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► **To cite this version:**

Joseph Yaméogo, Pawendkissou Isidore Pawendkissou. ASSESSMENT OF CLIMATE CHANGE ADAPTATION STRATEGIES IN DEVELOPING COUNTRIES: THE CASE OF BURKINA FASO. *Journal of Innovations and Sustainability*, In press, 7 (2), pp.1-32. <10.51599/is.2023.07.02.06>. <hal-04194453>

HAL Id: hal-04194453

<https://hal.science/hal-04194453v1>

Submitted on 2 Sep 2023

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ASSESSMENT OF CLIMATE CHANGE ADAPTATION STRATEGIES IN DEVELOPING COUNTRIES: THE CASE OF BURKINA FASO

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Yaméogo, J., & Yanogo, P. I. (2023). Assessment of climate change adaptation strategies in developing countries: the case of Burkina Faso. *Journal of Innovations and Sustainability*, 7(2), 06. <https://doi.org/10.51599/is.2023.07.02.06>.

Purpose. The objective of the study is to assess the sustainability of adaptation strategies promoted by farmers in agroforestry systems in Burkina Faso through the sustainable development analysis guide (SDAG). For this purpose, primary data were collected by the survey method. One hundred and four (104) people were interviewed using a questionnaire. Secondary data were also used. Descriptive statistics and the Excel logical test were used to analyse the collected data.

Results. The results show that in a context of climate variability, farmers mobilize several strategies such as: proactive, reactive and combined strategies. The adaptation strategy index shows that proactive strategies are strongly used, followed by combined proactive strategies, reactive strategies and silvicultural techniques. However, the first three strategies are used more by farmers. Moreover, the evaluation of the strategies used by farmers was based on the first three strategies. It was found that proactive and combined strategies are more sustainable than reactive ones, as farmers have difficulties in assessing the climate risks they face. Thus, the environmental component of sustainable development is strongly impacted by reactive strategies, which is reflected in the low weighting of respondents and experts.

Scientific novelty. The novelty is the use of the sustainable development analysis guide, which allows the sustainability of farmers' adaptation strategies to be assessed. The tool made it possible to compare the results of field survey and the opinions of experts (through a literature review) with dimensions of sustainable development (social, economic, environmental). Thus, for each dimension, variables and indicators were associated. Thanks to the tool, the results were achieved.

Practical value. The advantage of this approach is that sustainability assessment can be done through empirical data (from surveys). This is important for developing countries such as Burkina Faso where assessments based on economic techniques are difficult, as the rural population is mostly illiterate.

Key words: adaptation strategies, sustainable development analysis guide, farmer, Burkina Faso.

Introduction. Africa is affected by climate variability (Baarsch et al., 2020). Several sectors are affected, including agriculture (Olabanji et al., 2020; Seife, 2021), livestock (Descheemaeker et al., 2018; Brouillet & Sultan, 2023), forests (John et al., 2020; Friess et al., 2022), food security (Leisner, 2020; Molotoks et al., 2021) and water resources (Lu et al., 2019; Schilling et al., 2020). Fragile states in Sub-Saharan Africa still face challenges in responding to the effects of climate shocks.

The IPCC Fourth Assessment Report highlights that adaptation strategies are

essential (Claessens et al., 2012). Current understanding of the state of adaptation is poor in Africa (Epule et al., 2021). Studies are therefore being conducted on adaptation strategies (Montcho et al., 2022; Afokpe et al., 2022), as well as on the factors influencing their implementation (Mabe et al., 2014; Adeagbo et al., 2021; Ojo et al., 2021).

However, the question of the effectiveness of adaptation strategy options remains. In Benin, many strategies are schematized, but economic evaluation techniques are most often used (Gnanglè et al., 2012; Djohy & Sounon Bouko, 2021). Furthermore, in Burkina Faso, most studies are based on socio-economic factors of adoption of climate perceptions (Kaboré et al., 2019; Yaméogo et al., 2022; Traoré et al., 2022), adaptation to climate variability (Traoré et al., 2020; Arumugam et al., 2023).

