Original Scientific paper
10.7251/AGRENG2302012E
UDC 631/635

ASSESSMENT OF THE SUSTAINABILITY OF NEGLECTED AND UNDERUTILISED CROP SPECIES: SUSTLIVES APPROACH

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ABSTRACT

There are different approaches and frameworks for the assessment of sustainability in agriculture and food systems, but only a few of them focus on crops. This gap is even more evident when it comes to the so-called neglected and underutilised species (NUS). To bridge this gap, the present paper describes an approach for the assessment of the environmental, social and economic sustainability of NUS developed within the project SUSTLIVES (Sustaining and improving local crop patrimony in Burkina Faso and Niger for better lives and ecosystems). The indicators identified through a literature review, based on the Web of Science, have been integrated with other indicators used for sustainability evaluation in the agri-food sector. Based on that, a sustainability assessment approach (list of indicators, evaluation methods and units; scoring system and mode of aggregation of scores; reference crops for the selected NUS) was developed. Then, two workshops were organized in Niamey (January 2023) and Ouagadougou (February 2023) to validate the sustainability assessment approach. The validated sustainability assessment matrix contains 27 indicators divided into different themes covering the three dimensions of sustainability: environmental (environmental integrity, agronomic performance and productivity), social (cultural importance and relevance, nutritional quality and diversity, employment, equity and accessibility) and economic (competitiveness, profitability). A scoring system was proposed for each indicator; from 0 (unsustainable) to 10 (very sustainable) with 5 corresponding to the sustainability benchmark value. Besides sustainability assessment, the developed approach allows selecting the NUS with the highest potential in view of their promotion and the development of their value chains.

Keywords: *orphan crop, NUS, indicator, scoring system, sustainability benchmark.*

INTRODUCTION

Sustainability in agriculture and food systems can be assessed using different approaches and frameworks (Alaoui et al., 2022). These include Value Chain Analysis for Development (Fabre et al., 2021), Common agricultural policy performance indicators (European Commission, 2022), indicators described in SUSAGRI (Sustainable development in agriculture) project (Yli-Viikari, 1999), OECD Compendium of Agri-environmental Indicators (OECD, 2013), Response-Inducing Sustainability Evaluation (RISE) framework (Häni et al., 2003), Multi-attribute Assessment of Sustainability of Cropping Systems (MASC) (Sadok et al., 2009), Land Degradation Assessment in Drylands (LADA) framework (Nachtergaele et al., 2010), Sustainability Monitoring and Assessment RouTine (SMART) framework (Landert et al., 2020), Public goods (PG) framework (Gerrard et al., 2012), Farmer Sustainability Index (FSI) (Gayatri et al., 2016), Sustainability Assessment of Farming and the Environment (SAFE) framework (van Cauwenbergh et al., 2007), SALCAsustain method (Roesch et al., 2021), and *Indicateurs de Durabilité des Exploitations Agricoles* (IDEA)/Farm Sustainability Indicators method (Zahm et al., 2006). However, the assessment is usually not on the crop level and frameworks relate to the agricultural sector, countries, value chains, farms or others. This gap is even more evident when it comes to the so-called neglected and underutilised species (NUS).

NUS – also known as orphan crops (Padulosi, 2017) – represent tens of thousands of plant species (Chivenge et al., 2015) that are suitable for human nutrition. NUS are widely claimed to contribute to sustainability and sustainable development (El Bilali et al., 2023b) as they can help addressing environmental degradation, food and nutrition insecurity, water scarcity, poverty and climate change (El Bilali et al., 2023a; Mabhaudhi et al., 2019). NUS contribute to climate-resilient food systems (Mabhaudhi et al., 2019), conservation of agro-biodiversity and agro-ecosystems (Padulosi et al., 2013), reduction of environmental contamination from agriculture (Mabhaudhi et al., 2019), food and nutrition security, especially in developing countries (Mabhaudhi et al., 2019; Padulosi et al., 2013; Ulian et al., 2020) and rural livelihoods (El Bilali et al., 2023a; Kour et al., 2018; Padulosi et al., 2013). Therefore, Mabhaudhi et al. (2016) argue that the promotion of NUS could contribute to the achievement of the Sustainable Development Goals (SDGs). However, it is still difficult to assess the sustainability potential of NUS due to the lack of a specific framework. Following a review on the assessment of the sustainability of NUS, El Bilali et al. (2022) stated "*One of the main results of this analysis is that there is a dearth of quality scholarly documents that deal with the assessment of the sustainability of NUS. This is rather surprising and largely unexpected given the ongoing rhetoric on the enhancement and development of*

