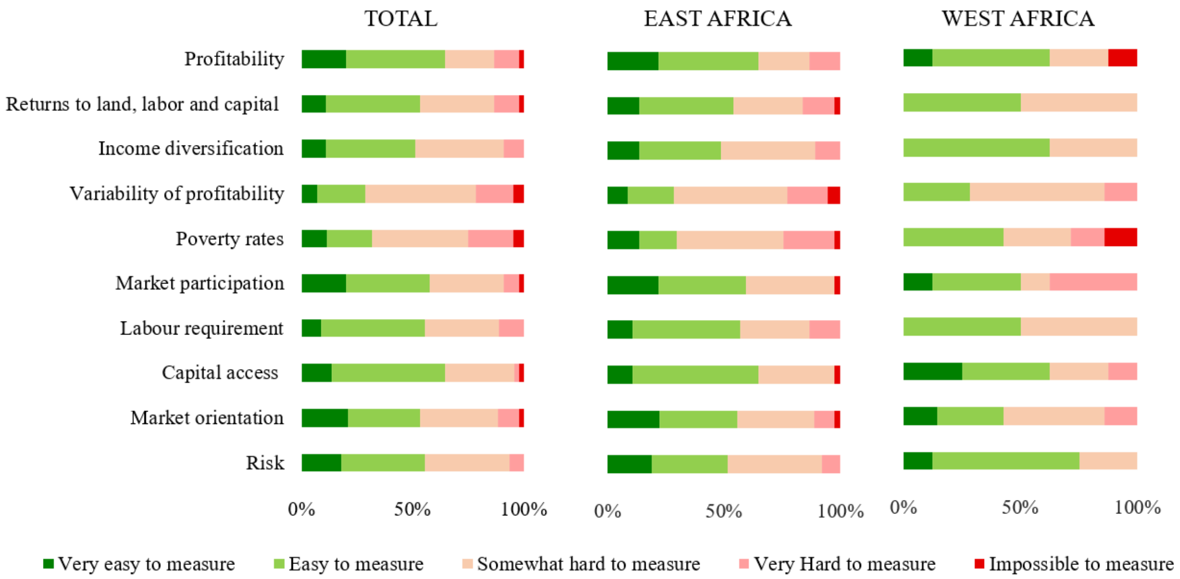

Figure 8 - Measurability score of the SI indicators in the economic domain as assigned by the East and West African researchers and the Total.

As regards the social domain, almost all African researchers (100% in West Africa and 95% in East Africa) considered the *educational level of farmer* indicator easy or very easy to measure (Figure 9). More than 50% of the researchers considered easy or very easy to measure other indicators such as *farmer access to multiple source of information* (70%), *gender equity* (68%), *age equity* (64%), *food self-sufficiency* (61%) *and conflicts over resources* (51%). The *level of collective action* was considered easy or very easy to measure by around 49% of the researchers and somewhat hard to measure by around 45%. Concerning the *farm worker happiness*, the *ability of farmers to negotiate fair prices* and the *level of social cohesion*, the percentage of researcher indicating easy or very easy to measure was around 30-35% with somewhat hard to measure ranging between 34% (*farm worker happiness*) and 56% (*ability of farmers to negotiate fair prices*). Around 23% of the researchers considered the *farm worker happiness* indicator as very hard to measure and a further 6% as impossible to measure.

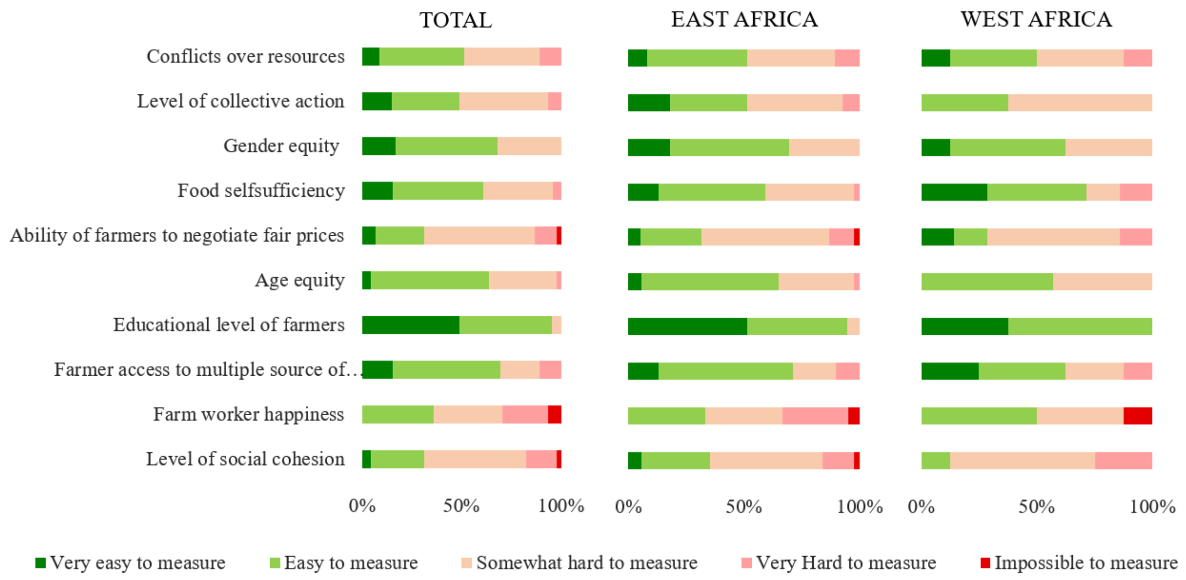

Figure 9 - Measurability score of the SI indicators in the social domain as assigned by the East and West African researchers and the Total.

About 72% of the researchers considered nutrition awareness as easy or very easy to measure, 13% as somewhat hard to measure, 11% as very hard to measure, and 4% as impossible to measure.

As regards the other indicators, the percentage of researchers who answered easy or very easy to measure was around 50-53%, with somewhat hard to measure response percentages around 30-44%, very hard to measure between 4 and 20% and impossible to measure between 0 and 2%.

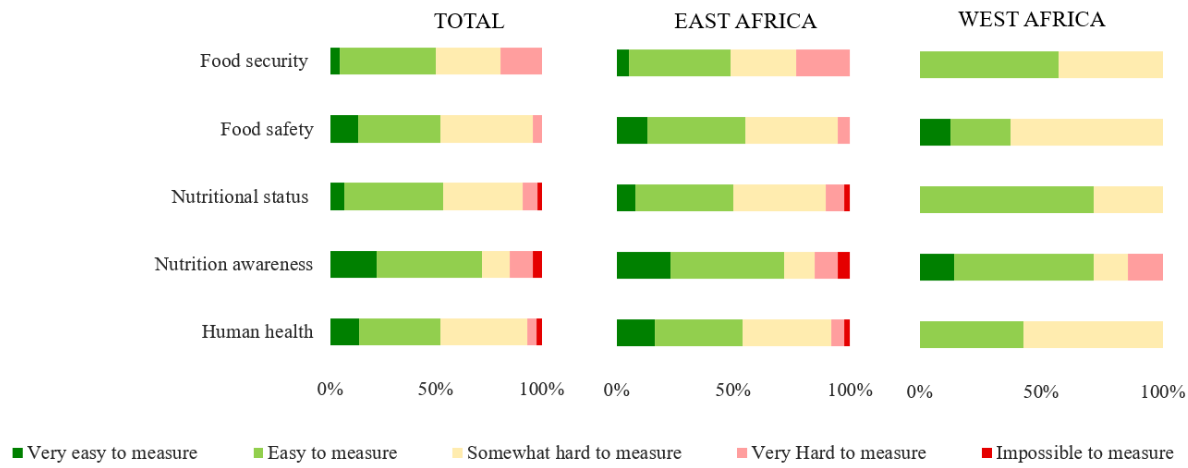

Figure 10 - Measurability score of the SI indicators in the human domain as assigned by the East and West African researchers and the Total.