However, few studies assess the effectiveness of adaptation strategies in Burkina Faso. The present study aims to fill this gap. The main objective of this study is to assess the coping strategies used by tree managers in agricultural fields in northern Burkina Faso using the Sustainability Analysis Guide Tool. In particular, it aims to:

- Identify the coping strategies used by tree managers (farmers) in agricultural fields;
- Evaluate the strategies used by tree managers in agricultural fields.

Review of literature. It examines the conceptual definition, empirical literature. *Conceptual definition.* Adaptation climatic: Adaptation refers to the adjustment of ecological, social, or economic systems in response to actual or expected climate forcing and environmental change (Smit & Pilifosova, 2003). Adaptation strategies also involve taking the right steps to reduce the negative effects of climate variability (or exploit the positive effects) by making appropriate adjustments and changes (Akinngbe & Irohibe, 2014). Several types of adaptation strategies can be distinguished, including reactive, anticipatory (proactive), autonomous, and planned adaptation (Fankhauser et al., 1999).

Sustainability: This concept became particularly important in the aftermath of World War II and because of the growth of human activity that was affecting the balance of the world's ecosystems (Purvis et al., 2018). It was in this context that the 1987 Brundtland Report of the World Commission on Environment and Development "Our Common Future", was produced. This report brought the concept of sustainability to the forefront of the international media. Sustainable development is promoted and defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland, 1987).

This is why the economic, social, and environmental balance has to be taken into account in the development process. Sustainability is the maintenance of this (social-economic-environmental) balance over time. It enables future generations to enjoy the natural world. Therefore, the concept of sustainability or sustainable development must be considered from a systemic perspective (Gallopín, 2003). This balance is illustrated in the diagram by Purvis et al. (2018) (Figure 1).

In this context, sustainability is considered from a systems perspective. For

Sakalasooriya (2021), sustainability is aimed at the preservation of ecological systems in order to support and enhance social systems. Gallopin (2003) identifies three (03) types of sustainability as follows: Human System Sustainable, Ecological System Sustainable and Socio-Ecological System Sustainable.

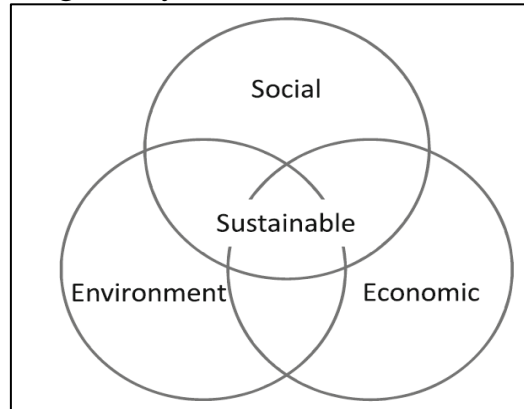


Figure 1. Components of sustainability

Source: Purvis et al., 2018.

The sustainability of the human system puts the human being at the center, and therefore the natural resources have to contribute to the functioning of the human sustainability system. This system is schematized by Gallopin (2003) (Figure 2).

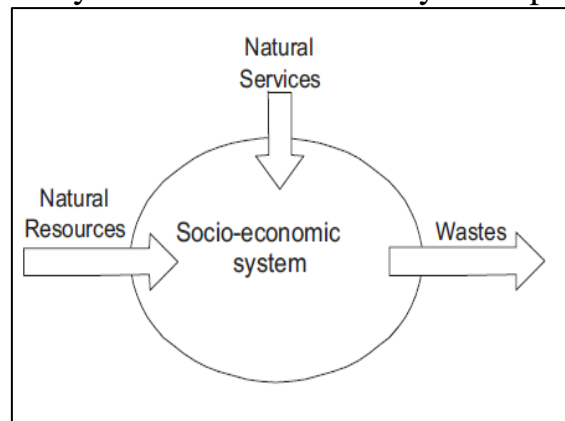


Figure 2. Human system sustainability

Source: Gallopin, 2003.

This sustainability does not take into account the problems of human activity on natural resources. Ecological system sustainability focuses on nature and society is relegated to second place, i.e., human activities are considered to disturb the ecological balance.