NUS and their value chains to address different challenges such as biodiversity loss, climate change, food insecurity and malnutrition, poverty and livelihoods vulnerability" (p. 27). To bridge this gap, the present paper describes a matrix for the assessment of the environmental, social and economic sustainability of NUS developed within the project SUSTLIVES (*SUSTaining and improving local crop patrimony in Burkina Faso and Niger for better LIVes and EcoSystems*).

MATERIAL AND METHODS

This work was carried out within the project SUSTLIVES in Burkina Faso and Niger (SUSTLIVES, 2023). The project focuses on six NUS in each country (SUSTLIVES, 2022):

- Burkina Faso: Sweet potato, Hausa potato/Fabirama, roselle, moringa, amaranth and Bambara groundnut/voandzou.
- Niger: Sweet potato, cassava, roselle, moringa, okra and Bambara groundnut/voandzou.

A first draft of the sustainability assessment matrix was developed based on a review of the literature (El Bilali et al., 2022). After that, the matrix draft was integrated with indicators from other sustainability assessment frameworks and approaches. These were mainly proposed by experts or retrieved from the literature. They include the Sustainability Assessment of Food and Agriculture systems (SAFA) framework (FAO, 2013, 2014), the Sustainability assessment framework developed within the Agriculture and Quality project in Apulia region (South-Eastern Italy) (Capone et al., 2016; El Bilali et al., 2020) and FAOSTAT (FAO, 2022). The selected indicators were required to be specific to the NUS (therefore they should be calculated/assessed for each crop/NUS; indicators regarding for example farms, households or food systems were excluded), easily measurable using available secondary data (indicators whose measurement requires a specific survey, trial or elaborated, demanding data collection were excluded), appropriate for NUS and the contexts of Burkina Faso and Niger, and relevant for the assessment of environmental, economic or social sustainability.
From the data collected, a sustainability evaluation matrix was developed. Then, two workshops were organized in Niamey – Niger (January 2023) and Ouagadougou – Burkina Faso (February 2023) to finalize and validate the matrix (Figure 1). At each workshop, there was first a presentation of the proposed NUS sustainability assessment approach followed by the presentation and discussion of each of the components of the approach (viz. list of indicators and units, scoring system and reference crops). Each workshop was attended by around twenty experts. Experts in the agri-food sector covered the environmental, social and economic dimensions of sustainability.

Figure 1. Workshop in Ouagadougou (Burkina Faso) to validate the sustainability assessment approach.

As for the operationalisation and contextualization of the proposed sustainability assessment approach, in line with Capone et al. (2016) and El Bilali et al. (2020), the developed assessment matrix uses equal weighting for indicators within themes as well as for themes within each sustainability dimension, and arithmetic averages for aggregating the scores of both indicators and themes. A rating and scoring system is developed for each indicator; from 0 (unsustainable) to 10 (very sustainable) with 5 corresponding to the sustainability benchmark value (value of the nearest exemplar crop or reference crop). A NUS is considered sustainable if it has an average score of 5/10 or higher. The calculation of the benchmark of each indicator for each crop is fundamental for sustainability assessment. Indeed, the level of sustainability of a NUS is assessed relative to a reference crop (Dawson et al., 2019). The reference crop is chosen from the main crops in each country within the group of the selected NUS (viz. roots/tubers, vegetables, legumes) and taking into account the product uses.