3. Minimum set of indicators related to the environmental, productivity, economic, human and social domains

The document prepared in collaboration with all the WP and Task Leaders which specifies a minimum set of 3-5 indicators related to the environmental, productivity, economic, human and social domains is reported below.

Some hints for common transversal SI indicators to assess within the different technologies tested in EWA-BELT

The following indicators can be referred to **plot/field scale** up to **household scale**. All indicators should be assessed for the specific technology tested in comparison to an **untreated control** and a **conventional/business and usual** treatment.

PRODUCTIVITY

Minimum set of indicators to measure for all technologies

- **Crop yield** (actual crop yield): amount of crop product per unit area (e.g. kg/ton/bags/crates m^{-2}/ha^{-1}/$acre^{-1}$); if expressed in bags, crates etc.: **always specify the average weight of each bag/crate**.
- ***Potential crop yield and yield gap***: *The level of potential yield can be defined as that level of yield that can be obtained in a certain environment by a particular species when the agronomic technique does not constitute a limitation to production, and all the "available knowledge" (on fertilizers, varieties, sowing time etc.) are applied in the best possible way. The potential yield is generally quantified through the use of theoretical models in which the limits of the climate and morphophysiological characteristics of the species are imposed. The results of these models must be compared with real data, represented by record productions in that environment and for that species, that is, from productions made in exceptional conditions.*
- **Input use intensity**: e.g., amount of input (seeds, fertilizers, pesticides, water, etc.) per unit area (e.g. g/kg/ml/L m^{-2}/ha^{-1}/$acre^{-1}$)
- **Input use efficiency**: ratio between crop yield and amount of input supplied (if possible ratio between harvested input (e.g. N or P) and amount of input supplied
- **Pest and disease incidence:** pest and disease abundance and severity by type (e.g. McKinney Index) the sampling dates will be decided according to the crop characteristics
    - incidence of mycotoxin (e.g. aflatoxins) (above the Maximum Level) in food/feed (µg of mycotoxin/kg of row product; and µg of mycotoxin/kg of processed product)

Other possible indicators that can be used for specific technologies/tasks

- **Post-harvest losses***: score between 0 and 10, where 0 is no losses and 10 is 100% of losses; difference between amount of crop product consumed and/or sold and crop yield as influenced only by pests and diseases damages (the sampling dates will be decided according to the crop characteristics)
- **Animal production (e.g. milk, meat, eggs etc.**): e.g. milk production per animal per day or per lactating season, etc**.** (**TASK 2.3 and some technologies of TASK 2.2.2.**)
- **Variability in production:** Coefficient of variability/probability of low productivity (0-1)
- **Cropping intensity and crop diversification:** Number of cropping seasons per year and % total land allocated to each crop (**intercropping/rotation TASK 2.2.2.**)
- **Morphological parameters:** e.g. number of seeds/pods/fruits/leaves/tubers per plant, plant height (cm), fruits or tuber caliber (mm), stem posture, thousand seeds weight (g), pod length (cm), cycle (phenological stages), etc. **(TASK 2.1)**
- **Animal health:** disease incidence, farmer-reported condition, growth rate, mortality rate (**TASK 2.3)**
- **Quality of product:** e.g. protein content, calorie, fiber content, feed value etc.

- **Water use efficiency (WUE):** the ratio (%) between effective water use and actual water withdrawal (Sub task 2.2.3).
- **Crop water productivity (CWP):** measure of the biophysical gain from the use of a unit of water (kg/m^3) consumed in crop production (Sub task 2.2.3).
- Production strata of the different livestock and crop integrated components over the year by the farmers-perennial harvesting of products from the same farm site (TASK 2.3)

ENVIRONMENT

Minimum set of indicators to measure for all technologies

- **Plant biodiversity**: Shannon index*
- **Crop and varietal diversity:** e.g. number of crops/varieties (within crop) per unit area
- **Crop uses**
- **Vegetation cover:** % vegetative cover by type (tree, shrub, grass, invasive), burned land (% or ha or acres), bare land (% or ha or acres)
- **Pesticide use**: Amount of active ingredient applied per unit area (e.g. mg/ml m^{-2}/ha^{-1}/acre^{-1}) and application frequency

** **Shannon index:** Species richness is estimated with the total number of observed species. The Shannon Diversity Index is calculated by multiplying a species proportional abundance by the natural log of that number:*

$$H' = -\sum_{i=1}^{R} p_i \ln p_i$$

where pi is the proportion of individuals found in the species "i". This index assumes that individuals are sampled randomly from an infinite or very large population. Similarly, it supposes that all species are represented in the sample. The value of the Shannon Diversity Index usually falls between 1.5 and 3.5 and only rarely exceeds 4.5.

For more details regarding field sampling, measurement and data processing for biodiversity, please see: http://www.fao.org/3/y5490e/y5490e0a.htm#:~:text=Species%20richness%20is%20estimated%20with,in%20the%20species%20%E2%80%9Ci%E2%80%9D.

Other possible indicators that can be used for specific technologies/tasks

- **Soil biology/carbon sequestration:** total carbon (% or Mg/ha), labile or 'active' carbon (POXC) and/or CO_2 mineralization, partial carbon budget, abundance of earthworms (**Some technologies of TASK 2.2.2. and TASK 2.3.**)
- **Soil erosion**: score between 0 and 10**???**, based on farmer reported change in soil depth (**TASK 2.2.1., TASK 2.2.2.)**
- **Insect biodiversity:** abundance and diversity of pollinators and beneficial insects (**e.g. intercropping, TASK 2.2.2.**)
- **Greenhouse gases emissions**: CO_2 equivalent emitted per unit area (ha or acre) or per kg of yield (directly measured if possible or estimated by models) (**TASK 2.2.2. and TASK 2.3.**)
- **Pollution:** concentration of fertilizer, crop protection chemicals, soil particulates and slurry run-off in waterways, **water soluble and total fluoride in the soil** (**TASK 2.2.1 and TASK 2.2.2.)**
- **Pest and disease incidence:** pest and disease abundance and severity by type (scoring)
- Natural vegetation recovery rate: *due to farmers practising sedentary or in-situ farming (Producing from the same location instead of shifting cultivation)-enhancing reforestation*

ECONOMY

Minimum set of indicators to measure for all technologies

Here the considered scale is the private outcome for the farmer.

- **Profitability:** Net income, ($/crop/ha/season), net present value, gross margin (allows assessment of whether benefits of production outweigh the costs of production)
- **Variability of profitability:** probability that net income or net present value is more than the current practice or status quo.
- **Income diversification:** Diversification index, Number of income sources (ensures that income is still available from alternative systems if a particular system fails. This should include also off-farm income if any
- **Returns to land, labour and capital:** monetary value of output/input used (profitability per unit of land, labour, and capital used)
- **Labour requirement:** e.g. hours/ha, farmer rating of labour requirements (ensures that the absolute input of labour is available and manageable for the farmer)

Other possible indicators that can be used for specific technologies/tasks

- **Number of tillage operations**
- **Poverty rates:** e.g. per capita household consumption expenditure, wealth categorization
- **Market participation:** e.g. % of products sold to the market
- **Market orientation:** e.g. % of land in cash crops
- **Risk:** e.g. Months of available grain stores reported by farmers
- **Variability of profitability:** e.g. Coefficient of variability of net income, Probability of low profitability (0-1)
- **Capital access:** e.g. benefit/cost, total factor productivity

SOCIAL

Minimum set of indicators to measure for all technologies

- **Technology ranking per gender** (in case more than one technology is tested/adopted by farmers)
- **Technology satisfaction per gender:** Satisfaction with the technology (Likert scale from 1 to 3) and reasons why (predetermined answers related to sub indicators)
  Within the satisfaction indicator with the technology, after literature review, bilateral meetings and focus group discussions with Partners end external stakeholders, the latter carried out in Ethiopia in March 2023 a preliminary list of determinants/sub indicators has been developed as follows**:**
  - Access to resources
  - Control over resources
  - Labour Input in the different phases of the technology
  - Time allocation/free time (well-being)
  - Accessibility of the technology and access to information
  - Efficacy of the technology
  - Resistance of the technology to drought or other environmental conditions and pests
  - (Food stability)- Achievement
  - Nutritional adequacy- Achievement
  - Preference in term of tastes (only for crops or varieties)
  - Economic achievement (market and income)

- Social cohesion
- Social acceptance of the technology
- Recommendation of technology to others and willingness to continue adopting the technology

-

The list can slightly change and be adjusted according to each specific technology. The sub-indicators considered for the technology satisfaction will also help to triangulate the data from the other domains.