Sustainability of the socio-ecological system: any system consisting of a societal (or human) element (subsystem) interacting with an ecological (or biophysical) element. This system, unlike the other two, refuses exclusion, but union and/or interaction. For Najjar (2022), sustainability is now undergoing a dynamic that brings together a range of disciplines from the humanities, ecology and economics.

Empirical literature. Obstacles to climate change adaptation decisions.

The literature points to several factors that affect adaptation to climate variability. Klein et al. (2015) find that lack of information is one of the major constraints that limit

farmers' adaptation strategies worldwide. Several other authors report more variables that negatively affect adaptation strategies. In Asia, factors such as lack of access to information, a lack of access to extension services, limited awareness and knowledge, and limited financial options are the main barriers to climate change adaptation (Nguyen et al., 2021). In Nepal, variables such as insufficient capital, high cost of agricultural inputs, poor information on adaptation provided to farmers, insufficient access to credit facilities and awareness, access to credit and extension services, number of plots cultivated, past experience of climate change, access to climate information, acceptance of climate change and belief in adaptation were highlighted by farmers (Lamichhane et al., 2022; Devkota et al., 2018; Khanal & Wilson, 2019). In Burma, however, lack of farmland, a shortage of farm labour, declining soil fertility, crop pest infestation, and credit are seen by farmers as hindering their adaptation strategies (Tun et al., 2017).

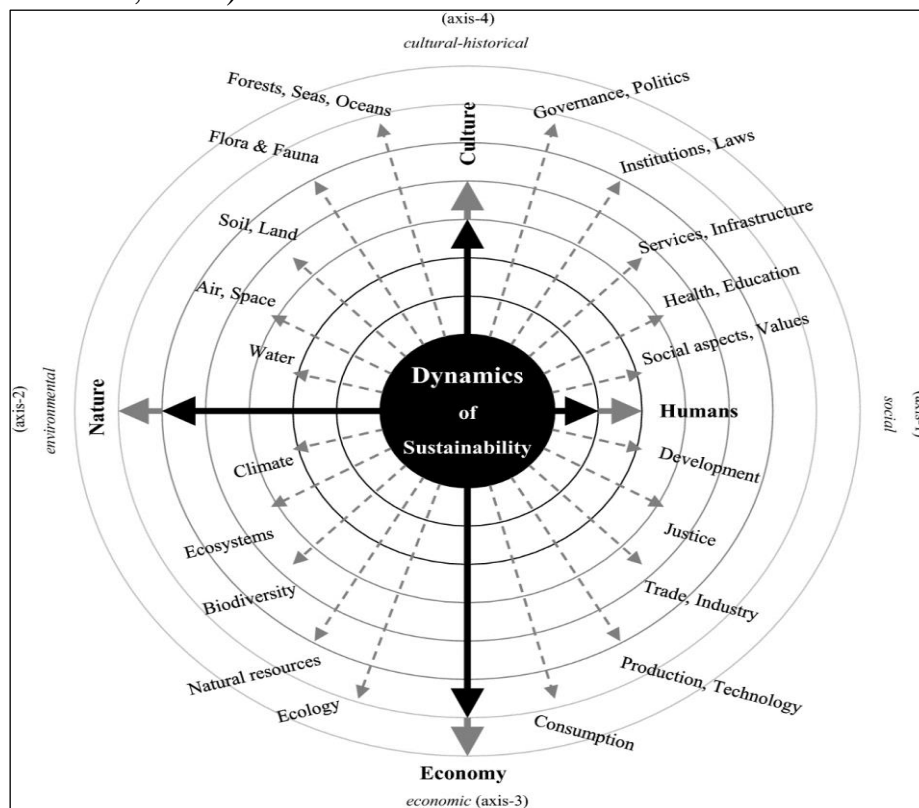


Figure 3. The dynamics of sustainability

Source: Najjar, 2022.

In Africa, particularly in west-central Ethiopia, small farmland size, agroecology, farmland location, financial constraints and lack of skills were the main barriers to adopting crop management strategies (Amare et al., 2018).