RESULTS AND DISCUSSION

The validated sustainability assessment matrix – with sustainability dimensions, themes, and indicators set with description and units – is presented in Table 1. It contains 27 indicators divided into themes covering the three dimensions of sustainability: environmental (environmental integrity, agronomic performance and productivity), social (cultural importance and relevance, nutritional quality and diversity, employment, equity and accessibility) and economic (competitiveness, profitability).

Table 1. SUSTLIVES matrix for the assessment of the environmental, social and economic sustainability of NUS.

Dimension	Theme	Indicator	Description and unit
Environmental (Env)	Env1. Environmental integrity	Env1.1 Nitrogen requirement	Quantity of nitrogen needed during a growing season per ha (kg/ha).
		Env1.2 Phosphorus requirement	Quantity of phosphorus needed during a growing season per ha (kg/ha).
		Env1.3 Pesticide requirement	Quantity of fungicides, insecticides and other plant protection products needed during a growing season per ha (kg/ha).
		Env1.4 Water demand	Volume of water needed during a growing season per ha (m^3/ha).
		Env1.5 Crop evapotranspiration	Crop evapotranspiration under standard conditions (ETc) in each country (m^3/ha/day).
		Env1.6 Genetic diversity	Number of known varieties.
		Env1.7 Nitrogen fixation	Amount of nitrogen fixed by the crop during a growing season per ha (kg/ha).
	Env2. Agronomic performance and productivity	Env2.1 Yield	Production during a growing season (t/ha). For crops with staggered harvest, this represents cumulative production, of the main product, over the whole growing season.
		Env2.2 Length of the growing season	Duration of the growing season till the harvest (days). For crops with staggered harvest, this represents the time to the first harvest.
		Env2.3 Growing degree days	Modified growing degree days (GDD), taking into consideration both lower and higher baseline temperatures, till maturity or first harvest (°C).
		Env2.4 Level of tolerance to salinity	Maximum level of soil salinity tolerated by the crop (dS/m).
		Env2.5 Level of tolerance to high temperatures	Maximum temperature tolerated by the crop without significant damages (°C).
		Env2.6 Level of tolerance/resistance to pests and diseases	Number of known key pests, diseases and parasitic plants.
		Env2.7 Seed	Quantity of seeds and planting material

		availability	available in the country on a yearly basis (Tons).
		Env2.8 Seed suitability	Number of domestic varieties, adapted to local conditions, available in the country.
		Env2.9 Seed quality	Number of improved/certified varieties available in the country.
Social (S)	S1. Cultural significance and relevance	S1.1 Number of documented uses	Number of categories of uses documented (human food, technology/tool, medicinal, firewood, animal feed, symbolic/religious/cultural uses, textile, cosmetic).
	S2. Nutritional quality and diversity	S2.1 Content of bioactive and health-promoting compounds	Content (g/kg of fresh produce) of proteins, fibres, vitamins and minerals (potassium, phosphorus, magnesium, calcium and iron).
		S2.2 Protein content	Content of proteins (% of fresh produce).
		S2.3 Duration of fresh produce conservation	Number of days, from harvest, of conservation and storage of produce in ambient conditions without significant deterioration of its quality or its loss.
	S3. Employment	S3.1 Labour requirement	Number of working days per growing season (person-days/ha).
	S4. Equity and fair accessibility	S4.1 Seed access	Seed price during the main planting/sowing period (EUR/ton).
Economic (Econ)	Econ1. Competitiveness	Econ1.1 Price	Producer price of fresh produce, unprocessed products (EUR/ton).
		Econ1.2 Market demand	Consumption in the country (kg/capita/year). Food supply (cf. Food balance sheets of FAO) can be used as a proxy.
		Econ1.3 Production cost	Cost of production for a growing season (EUR/ha).
	Econ2. Profitability	Econ2.1 Gross profit margin	Gross margin for a growing season (EUR/ha). It is the difference between income from product sales and variable costs.
		Econ2.2 Income	Net income for a growing season (EUR/ha). It is the difference between total income and total expenses.