Other indicators that can be used for specific technologies

- **Gender equity:** WEAI pre and post implementation of the technology only for NUS.

HUMAN

Minimum set of indicators to measure for all technologies

- **Food security:** number of calories produced by each crop in business as usual and in the cropping system with the tested technology (please collect info on the composition of the household per age and per gender).
- **Nutrition**: macro nutrients (carbohydrates, proteins and fats) produced by each crop per unit area per cropping season in the business as usual and in the cropping system with the tested technology.
- **Months of food insecurity**: both in the cropping system with the tested technology and in the business as usual. Specific question on the months of food insecurity (rating of food security by farmers)
- **Food safety:** chemical contamination due to the use of agro-chemicals (see environmental indicators n°2)

4. Selection of the SI technologies to be assessed and customization and refinement of the set of indicators to be measured for each technology

In December 2022, two online workshops were held among partners in order to discuss on the indicators to be measured for each of the five technologies selected and a short list of indicators was then circulated in the first months of 2023 for further reflections and feedbacks. Some of the indicators initially envisaged in the document: "*Some hints for common transversal SI indicators to assess within the different technologies tested in EWA-BELT*" reported in paragraph 3 have been totally abandoned and replaced with other indicators with greater characteristics of measurability and relevance for the specific technologies selected. All details related to the indicators finally chosen for the five technologies groups (Neglected and Underutilized crop species, Organic fertilization, Bio-pesticides, Aflasafe and Water harvesting) tested by different partners in different agro-ecological zones of West and East Africa, are given in Annex IV. Further small changes may be possible once the collection of the data will start and limitations and constraints will be encountered. The data collection is now starting and the outcomes will be presented in the deliverable 5.3.

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ANNEXES

Annex I: Literature Analysis

Annex II: Preliminary List of Sustainable Intensification Indicators

Annex III: Survey on Sustainable Intensification Indicators

Annex IV: Refinement of the set of indicators to be measured for the selected technologies

Annex I:

Literature Analysis

Search settings Search engine: Google scholar Search field: Title Keywords: “Sustainable intensification” AND (indicator OR indicators)” Timespan: Anytime Language: Any language	
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Search settings

Search engine: Google scholar
Search field: Title
Keywords: "Sustainable intensification" AND "East Africa"; "Sustainable intensification" AND "Eastern Africa"; "Sustainable intensification" AND "West Africa"; "Sustainable intensification" AND "Western Africa"; "Sustainable intensification" AND "Sub-Saharan Africa"
Language: Any language

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Annex II:

Preliminary List of Sustainable Intensification Indicators

Domain	Indicator
Productivity	Crop yield
Productivity	Crop quality
Productivity	Crop biomass
Productivity / economic / environmental	Crop diversity
Productivity / economic	Fodder production
Productivity / economic	Fodder quality
Productivity / economic / environmental	Cropping intensity
Productivity / economic / environmental	Input use intensity (fertilizer, seeds, water, pesticides, water, energy, labour etc)
Productivity / economic	Input use efficiency (fertilizer, seeds, water, pesticides etc)
Productivity / economic	Yield gap
Productivity / economic	Yield variability
Productivity	Pre-harvest losses
Productivity	Post-harvest losses
Productivity / economic / environmental	Irrigated surface
Productivity	Soft tillage surface
Productivity	Pasture surface
Productivity	Animal production (milk, meat or eggs) (primary)
Productivity	Animal production (by-products)
Productivity	Animal health
Productivity / environmental	Livestock density
Productivity / economic	Variability in production
Environmental	Soil biology/Carbon sequestration
Environmental	Soil erosion
Environmental / economic	Top soil loss (tonnes per hectare per year)
Environmental / economic	Soil organic matter
Environmental	Soil acidity
Environmental	Soil salinity
Environmental	Soil water
Environmental	Soil nutrients (N, P, etc)
Environmental	Soil physical quality
Environmental / economic	Soil compaction
Environmental / economic	Diversity of soil biota
Environmental	Beneficial microorganisms
Environmental	Number of earthworms per metre squared
Environmental	Greenhouse gas emissions
Environmental	Water availability
Environmental	Water Insecurity (% households with no incidence of water insecurity)
Environmental	Water quality
Environmental	Concentration of fertilizer run-off in waterways
Environmental	Concentration of crop protection chemicals in waterways
Environmental	Concentration of soil particulates in waterways
Environmental	Concentration of slurry run-off in waterways

Domain	Indicator
Environmental	Vegetation cover
Environmental	Habitat or biodiversity loss
Environmental	Plant biodiversity
Environmental	Insect biodiversity
Environmental	Treated surface with pesticide
Environmental	Pesticide use
Environmental	Pest levels
Environmental	Chemical input reduction
Environmental	Treated surface with mineral nutrient on farm
Environmental	Treated surface with herbicide
Environmental	Incidence of herbicide-resistant weeds
Environmental	Particulate matter in the air
Environmental	Volume of waste produced on farm
Environmental	Number of tillage operations
Environmental	Use of ‘precision agriculture’ techniques
Environmental	Percentage of precision agriculture helped by technological input
Environmental	Percentage of improved soil management practices
Environmental	Percentage of alternative pest management
Environmental	Percentage of biological control
Environmental	Percentage of protected area
Environmental	Use of crop rotations
Environmental	Use of monocultures
Environmental	Use of agroforestry techniques
Environmental	Use of grain as animal feed
Environmental	Use of grass as animal feed
Environmental	Use of organic manure
Environmental	Use of management practices for waterway conservation
Environmental	Number of ponds
Environmental	Frequency of extreme whether events
Environmental	Farmland bird numbers
Environmental / economic	Number of pollinators per ha
Environmental / economic	Percentage of land under agricultural production
Environmental / economic	Quality of energy used per farm
Environmental / economic	Amount of renewable energy generated on farm
Environmental / economic/ social	Size of farms (Larger farms for economic sustainability; small farms for social sustainability and potentially environmental sustainability)
Environmental / economic	Use of genetically modified crops
Environmental / economic	Length of hedgerows per ha
Environmental / economic	Number of livestock units per hectare
Environmental / social	Monitoring of water quality by the Environment Agency
Environmental / social	Presence of national polices on biodiversity
Environmental / social	Presence of international polices on climate change

Domain	Indicator
Environmental / social	Presence of national polices on climate change
Environmental / social	Presence of national polices on water quality
Environmental / social	Presence of subsidies to encourage more environmentally sensitive farming
Environmental / social	High nature value farming ratio
Economic	Profitability
Economic	Variability of profitability
Economic	Percentage of total land allocated to each crop (crop diversification)
Economic	Farmer income
Economic	Agricultural income
Economic	Income diversification
Economic	Presence of farm income from non-agricultural activities
Economic	Presence of farm income from off-farm employment
Economic	Total income from subsidies
Economic	Cost of production
Economic	Returns to land, labour and capital
Economic	Percentage of household selling product to the market (Market participation)
Economic	Market orientation
Economic	Labour requirement
Economic	Number of retailers to which each farm supplies
Economic	Number of crops by farm and by surface
Economic	Risk
Economic	Reduced poverty rates
Economic	Stocking rate
Economic / social	Farmer access to credit
Economic / social	Capital access
Economic	Capital productivity
Economic	Household purchases
Economic	Net returns (monetary value of output/input used)
Economic	Age of farm infrastructure
Economic	Casualization of employment in agriculture
Economic	Farmer financial savings
Economic	Farmers’ attitudes towards debt
Economic	Farmers’ attitudes towards farm succession
Economic	Farmers’ attitudes towards farming and agriculture
Economic	Farmers’ attitudes towards technology
Economic	Extent of farm mechanisation
Economic	Use of loss-leader pricing of food by supermarkets
Economic	Trends in agricultural output prices
Economic	Consumer preference for cheaper food
Economic	Time taken for livestock to reach maturity
Economic	Incidence of livestock disease