Adaptation strategies and different assessment approaches. Climate adaptation has become an urgent issue due to the effects of climate change. In addition, several adaptation strategies are being developed by people facing climate change. This raises the question of the effectiveness of adaptation strategies (Savari & Moradi, 2022; Eriksen et al., 2011; Schipper, 2020). This has led several authors (Pisor et al., 2022; Singh et al., 2022) to address this issue. However, assessing the effectiveness of climate

change adaptation is difficult, as it relies on quantitative and qualitative measures or indicators to show the relationships between effects and observable outcomes (Owen et al., 2020). Osbahr et al. (2011) add that the effectiveness of any adaptation assessment is also limited by the scale of analysis, in terms of the temporal and spatial boundaries of the system under study. Dilling et al. (2019) further explain that the concept of successful or efficient adaptation is confusing and therefore does not offer sufficient readability to understand it properly.

However, there are different approaches to assessing coping strategies (Haque, 2016). Van Alphen et al. (2021) identify four (04) that are commonly used in the field of adaptation to climate variability. These are cost-benefit analysis (CBA), cost-effectiveness analysis (CEA) or cost-effectiveness analysis (CEA), cost comparison (CC) and multi-criteria analysis (MCA). However, evaluation methods are more oriented towards economic evaluation methods (CB, CEA, CC). However, Adger et al. (2005) stress that sustainable adaptations must be based on elements of effectiveness, efficiency, equity and legality. In other words, the sustainability of strategies must take into account economic, social and ecological criteria.

The Sustainability Analysis Guide (SAG): a tool for assessing climate change adaptation strategies in developing countries.

Examining the sustainability of adaptation is particularly complicated, as adaptation measures are often difficult to distinguish from development interventions, leading to classification difficulties (Owen, 2020; Schipper et al., 2020). In addition, evaluation methods are more oriented towards economic techniques (Owen, 2020). This does not allow for an effective assessment of sustainability, as many developing countries like Burkina Faso have a poorly educated population. This makes it difficult to have adequate data for economic analyses. This is what prompted researchers to look into this issue. The Eco-Consultancy Chair at UQAC in Canada has developed a tool called the Sustainable Development Analysis Guide (SDAG). The SDAG is a systemic questioning tool based on six dimensions (social, ecological, economic, cultural, ethical and governance) that allows for an assessment of the degree of sustainability of a policy, strategy, programme or project (Villeneuve et al., 2016).

The tool is based on the responses of people interviewed in the field for the evaluation of strategies, programmes or projects, and uses a literature review for the evaluation of policies. The SDAG therefore incorporates the respondents' perceptions of the subject matter of the research. The views of the respondents are also compared to the observations and interviews in order to weight them appropriately. For example, when a farmer claims to have become wealthy from an activity, the normal evidence should be his income, but as it is difficult to quantify. So, the assessor needs to look at tangible evidence of wealth. The evidence provided is:

- the high level of convenience in the house;
- the household food situation is good (food in the house);
- the number of shops or houses rented;
- children in the household are in school.

This cohort of evidence should therefore guide the assessment. This tool is therefore appropriate in countries where the majority of the population is illiterate and has difficulty keeping minimal activity records. For this reason, the weighting of surveys is an important part of this tool.

Presentation of SAG's Dimensions of sustainability. The Sustainable Development Analysis Guide is a sustainability assessment tool developed by the Eco-Consultancy Chair of the University of Quebec at Chicoutimi, Canada (Villeneuve et al., 2016). It has been tested in developed, developing and emerging countries around the world (Algeria, Benin, Burkina Faso, Cameroon, Canada, China, Comoros, Ivory Coast, Democratic Republic of Congo, France, Gabon, Guinea, Haiti, Madagascar, Mali, Morocco, Sao Tome and Principe, Senegal, Togo and the USA) (Villeneuve et al., 2017). The SDAG is composed of six dimensions such as: social, ecological, economic, cultural, ethical and governance, with associated assessment themes (Figure 4).