To implement the sustainability assessment matrix, in line with Capone et al. (2016) and El Bilali et al. (2020), the scores of the indicators (not absolute values) are aggregated to obtain an overall score on the performance/sustainability of a NUS (Table 2).

Table 2. Methods of calculation of average scores for sustainability themes and dimensions as well as the overall sustainability score for each NUS.

Score type	**Calculation formula**
Sustainability theme score	*Score Theme I = sum of scores of all indicators of the theme I / number of indicators of the theme I*
Sustainability dimension score	*Score Dimension J = sum of average scores of all themes of the dimension J / number of themes of the dimension J*
NUS overall sustainability score	*Overall sustainability score of NUS N = sum of scores of environmental, social and economic dimensions for NUS N / 3*

To better understand how the scoring system is applied to indicators, an example is provided in Table 3. It distinguishes between 'positive indicators' and 'negative indicators'. For 'positive indicators', there is a positive correlation between the indicator value and its sustainability score i.e. sustainability score increases with indicator value (e.g. yield). Whereas in the case of 'negative indicators', there is a negative correlation between the indicator value and its sustainability score i.e. sustainability score decreases with the increase of the indicator value (e.g. nitrogen requirement).

Table 3. Example of a scoring system applied to a 'positive indicator' and a 'negative indicator'.

Positive indicator			**Negative indicator**		
Indicator value (IV) intervals	Interval central point	Sustainability score	Indicator value (IV) intervals	Interval central point	Sustainabilit y score
IV < IB - 90% IB	-100%	0	IV > IB + 90% IB	+100%	0
IB - 70% IB < IV ≥ IB - 90% IB	-80%	1	IB + 70% IB < IV ≥ IB + 90% IB	+80%	1
IB - 50% IB < IV ≥ IB - 70% IB	-60%	2	IB + 50% IB < IV ≥ IB + 70% IB	+60%	2
IB - 30% IB < IV ≥ IB - 50% IB	-40%	3	IB + 30% IB < IV ≥ IB + 50% IB	+40%	3
IB - 10% IB < IV ≥ IB - 30% IB	-20%	4	IB + 10% IB < IV ≥ IB + 30% IB	+20%	4
Indicator benchmark (IB) +/- 10% IB	0	5	Indicator benchmark (IB) +/- 10% IB	0	5
IB + 10% IB > IV ≤ IB + 30% IB	+20%	6	IB - 10% IB > IV ≤ IB - 30% IB	-20%	6

Positive indicator			Negative indicator		
IB + 30% IB > IV ≤ IB + 50% IB	+40%	7	IB - 30% IB > IV ≤ IB - 50% IB	-40%	7
IB + 50% IB > IV ≤ IB+ 70% IB	+60%	8	IB - 50% IB > IV ≤ IB - 70% IB	-60%	8
IB + 70% IB > IV ≤ IB + 90% IB	+80%	9	IB - 70% IB > IV ≤ IB - 90% IB	-80%	9
IV > IB + 90% IB	+100%	10	IV > IB - 90% IB	-100%	10

IB: Indicator benchmark. IV: Indicator value.

A reference crop was identified for each NUS and in each country, and co-validated during the workshops (Table 4).

Table 4. List of the reference crops for NUS selected within SUSTLIVES project.

Country	**NUS selected**	**Reference crop**
Niger	Sweet potato (*Ipomoea batatas*)	Potato
	Cassava (*Manihot esculenta*)	Potato
	Roselle (*Hibiscus sabdariffa*)	Cabbage
	Moringa (*Moringa oleifera*)	Cabbage
	Okra (*Abelmoschus esculentus*)	Pepper
	Bambara groundnut (*Vigna subterranea*)	Cowpea
Burkina Faso	Sweet potato (*Ipomoea batatas*)	Potato
	Fabirama (*Solenostemon rotundifolius*)	Potato
	Roselle (*Hibiscus sabdariffa*)	Cabbage
	Moringa (*Moringa oleifera*)	Cabbage
	Amaranth (*Amaranthus sp.*)	Spinach
	Bambara groundnut (*Vigna subterranea*)	Cowpea