Domain	Indicator
Economic	Incidents of antibiotic resistant livestock diseases
Economic	Number of offspring produced per animal per year
Economic/ environmental	Agricultural land use intensity
Economic/ environmental	Depth of water table
Economic / social	Quantity of work on farm (hours) by surface
Economic / social	Age of farmers
Human	Nutrition awareness
Human	Food security
Human	Percentage of households with no incidence of food insecurity (Food Insecurity)
Human	Food safety
Human	Incidence of pesticides in food
Human	Capacity to experiment
Human	Human health
Human	Fuel availability (energy security)
Human	Food self-sufficiency
Social	Gender equity (access to resources, to information, agency, achievements, rating of technologies)
Social	Gender gap
Social	Age equity (access to resources, to information, agency, achievements, rating of technologies)
Social	Equity of marginalized groups (access to resources, to information, agency, achievements, rating of technologies)
Social	Social capital
Social	Level of social cohesion
Social	Level of collective action
Social	Farmer social networks
Social	Interactions between farmers
Social	Presence of collaborative networks of farmers
Social	Conflicts over resources (e.g. livestock grazing)
Social	Inter-municipal cooperation
Social	Prestige in community
Social	Farmers' perception of their relationship with landlord
Social	Ability of farmers to negotiate fair prices
Social	Labour intensity reduction
Social	Quantity of work on farm (hours) by surface
Social	Presence of animal welfare standards
Social	Animal welfare
Social	Farm worker happiness
Social	Affordability of rural housing
Social	Educational level of farmers
Social	Farmers' attitudes towards nature
Social	Farmers' attitudes towards their peers
Social	Farmer access to multiple source of information

Domain	**Indicator**
Social	Number of native language speakers
Social	Number of public engagement activities
Social	Use of household livestock systems
Social	Public perception of agriculture
Social	Consumer preference for high welfare livestock products
Social / economic	Number of visitors to a farm
Social / economic / environmental	Number of short-term farm tenancies (3-5 years)
Social / economic	Number of people in agricultural employment
Social / economic	Amount of financial capital invested in farm
Social / economic	Presence of a farm succession plan

Annex III:

Survey on Sustainable Intensification Indicators

Section I

Q1. Select the organization(s) for which you work

- □ NRD-UNISS
- □ FONDAZIONE ACRA
- □ CRAFIELD UNIVERSITY
- □ INSTITUT DE RECHERCHE POUR LE DEVELOPPEMENT
- □ ARISTOTELIO PANEPISTIMIO THESSALONIKIS
- □ UNIVERSITE NAZI BONI
- □ INSTITUT DE L'ENVIRONNEMENT ET DE RECHERCHES AGRICOLES
- □ THE UNIVERSITY OF MAKENI
- □ COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH-SARI
- □ KUNDOK DEVELOPMENT CONSULT LIMITED
- □ KENYA AGRICULTURAL AND LIVESTOCK RESEARCH ORGANISATION
- □ UNIVERSITY OF NAIROBI
- □ THE NELSON MANDELA AFRICAN INSTITUTE OF SCIENCE AND TECHNOLOGY
- □ TANZANIA AGRICULTURAL RESEARCH INSTITUTE
- □ HAWASSA UNIVERSITY
- □ JIMMA UNIVERSITY
- □ INTERNATIONAL CENTRE FOR RESEARCH IN AGROFORESTRY
- □ STMICROELECTRONICS SRL
- □ OSSERVATORIO PER LA COMUNICAZIONE CULTURALE E AUDIOVISIVANEL MEDITERRANEO E NEL MONDO
- □ CENTRE DE COOPERATION INTERNATIONALE EN RECHERCHEAGRONOMIQUE POUR LE DEVELOPPEMENT

Q2. Please, enter your Name and Surname

Q3. In which geographical area is your institution located?

- □ East Africa
- □ West Africa
- □ Europe

Q4. How many case studies is your institution responsible for? (0-10)

Section II: Productivity domain

Q5. According to your knowledge, which are the most relevant indicators for SI assessment within the PRODUCTIVITY domain?
Rank from first to 10th

	first	*second*	*third*	*4th*	*5th*	*6th*	*7th*	*8th*	*9th*	*10th*
Crop yield	○	○	○	○	○	○	○	○	○	○
Post-harvest losses (% losses)	○	○	○	○	○	○	○	○	○	○
Input use intensity (fertilizer, seeds, water, pesticides, water, energy, labor etc)	○	○	○	○	○	○	○	○	○	○
Variability of production (e.g. coefficient of variations across years)	○	○	○	○	○	○	○	○	○	○
Cropping intensity (nr of cropping seasons per year)	○	○	○	○	○	○	○	○	○	○
Input use efficiency (fertilizer, seeds, water, pesticides etc) product per input	○	○	○	○	○	○	○	○	○	○
Yield gap (yield respect to yield potential)	○	○	○	○	○	○	○	○	○	○
Animal production (e.g. milk, meat or eggs)	○	○	○	○	○	○	○	○	○	○
Animal health (e.g. disease incidence, Growth rate, Mortality rate)	○	○	○	○	○	○	○	○	○	○
Pre-harvest losses (% losses)	○	○	○	○	○	○	○	○	○	○

Q6. Are the following indicators for SI assessment easily measurable in your study area?
If you don't directly manage any case study, please, just skip this question.

	Impossible to measure	*Very Hard to measure*	*Somewhat hard to measure*	*Easy to measure*	*Very easy to measure*
Crop yield	○	○	○	○	○
Post-harvest losses (% losses)	○	○	○	○	○
Input use intensity (fertilizer, seeds, water, pesticides, water, energy, labor etc)	○	○	○	○	○
Variability of production (e.g. coefficient of variations across years)	○	○	○	○	○
Cropping intensity (nr of cropping seasons per year)	○	○	○	○	○
Input use efficiency (fertilizer, seeds, water, pesticides etc) product per input	○	○	○	○	○
Yield gap (yield respect to yield potential)	○	○	○	○	○
Animal production (e.g. milk, meat or eggs)	○	○	○	○	○
Animal health (e.g. disease incidence, Growth rate, Mortality rate)	○	○	○	○	○
Pre-harvest losses (% losses)	○	○	○	○	○

Q7. PRODUCTIVITY: What other indicators, not indicated in the previous list, do you think are important to consider for the evaluation of the SI? Please, list them starting from the most important to the least important and, if your institution is responsible for one or more study areas, specify the measurability rate in parentheses (Impossible to measure, Very hard to measure, Somewhat hard to measure, Easy to measure, Very easy to measure).

Section III: Economic domain

Q8. According to your knowledge, which are the most relevant indicators for SI assessment within the ECONOMIC domain?
Rank from first to 10th

	first	second	third	4th	5th	6th	7th	8th	9th	10th
Profitability (Net income, Gross margin, $/crop/ha/season) / Gross margin	○	○	○	○	○	○	○	○	○	○
Variability of profitability (e.g. Coefficient of variation of net income, Probability of low profitability)	○	○	○	○	○	○	○	○	○	○
Income diversification (e.g. Net income, Gross margin, $/crop/ha/season)	○	○	○	○	○	○	○	○	○	○
Returns to land, labour and capital (monetary value of output/input used)	○	○	○	○	○	○	○	○	○	○
Poverty rates (e.g. per capita household consumption expenditure, wealth categorization)	○	○	○	○	○	○	○	○	○	○
Market participation (e.g. % of products sold to the market)	○	○	○	○	○	○	○	○	○	○
Market orientation (e.g. % of land in cash crops)	○	○	○	○	○	○	○	○	○	○
Labour requirement (e.g. hours/ha, farmer rating of labour)	○	○	○	○	○	○	○	○	○	○
Capital access (e.g. benefit/cost)	○	○	○	○	○	○	○	○	○	○
Risk (e.g. Months of available grain stores reported by farmers)	○	○	○	○	○	○	○	○	○	○

Q9. Are the following indicators for SI assessment easily measurable in your study area?
If you don't directly manage any case study, please, just skip this question.