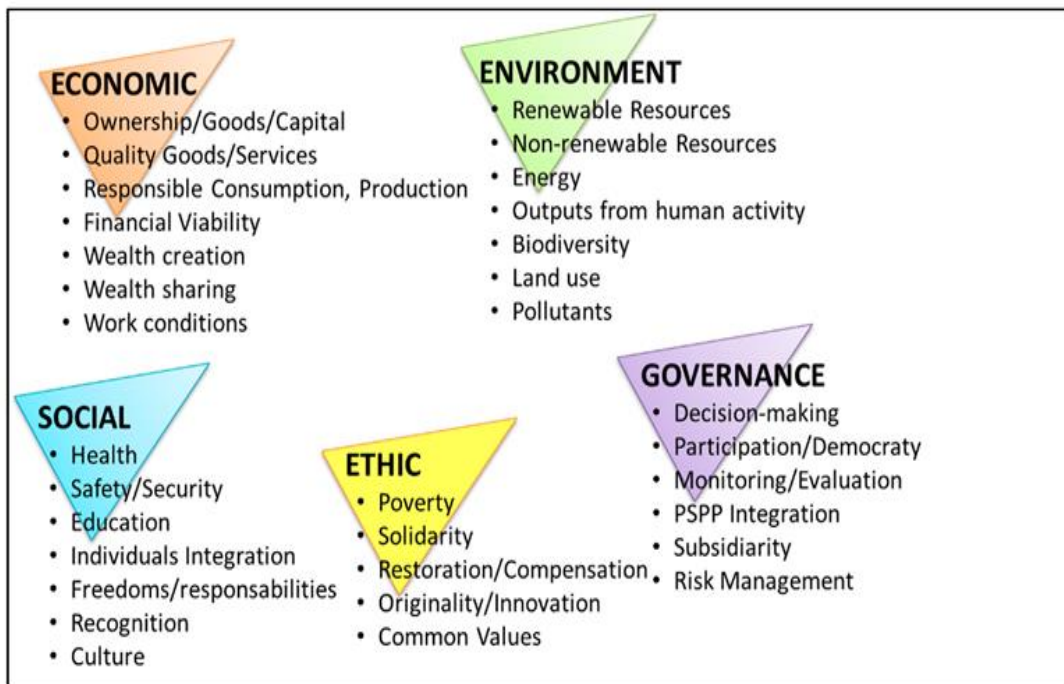


Figure 4. Dimensions of sustainability and their associated themes

Source: Villeneuve et al., 2017.

The tool is also integrated into the Excel spreadsheet. Three (03) versions are proposed, including the 2016 and 2017 and 2022 versions. In this study, the 2016 version was chosen. This is because it is more manageable than the other versions which have been modified over the years.

Materials and methods. The objective of the study is to assess the sustainability of adaptation strategies promoted by farmers in agroforestry systems in Burkina Faso through the sustainable development analysis guide.

The study area. The study area is located in the commune of Samba, in the province of Passoré, in the northern region (Figure 5).

The study areas are experiencing significant population dynamics (Figure 5). Shea

and African locust bean (néré) are the main trees in the agricultural fields of the study villages. The area is severely affected by rainfall variability, which makes farming in the area more difficult (Yanogo & Yaméogo, 2023).

Methods. It begins by highlighting the method for identifying the relative importance of coping strategies, followed by the Sustainability Analysis Guide (SAG) method, sampling, and data collection, data sources and collection methods, and the data analysis method.

Method for identifying the relative importance of coping strategies. In order to identify which coping strategies are relatively important compared to others operated by farmers, an adaptation index procedure was implemented by Uddin et al. (2014). For the authors, this index consists of asking farmers to give their opinions on the importance of strategies deployed to cope with the pernicious effects of climate variability. The response options were placed on a Likert scale as follows: high, medium, low and not at all. The scores assigned to the responses were 3, 2, 1 and 0 respectively.