The determination of the reference crop allows calculating the benchmark and developing the scoring scale for each indicator. For example, in the case of potato, the scoring scale for the yield indicator is provided in table 5. The benchmark values are the average potato yields (PY) in Burkina Faso (111832 hg/ha i.e. 11.18 tons/ha) and Niger (311234 hg/ha i.e. 31.12 tons/ha) in 2020 from FAOSTAT. Therefore, for sweet potato, with a yield of 10.5 t/ha, it has a score of 5 in Burkina Faso (viz. 10.06 < PY ≥ 12.30) and 2 in Niger (viz. 9.34 < PY ≥ 15.56).

Table 5. Scoring scales of yield indicator for potato in Burkina Faso and Niger.

Indicator value (IV) intervals	**Burkina Faso – Potato yield (PY) intervals**	**Niger – Potato yield (PY) intervals**	**Sustainability score**
IV < IB - 90% IB	PY < 1.12	PY < 3.11	0
IB - 70% IB < IV ≥ IB - 90% IB	1.12 < PY ≥ 3.35	3.11 < PY ≥ 9.34	1
IB - 50% IB < IV ≥ IB - 70% IB	3.35 < PY ≥ 5.59	9.34 < PY ≥ 15.56	2
IB - 30% IB < IV ≥ IB - 50% IB	5.59 < PY ≥ 7.83	15.56 < PY ≥ 21.78	3
IB - 10% IB < IV ≥ IB - 30% IB	7.83 < PY ≥ 10.06	21.78 < PY ≥ 28.01	4
Indicator benchmark (IB) +/- 10% IB	10.06 < PY ≥ 12.30	28.01< PY ≥ 34.23	5
IB + 10% IB > IV ≤ IB + 30% IB	12.30 > PY ≤ 14.53	34.23 > PY ≤ 40.46	6
IB + 30% IB > IV ≤ IB + 50% IB	14.53 > PY ≤ 16.77	40.46 > PY ≤ 46.68	7
IB + 50% IB > IV ≤ IB+ 70% IB	16.77 > PY ≤ 19.01	46.68 > PY ≤ 52.90	8
IB + 70% IB > IV ≤ IB + 90% IB	19.01 > PY ≤ 21.24	52.90 > PY ≤ 59.13	9
IV > IB + 90% IB	PY > 21.24	PY > 59.13	10
IB	11.18	31.12	

IB: Indicator benchmark. IV: Indicator value.

CONCLUSIONS

To the best of our knowledge, this is the first sustainability assessment approach specifically developed for neglected and underutilized crop species. The approach, co-developed with local actors and stakeholders, provides a tool for efficient, effective and sustainable promotion of NUS in Burkina Faso, Niger and the Sahel and West Africa. The proposed sustainability assessment approach allows not only to objectively assess the environmental, social and economic sustainability of each NUS, and to relate it to that of the main reference crop, but also can be used for the prioritization of NUS to be promoted based on their potential impact. Although the matrix was developed for the NUS selected within SUSTLIVES project (amaranth, fabirama, okra, cassava, moringa, roselle, sweet potato, voandzou), it can be used for other crops and in other countries after a contextualization. In particular, this step implies the identification of the reference crop and the development of the scoring scale. The next step will be the application of the sustainability assessment approach developed on the NUS selected in Burkina Faso (amaranth, fabirama, moringa, roselle, sweet potato, voandzou) and Niger (okra, cassava, moringa, roselle, sweet potato, voandzou) for its final validation.

ACKNOWLEDGMENTS

This work was carried out within the project SUSTLIVES (*SUSTaining and improving local crop patrimony in Burkina Faso and Niger for better LIVes and EcoSystems* - https://www.sustlives.eu), of the DeSIRA initiative (Development Smart Innovation through Research in Agriculture), financed by the European Union (contribution agreement FOOD/2021/422-681).

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