	Impossible to measure	Very Hard to measure	Somewhat hard to measure	Easy to measure	Very easy to measure
Profitability (Net income, Gross margin, $/crop/ha/season) / Gross margin	○	○	○	○	○
Variability of profitability (e.g. Coefficient of variation of net income, Probability of low profitability)	○	○	○	○	○
Income diversification (e.g. Net income, Gross margin, $/crop/ha/season)	○	○	○	○	○
Returns to land, labour and capital (monetary value of output/input used)	○	○	○	○	○
Poverty rates (e.g. per capita household consumption expenditure, wealth categorization)	○	○	○	○	○
Market participation (e.g. % of products sold to the market)	○	○	○	○	○
Market orientation (e.g. % of land in cash crops)	○	○	○	○	○
Labour requirement (e.g. hours/ha, farmer rating of labour)	○	○	○	○	○
Capital access (e.g. benefit/cost)	○	○	○	○	○
Risk (e.g. Months of available grain stores reported by farmers)	○	○	○	○	○

Q10. ECONOMY: What other indicators, not indicated in the previous list, do you think are important to consider for the evaluation of the SI? Please, list them starting from the most important to the least important and, if your institution is responsible for one or more study areas, specify the measurability rate in parentheses (Impossible to measure, Very hard to measure, Somewhat hard to measure, Easy to measure, Very easy to measure).

Section IV: Environmental domain

Q11. According to your knowledge, which are the most relevant indicators for SI assessment within the ENVIRONMENTAL domain?
Rank from first to 9th

	first	*second*	*third*	*4th*	*5th*	*6th*	*7th*	*8th*	*9th*
Vegetation cover (% Vegetation cover by type, % Burned land % Bare land)	○	○	○	○	○	○	○	○	○
Plant biodiversity (e.g. Alpha Diversity Index, n° of species or varieties)	○	○	○	○	○	○	○	○	○
Water quality (e.g. Rating of water quality)	○	○	○	○	○	○	○	○	○
Soil erosion (e.g. Soil loss - tons ha-1 year-1, Rating of erosion, C-value (erosivity), Farmer reported change in soil depth)	○	○	○	○	○	○	○	○	○
Soil biology/Carbon sequestration (e.g. Total carbon (% or Mg/ha), Labile or 'active' carbon (POXC) and/or CO2 mineralization, Partial carbon budget, Earthworms)	○	○	○	○	○	○	○	○	○
Soil nutrients (N, P, etc) (Soil nutrient levels, Nutrient partial balance, Biological nitrogen fixation)	○	○	○	○	○	○	○	○	○
Soil physical quality (Aggregate stability, Bulk density, Water holding capacity, Infiltration rate)	○	○	○	○	○	○	○	○	○
Greenhouse gas emissions (e.g. CO2 equivalent emitted per ha or per kg yield)	○	○	○	○	○	○	○	○	○
Pesticide use (e.g. Active ingredient applied per ha)	○	○	○	○	○	○	○	○	○

Q12. Are the following indicators for SI assessment easily measurable in your study area?
If you don't directly manage any case study, please, just skip this question.

	Impossible to measure	*Very Hard to measure*	*Somewhat hard to measure*	*Easy to measure*	*Very easy to measure*
Vegetation cover (% Vegetation cover by type, % Burned land % Bare land)	○	○	○	○	○
Plant biodiversity (e.g. Alpha Diversity Index, n° of species or varieties)	○	○	○	○	○
Water quality (e.g. Rating of water quality)	○	○	○	○	○
Soil erosion (e.g. Soil loss - tons ha-1 year-1, Rating of erosion, C-value (erosivity), Farmer reported change in soil depth)	○	○	○	○	○
Soil biology/Carbon sequestration (e.g. Total carbon (% or Mg/ha), Labile or 'active' carbon (POXC) and/or CO2 mineralization, Partial carbon budget, Earthworms)	○	○	○	○	○
Soil nutrients (N, P, etc) (Soil nutrient levels, Nutrient partial balance, Biological nitrogen fixation)	○	○	○	○	○
Soil physical quality (Aggregate stability, Bulk density, Water holding capacity, Infiltration rate)	○	○	○	○	○
Greenhouse gas emissions (e.g. CO2 equivalent emitted per ha or per kg yield)	○	○	○	○	○
Pesticide use (e.g. Active ingredient applied per ha)	○	○	○	○	○

Q13. ENIVIRONMENT: What other indicators, not indicated in the previous list, do you think are important to consider for the evaluation of the SI? Please, list them starting from the most important to the least important and, if your institution is responsible for one or more study areas, specify the measurability rate in parentheses (Impossible to measure, Very hard to measure, Somewhat hard to measure, Easy to measure, Very easy to measure).

Section V: Human domain

Q14. According to your knowledge, which are the most relevant indicators for SI assessment within the HUMAN domain?
Rank from first to 5th

	first	*second*	*third*	*4th*	*5th*
Nutritional status (e.g. % protein)	○	○	○	○	○
Nutrition awareness	○	○	○	○	○
Food security (Food production - Calories/ha/year, Days additional food from adopting technology)	○	○	○	○	○
Food safety (Biological contaminants, Mycotoxins (toxicity units per gram), Chemical contaminants, Pesticide contamination, Heavy metal contamination, Physical contaminants, Quantity of rocks per ton of grain)	○	○	○	○	○
Human health (Incidence of zoonotic diseases, Incidence of vector borne diseases)	○	○	○	○	○

Q15. Are the following indicators for SI assessment easily measurable in your study area?
If you don't directly manage any case study, please, just skip this question.

	Impossible to measure	*Very Hard to measure*	*Somewhat hard to measure*	*Easy to measure*	*Very easy to measure*
Nutritional status (e.g. % protein)	○	○	○	○	○
Nutrition awareness	○	○	○	○	○
Food security (Food production - Calories/ha/year, Days additional food from adopting technology)	○	○	○	○	○
Food safety (Biological contaminants, Mycotoxins (toxicity units per gram), Chemical contaminants, Pesticide contamination, Heavy metal contamination, Physical contaminants, Quantity of rocks per ton of grain)	○	○	○	○	○
Human health (Incidence of zoonotic diseases, Incidence of vector borne diseases)	○	○	○	○	○

Q16. HUMAN: What other indicators, not indicated in the previous list, do you think are important to consider for the evaluation of the SI? Please, list them starting from the most important to the least important and, if your institution is responsible for one or more study areas, specify the measurability rate in parentheses (Impossible to measure, Very hard to measure, Somewhat hard to measure, Easy to measure, Very easy to measure).

Section VI: Social domain

Q17. According to your knowledge, which are the most relevant indicators for SI assessment within the SOCIAL domain?
Rank from first to 9th

	first	*second*	*third*	*4th*	*5th*	*6th*	*7th*	*8th*	*9th*
Gender equity (% women - Access to resources, to information, Agency, Achievements, Rating of technologies)	○	○	○	○	○	○	○	○	○
Age equity (% individuals belonging to key groups - Access to resources, to information, Agency, Achievements, Rating or technologies)	○	○	○	○	○	○	○	○	○
Level of collective action (Participation in a collective action group)	○	○	○	○	○	○	○	○	○
Conflicts over resources (e.g. livestock grazing - probability 0-1)	○	○	○	○	○	○	○	○	○
Food self-sufficiency (Reduction in overall time req. to perform agricultural activities)	○	○	○	○	○	○	○	○	○
Ability of farmers to negotiate fair prices	○	○	○	○	○	○	○	○	○
Educational level of farmers	○	○	○	○	○	○	○	○	○
Farmer access to multiple source of information	○	○	○	○	○	○	○	○	○
Farm worker happiness	○	○	○	○	○	○	○	○	○

Q18. Are the following indicators for SI assessment easily measurable in your study area?
If you don't directly manage any case study, please, just skip this question.