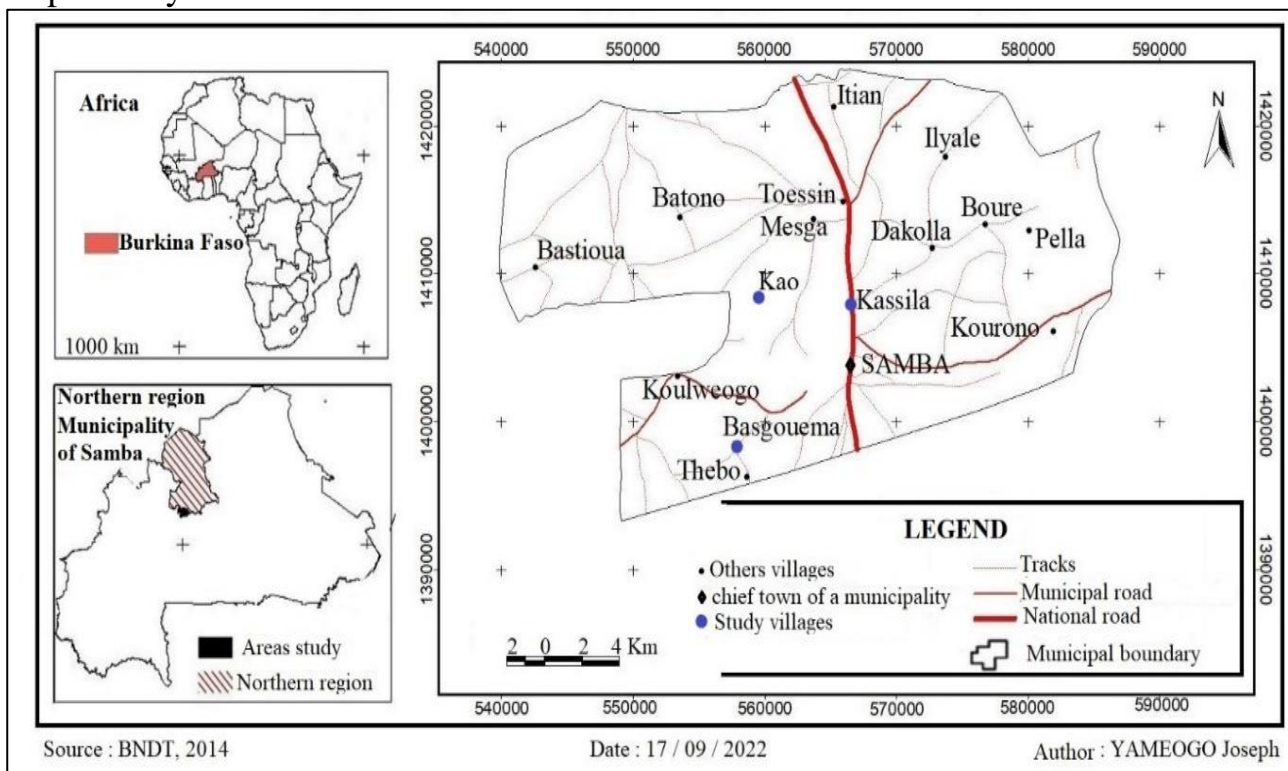


Figure 5. Location of the study area

Source: authors' research.

Method Sustainability Analysis Guide (SAG). Process for selecting variables, sustainability indicators.

First, the software (Excel spreadsheet) was modified to include only the economic, social and ecological criteria or dimensions for assessing the sustainability of coping strategies. Second, exploratory surveys were conducted with an average of 10 people in the study villages to test the different variables and indicators. For the social, economic and ecological dimension, the variables and indicators are listed in Table 1.