	Impossible to measure	*Very Hard to measure*	*Somewhat hard to measure*	*Easy to measure*	*Very easy to measure*
Gender equity (% women - Access to resources, to information, Agency, Achievements, Rating of technologies)	○	○	○	○	○
Age equity (% individuals belonging to key groups - Access to resources, to information, Agency, Achievements, Rating or technologies)	○	○	○	○	○
Level of collective action (Participation in a collective action group)	○	○	○	○	○
Conflicts over resources (e.g. livestock grazing - probability 0-1)	○	○	○	○	○
Food self-sufficiency (Reduction in overall time req. to perform agricultural activities)	○	○	○	○	○
Ability of farmers to negotiate fair prices	○	○	○	○	○
Educational level of farmers	○	○	○	○	○
Farmer access to multiple source of information	○	○	○	○	○
Farm worker happiness	○	○	○	○	○

Q19. SOCIAL: What other indicators, not indicated in the previous list, do you think are important to consider for the evaluation of the SI? Please, list them starting from the most important to the least important and, if your institution is responsible for one or more study areas, specify the measurability rate in parentheses (Impossible to measure, Very hard to measure, Somewhat hard to measure, Easy to measure, Very easy to measure).

Annex IV:

Refinement of the set of indicators to be measured for the selected technologies

Neglected and Underutilized crop species

Table 1 - Partners involved in field trials related to the technology: Neglected and Underutilized Crop species, details of treatments and crops tested.

Partner	Country	Crops
ACRA	BF	Fonio/cowpea
CSIR-SARI	GH	Frafra Potato/cowpea
KDC	GH	Fonio/cowpea
HU	ET	Enset/common beans
JU	ET	Teff/Lima beans
TARI	TZ	Finger millet/lablab
UoN	KY	Finger millet/groundnuts
KALRO	KY	Finger millet/groundnuts

NUS in intercropping

Table 2 - Details related to the indicators selected within each of the five domains for the technology: NUS in intercropping.

Domain	Indicators
Productivity	**1) Land Equivalent Ratio Index** (LER): is the sum of the fractions of the intercropped yields divided by the sole-crop yield and describes the relative land area required under sole cropping to produce the same yield as under intercropping. Data on the yield (possibly in dry matter basis) of each single crop (both NUS and all the others) in monocropping and intercropping. The control should be the business as usual practice that could be intercropping with another crop instead of NUS or monocropping. **2) Input use intensity**: amount of inputs (fertilizers, agro-chemicals, seeds etc.) per cropping season per crop (for all crops of the cropping systems) per unit area. **3) Input use efficiency:** ratio between crop yield and amount of input supplied (if possible ratio between harvested input, i.e. N or P concentration in the harvested biomass that will require lab analysis, and amount of input supplied) for all the crops in the cropping system. **4) Crop residue biomass** (in dry matter basis): for each crop of the cropping system with and without NUS (business as usual).
Environment	**1) Crop and varietal diversity**: number of crops/varieties (within crop) per unit area per cropping season. **2) Agrochemicals use** (for weed control and pest and disease control): amount of active ingredient applied per unit area per cropping season for the entire cropping system (e.g. mg/ml m^{-2}/ha^{-1}/$acre^{-1}$) and application frequency. **3) Soil fertility** (at least mineral N, available P contents): at the beginning of the cropping season and at the end of the cropping season in the business as usual and in the cropping system with NUS. **4) Crop residues use**: for each crop of the cropping system indicate the fate of the crop residues (e.g. incorporated into the soil, used for animal feeding, burned, or other uses - specify) in the business as usual and in the cropping system with NUS.

Domain	Indicators
Economy	**1) Net margin (profit):** the difference between revenue and production cost (plot and farm scales). Revenue is the product of the unit price of the product and the quantity of the product produced. Production cost is the sum of all product of all inputs used and their respective quantities used (profit = revenue-production cost). **2) Profit prevalence rate:** the probability of the plot or farm being profitable. It is the ratio of the number of profitable farms to the total number of sample farms expressed as a percentage (plot and farm scales). **3) Returns to labour**: it is the ratio of the monetary value of the output obtained to input used (output per unit of input used (labour) (plot and farm scales). **4) Benefit cost ratio**: ratio of total benefits to total cost.
Social	**1) Gender equity**: WEAI pre and post implementation of the technology. **2) Technology ranking per gender** (in case more than one technology is tested/adopted by farmers). **3) Technology satisfaction per gender:** Satisfaction with the technology (Likert scale from 1 to 3) and reasons why (predetermined answers related to sub indicators).
Human	**1) Food security:** number of calories produced by each crop in business as usual and in the cropping system with NUS (please collect info on the composition of the household per age and per gender). **2) Nutrition: macro nutrients (carbohydrates, proteins and fats):** produced by each crop per unit area per cropping season in the business as usual and in the cropping system with NUS. **3) Months of food insecurity:** both in the business as usual, in the cropping system with NUS and in the business as usual. Specific question on the months of food insecurity before and after NUS (rating of food security by farmers). **4) Food safety:** chemical contamination due to the use of agro-chemicals (see environmental indicators n°2).

NUS in rotation

Table 3 - Details related to the indicators selected within each of the five domains for the technology: NUS in rotation.

Domain	Indicators
Productivity	**1) Variation (%) between the overall production per unit area per cropping season of the entire cropping system** (NUS plus other crops). The business as usual system, i.e. the crop rotation without NUS, is the control. **2) Variation (%) between the yield of the main staple crop (e.g., maize)** with or without NUS as preceding crop. **3) Input use intensity**: amount of inputs (fertilizers, agro-chemicals, seeds) per cropping season per crop (for all crops in the rotation) of the cropping systems) per unit area. **3) Input use efficiency**: ratio between crop yield and amount of input supplied (if possible ratio between harvested input (i.e. N or P concentration in the harvested biomass that will require lab analysis) and amount of input supplied) for all the crops in the rotation. **4) Crop residue biomass** (in dry matter basis): for each crop of the cropping system with and without NUS.
Environment	**1) Crop and varietal diversity**: number of crops/varieties (within crop) per unit area per cropping season. **2) Agrochemicals use** (for weed control and pest and disease control): amount of active ingredient applied per unit area per cropping season for the entire cropping system (e.g. mg/ml m^{-2}/ha^{-1}/$acre^{-1}$) and application frequency. **3) Soil fertility** (at least mineral N, available P contents): at the beginning of the cropping season and at the end of the cropping season in the business as usual and in the cropping system with NUS. **4) Crop residues use**: for each crop of the cropping system indicate the fate of the crop residues (e.g. incorporated into the soil, used for animal feeding, burned, or other uses - specify) in the business as usual and in the cropping system with NUS.
Economy	**1) Net margin (profit):** the difference between revenue and production cost (plot and farm scales). Revenue is the product of the unit price of the product and the quantity of the product produced. Production cost is the sum of all product of all inputs used and their respective quantities used (profit = revenue-production cost). **2) Profit prevalence rate:** the probability of the plot or farm being profitable. It is the ratio of the number of profitable farms to the total number of sample farms expressed as a percentage (plot and farm scales). **3) Returns to labour**: It is the ratio of the monetary value of the output obtained to input used (output per unit of input used (labour) (plot and farm scales) **4) Benefit cost ratio**: ratio of total benefits to total cost.
Social	**1) Gender equity**: WEAI pre and post implementation of the technology. **2) Technology ranking per gender** (in case more than one technology is tested/adopted by farmers). **3) Technology satisfaction per gender:** Satisfaction with the technology (Likert scale from 1 to 3) and reasons why (predetermined answers related to sub indicators).

Domain	Indicators
Human	**1) Food security:** number of calories produced by each crop in business as usual and in the cropping system with NUS (please collect info on the composition of the household per age and per gender). **2) Nutrition:** macro nutrients (carbohydrates, proteins and fats) produced by each crop per unit area per cropping season in the business as usual and in the cropping system with NUS. **3) Months of food insecurity:** both in the business as usual, in the cropping system with NUS and in the business as usual. Specific question on the months of food insecurity before and after NUS (rating of food security by farmers) **4) Food safety: c**hemical contamination due to the use of agro-chemicals (see environmental indicators n°2)

Organic fertilization

Table 4 - Partners involved in field trials related to the technology: Organic fertilization, details of treatments and crops tested.

Partner	Country	Crops
CSIR-SARI	GH	Sorghum (cv. Kapala); millet (cv. WAAPP Naara)
KDC	GH	Maize (cv. sanzal suma)
ACRA	BF	Fonio
UNB and INERA	BF	Sorghum (Sariasso 01) and ii) maize (Espoir, SR 21).
UNB and INERA	BF	Cotton, sorghum and maize
TARI	TZ	Maize
KALRO	KY	Finger millet, sorghum, maize
UoN	KY	Sorghum, maize rotated with groundnuts

Table 5 - Details related to the indicators selected within each of the five domains for the technology: Organic fertilization.

Domain	Indicators
Productivity	**1) Variation (%) between the overall yield per unit area per cropping season of the entire cropping system** (all the crops) comparing the business as usual system (business as usual fertilization practice) and the organic fertilization. **2) Input use intensity**: amount of inputs (inorganic fertilizers, agro-chemicals, seeds) per cropping season per crop (for all crops in the cropping systems per unit area. **3) Input use efficiency**: ratio between crop yield and amount of input supplied (if possible ratio between harvested input (i.e. N or P concentration in the harvested biomass that will require lab analysis) and amount of input supplied) for all the crops in the cropping systems. **4) Crop residue biomass** (dry matter): for each crop of the cropping system with the organic fertilizer and in the business as usual.
Environment	**1) Agrochemicals** (for weed control and pest and disease control) use: Amount of active ingredient applied per unit area per cropping season for the entire cropping system (e.g. mg/ml m^{-2}/ha^{-1}/$acre^{-1}$) and application frequency. **2) Pest and disease incidence:** scoring. **3) Soil fertility** (at least mineral N, available P contents): at the beginning of the cropping season and at the end of the cropping season in the business as usual and in cropping system with the organic fertilizer. **4) Crop residues use**: For each crop of the cropping system indicate the fate of the crop residues (incorporated into the soil, used for animal feeding, burned, other uses - specify) in the business as usual and in the cropping system with the organic fertilizer and in the business as usual. **5) GHG emission** (with Dssat UNISS): data on climate, soil and crop management.
Economy	**1) Net margin (profit):** the difference between revenue and production cost (plot and farm scales). Revenue is the product of the unit price of the product and the quantity of the product produced. Production cost is the sum of all product of all inputs used and their respective quantities used (profit = revenue-production cost). **2) Profit prevalence rate:** the probability of the plot or farm being profitable. It is the ratio of the number of profitable farms to the total number of sample farms expressed as a percentage (plot and farm scales). **3) Returns to labour**: It is the ratio of the monetary value of the output obtained to input used (output per unit of input used (labour) (plot and farm scales). **4) Benefit cost ratio**: ratio of total benefits to total cost.

Domain	Indicators
Social	**1) Technology ranking per gender** (in case more than one technology is tested/adopted by farmers). **2) Technology satisfaction per gender:** Satisfaction with the technology (Likert scale from 1 to 3) and reasons why (predetermined answers related to sub indicators).
Human	**1) Food security:** number of calories produced by each crop in business as usual and in the cropping system with the organic fertilizer (please collect info on the composition of the household per age and per gender). **2) Nutrition:** macro nutrients (carbohydrates, proteins and fats) produced by each crop per unit area per cropping season in the business as usual and in the cropping system with the organic fertilizer. **3) Months of food insecurity:** both in the business as usual, in the cropping system with the organic fertilizer and in the business as usual. Specific question on the months of food insecurity before and after the organic fertilizer treatment (rating of food security by farmers). **4) Food safety:** chemical contamination due to the use of agro-chemicals (see environmental indicators n°2)

Water harvesting

Table 6 - Partners involved in field trials related to the technology: Water harvesting, details of treatments and crops tested.

Partner	Country	Treatment details	Crops
ACRA	BF	Zai pits: typical of the central plateau in BF (Ouagadougou)	Millet
CSIR-SARI & KDC	GH	Stone-bunds: traditional in northern Ghana	Maize
TARI	TZ	Zai pits (chololo)	Maize

Table 7 - Details related to the indicators selected within each of the five domains for the technology: Water harvesting

Domain	Indicators
Productivity	**1) Variation (%) between the overall yield per unit area per cropping season of the entire cropping system** (all the crops) comparing the business as usual system (business as usual water harvesting practice or no water harvesting practice) and the tested water harvesting practice. **2) Input use intensity**: amount of inputs (fertilizers, agro-chemicals, seeds) per cropping season per crop (for all crops in the cropping systems per unit area. **3) Input use efficiency (water)**: ratio between crop yield and amount of input supplied (if possible ratio between harvested input (i.e. N or P concentration in the harvested biomass that will require lab analysis) and amount of input supplied) for all the crops in the cropping systems. **4) Crop residue biomass** (dry matter) for each crop of the cropping system with the organic fertilizer and in the business as usual **5) Crop cycle up to the harvesting** (anticipation or delay of the crop cycle). **6) Weed competition.** **7) Water competition.**
Environment	**1) Soil erosion:** it can be collected in a qualitative way (e.g. scoring, survey, focus groups). **2) Crop residues use**: For each crop of the cropping system indicate the fate of the crop residues (incorporated into the soil, used for animal feeding, burned, other uses - specify) in the business as usual and in the cropping system with the organic fertilizer and in the business as usual.
Economy	**1) Net margin (profit):** the difference between revenue and production cost (plot and farm scales). Revenue is the product of the unit price of the product and the quantity of the product produced. Production cost is the sum of all product of all inputs used and their respective quantities used (profit = revenue-production cost). **2) Profit prevalence rate:** the probability of the plot or farm being profitable. It is the ratio of the number of profitable farms to the total number of sample farms expressed as a percentage (plot and farm scales). **3) Returns to labour**: It is the ratio of the monetary value of the output obtained to input used (output per unit of input used (labour) (plot and farm scales) **4) Benefit cost ratio**: ratio of total benefits to total cost.
Social	**1) Technology ranking per gender** (in case more than one technology is tested/adopted by farmers) **2) Technology satisfaction per gender:** Satisfaction with the technology (Likert scale from 1 to 3) and reasons why (predetermined answers related to sub indicators)

Domain	Indicators
Human	**1) Food security:** number of calories produced by each crop in business as usual and in the cropping system with the water harvesting technique (please collect info on the composition of the household per age and per gender). **2) Nutrition:** macro nutrients (carbohydrates, proteins and fats) produced by each crop per unit area per cropping season in the business as usual and in the cropping system with water harvesting technique. **3) Months of food insecurity:** both in the business as usual, in the cropping system with the organic fertilizer and in the business as usual. Specific question on the months of food insecurity before and after the water harvesting technique (rating of food security by farmers).

Bio-pesticides

Table 8 - Partners involved in field trials related to the technology: Bio-pesticides, details of treatments and crops tested.

Partner	Country	Treatment details	Crops
INERA	BF	BATIK (Bacillus thuringiensis); application of **Cassia nigricans extract + pepper + shea butter**	Cotton
INERA	BF	***Cassia nigricans* Vahl** extract, releases of ***Phonoctonus lutescens.***	Cotton
INERA	BF	**Neem** oil and Nanotechnology innovation, ***Phonoctonus lutescens*** [endemic natural enemy of Dysdercus sp.] + synthetic pesticide	Cotton
ACRA	BF	***Cassia nigricans* Vahl extract, Neem extract**	Cowpea
INERA	BF	Essential oil biopesticides **(Lirane (made with *Lippia multiflora*), Ocirane *(Occimum americanum)* and *Chirane (Cymbopogon* shoananthus))** (post-harvest: TBC)	Cereals and legumes
KDC	GH	**Neem** oil extract and ***Securidaca longipedunculata* Fresen, root extract**	Cowpea
CSIR-SARI	GH	**Neem** seed oil (NSO), Emastar 112 EC (synthetic insecticide) and no spray, while sub-plots contained sole maize, maize + groundnut and maize + soybean.	Maize, groundnuts and soybean
CSIR-SARI	GH	Demonstration on the field efficacy of **neem** extracts for fall armyworm (FAW)	Maize
TARI	TZ	home-made bio-pesticide (**mixture of pepper (*Capsicum* sp.), Tephrosia vogelii (fish bean) and Neem (*Azadirachta indica* A.Juss.)** and synthetic pesticide (MultiAlpha)	Lab Lab Bean (*Dolichos lablab* L.) and common bean
HU	ET	Biological control of pepper wilt. Treatments: **Trichoderma T22 /commercial, Trichoderma sp. (native), ApronStar/chemical control, Thiamethoxam, Metalaxyl–M, Difenoconazole, Sterile water/untreated control**	Hot papper

Table 9 - Details related to the indicators selected within each of the five domains for the technology: Bio-pesticides.

Domain	Indicators
Productivity	**1) Variation (%) between the overall yield per unit area for all crops in the cropping systems** comparing the business as usual (business as usual pest management practice) and the use of bio-control tools. **2) Input use intensity**: amount of inputs (agro-chemicals) per cropping season per crop (for all crops in the cropping systems per unit area); **3) Crop residue biomass** (dry matter) for each crop of the cropping system with the organic fertilizer and in the business as usual
Environment	**1) Agrochemicals** (for pest/disease control) use: Amount of active ingredient applied per unit area per cropping season for the entire cropping system (e.g. mg/ml m^{-2}/ha^{-1}/$acre^{-1}$) and application frequency. **2) Pest/disease incidence:** scoring. **3) Crop residues use**: For each crop of the cropping system indicate the fate of the crop residues (incorporated into the soil, used for animal feeding, burned, other uses - specify) in the business as usual and in the cropping system with the organic fertilizer and in the business as usual.

Domain	Indicators
Economy	**1) Net margin (profit):** the difference between revenue and production cost (plot and farm scales). Revenue is the product of the unit price of the product and the quantity of the product produced. Production cost is the sum of all product of all inputs used and their respective quantities used (profit = revenue-production cost). **2) Profit prevalence rate:** the probability of the plot or farm being profitable. It is the ratio of the number of profitable farms to the total number of sample farms expressed as a percentage (plot and farm scales). **3) Returns to labour**: It is the ratio of the monetary value of the output obtained to input used (output per unit of input used (labour) (plot and farm scales). **4) Benefit cost ratio**: ratio of total benefits to total cost.
Social	**1) Technology ranking per gender** (in case more than one technology is tested/adopted by farmers). **2) Technology satisfaction per gender:** Satisfaction with the technology (Likert scale from 1 to 3) and reasons why (predetermined answers related to sub indicators).
Human	**1) Food security:** number of calories produced by each crop in business as usual and in the cropping system with the bio-pesticide treatment (please collect info on the composition of the household per age and per gender). **2) Nutrition:** macro nutrients (carbohydrates, proteins and fats) produced by each crop per unit area per cropping season in the business as usual and in the cropping system with the bio-pesticide treatment. **3) Months of food insecurity:** both in the business as usual, in the cropping system with the bio-pesticide treatment and in the business as usual. Specific question on the months of food insecurity before and after the bio-pesticide treatment (rating of food security by farmers). **4) Food safety:** chemical contamination due to the use of agro-chemicals (see environmental indicators n°2).

Aflasafe

Table 10 - Partners involved in field trials related to the technology: Aflasafe, details of treatments and crops tested.

Partner	Country	Details	Crops
CSIR-SARI	GH	Main factor: fertilizer type (NPK and YaraActyva), sub plot factor was inoculant application (control, **Aflasafe**), sub-sub plot factor: harvest interval (90, 100, 110 and 120 days after planting).	Maize
CSIR-SARI	GH	Factor A: variety (SARINUT 2 and Yenyawaso), Factor B: Mineral fertilizer (Yara Legume, TSP, control), and Factor C: application of inoculants (Rhizobia inoculant, **AflasafeTM**, and control)	Groundnuts
KALRO	KY	**Aflasafe** KE01 for management of mycotoxins in maize, finger millet and groundnuts in western Kenya	Maize, finger millet and groundnuts

Table 11 - Details related to the indicators selected within each of the five domains for the technology: Aflasafe.

Domain	Indicators
Productivity	**1) Variation (%) between the overall edible yield with aflatoxin content below the max limit** (for treated crops) comparing the business as usual system (non-use of Aflasafe) with the Aflasafe treatment. **2) Input use intensity**: amount of inputs (agro-chemicals) per cropping season per crop (for the tested crops per unit area. **3) Input use efficiency**: ratio between crop yield and amount of input supplied (if possible ratio between harvested input (i.e. N or P concentration in the harvested biomass that will require lab analysis) and amount of input supplied) for all the crops in the cropping systems. **4) Crop residue biomass** (dry matter) for the treated crop with the Aflasafe and in the business as usual.
Environment	1) **Agrochemicals** use (for disease control): Amount of active ingredient applied per unit area per cropping season for the entire cropping system (e.g. mg/ml $m^{-2}/ha^{-1}/acre^{-1}$) and application frequency. **2) Crop residues use**: For the tested crop indicate the fate of the crop residues (incorporated into the soil, used for animal feeding, burned, other uses - specify) in the business as usual and in the treatment with Aflasafe.
Economy	**1) Net margin (profit):** the difference between revenue and production cost (plot and farm scales). Revenue is the product of the unit price of the product and the quantity of the product produced. Production cost is the sum of all product of all inputs used and their respective quantities used (profit = revenue-production cost). **2) Profit prevalence rate:** the probability of the plot or farm being profitable. It is the ratio of the number of profitable farms to the total number of sample farms expressed as a percentage (plot and farm scales). **3) Returns to labour**: It is the ratio of the monetary value of the output obtained to input used (output per unit of input used (labour) (plot and farm scales). **4) Benefit cost ratio**: ratio of total benefits to total cost. **5) Crop diversification:** The number of crop enterprises per farm/household (farm and household scale).

Domain	Indicators
Social	**1) Technology ranking per gender** (in case more than one technology is tested/adopted by farmers). **2) Technology satisfaction per gender:** Satisfaction with the technology (Likert scale from 1 to 3) and reasons why (predetermined answers related to sub indicators).
Human	**1) Food safety:** Aflatoxin contamination. Toxicity unit per gram of the interested/targeted crop. **2) Food security:** number of calories produced by each crop in business as usual and in the cropping system with the Aflasafe treatment (please collect info on the composition of the household per age and per gender). **3) Nutrition:** macro nutrients (carbohydrates, proteins and fats) produced by each crop per unit area per cropping season in the business as usual and in the cropping system with the Aflasafe treatment. **4) Months of food insecurity:** both in the business as usual, in the cropping system with the Aflasafe treatment and in the business as usual. Specific question on the months of food insecurity before and after the Aflasafe treatment (rating of food security by farmers). **5) Human and animal health (TBC):** aflatoxin level in the diet – proxy: incidence of aflatoxin associated disease (cancer etc.). Literature data, expert knowledge.