Table 1

Variables and indicators of sustainability chosen for the study

Themes	Variables	Indicators
Social Dimension		
Food	<ul style="list-style-type: none"> - Ensuring access to food - Ensuring the nutritional quality of food - Ensuring food security - Promote food sovereignty 	<ul style="list-style-type: none"> - Level of frequency of fruit consumption - Number of bags of cereals purchased
Health	<ul style="list-style-type: none"> - Improve and maintain the health status of the population - Ensure access to health services - Promote preventive health actions, healthy environments and the adoption of healthy lifestyles 	<ul style="list-style-type: none"> - Medicines purchased - Frequency level in hospitals
Safety	<ul style="list-style-type: none"> - Creating a sense of food security 	<ul style="list-style-type: none"> - Number of bags of cereals purchased
Education	<ul style="list-style-type: none"> - Providing basic education 	<ul style="list-style-type: none"> - Number of children enrolled in school
Gender	<ul style="list-style-type: none"> - Participation in activities regardless of gender 	<ul style="list-style-type: none"> - Level of participation of family members in the activity
Economic dimension	Variable	Indicators
Responsible production	<ul style="list-style-type: none"> - Producing quality goods and services, in line with needs 	<ul style="list-style-type: none"> - Level of pesticide use
Responsible consumption	<ul style="list-style-type: none"> - Promote responsible purchasing, consumption and investment 	<ul style="list-style-type: none"> - Level of production destroyed
Economic model	<ul style="list-style-type: none"> - Ensure economic viability 	<ul style="list-style-type: none"> - Level of products sold (market oriented)
Work	<ul style="list-style-type: none"> - Promote access to occupation 	<ul style="list-style-type: none"> - Level of occupation of household members per month
Wealth and prosperity	<ul style="list-style-type: none"> - Aiming for prosperity through higher incomes 	<ul style="list-style-type: none"> - Level of income generated
Ecological dimension	Variables	Indicators
Ecosystems	<ul style="list-style-type: none"> - Protecting ecosystems 	<ul style="list-style-type: none"> - Number of tree species increased - Number of tree species decreased
Biodiversity	<ul style="list-style-type: none"> - To promote the protection of biodiversity 	<ul style="list-style-type: none"> - Number of tree species to be increased
Land use	<ul style="list-style-type: none"> - Restoration of degraded soil 	<ul style="list-style-type: none"> - Level of fallow land

Source: authors' research.

Process of weighting and assessment of the sustainability variables selected for the study. The weighting and evaluation of adaptation strategies are carried out simultaneously. Indeed, weighting consists of assessing the importance of the different strategies by selecting variables from the social, economic and ecological dimensions. In other words, weighting is like a scale for assessing the variables of each sustainability dimension selected. The example of the variables of the social dimension is presented in Figure 6 below.

SOCIAL DIMENSION				
	Foundation	Justification of the weighting	Evaluation	Actions planned or already implemented
3 Feeding of food				
3.1	Ensuring access to food	Weighting: choose 1, 2 or 3		
3.2	Ensuring the nutritional quality of food	Weighting: choose 1, 2 or 3		
3.3	Ensuring food availability	Weighting: choose 1, 2 or 3		
3.4	Fostering food sovereignty	Weighting: choose 1, 2 or 3		
Average weighting: Food		0.0	Average weighting: Food 0%	

Figure 6. SAG 2016 spreadsheet interface with weight case in red

Source: authors' research.

Three (03) levels of appreciation were thus retained as:

- Value 1 indicates a low weighting (the strategy takes little account of this variable);
- Value 2 gives a medium weighting (the strategy takes this variable into account to a moderate extent);
- Value 3 indicates a high weighting (the strategy takes this variable strongly into account).

The weighting takes into account the opinions of the respondents and the scientific work on the subject to weight dimensions of sustainability. Thus, there are two weightings, one given by the respondents and the other according to scientific work in the field. The weighting of the respondents and the weighting of the scientific literature on the subject are then averaged.

The evaluation is done by means of a rating scale (Table 2), which is to be used as a basis for rating the variables from the sustainability dimensions.

Table 2

Scale for evaluating the strategies used by the respondents

Scale of evaluation of the strategy chosen by the respondents	Interpretation
Less than 20 %	Critical situation: the dimension or variable is negatively affected by the respondent's strategy(s)
Between 20 % and 39 %	Problem situation: the dimension or variable is insufficiently taken into account by the respondent (through his/her strategies), with negative impacts on the environment (biodiversity is damaged in agricultural fields)
Between 40 % and 59 %	Problem situation: the dimension or variable is insufficiently taken into account by the respondent (through his/her strategies), with moderate impacts on the environment (biodiversity is threatened)
Between 60 % and 79 %	Satisfactory situation: the dimension or variable is taken into account by the respondent (through his/her strategies), low positive impacts (social and economic sustainability) are expected
Between 80 % and 100 %	Excellent situation: the dimension or variable is strongly considered by the respondent (through his/her strategies), high positive impacts (social, economic and ecological sustainability) are expected

Source: SAG, 2016 and author.

A link exists between weighting and evaluation. A low weighting of both the respondents and the scientific base results in a low evaluation. Table 3 below.

Table 3

Relationship between weighting and evaluation

Weighting of respondents	Weighting on the scientific basis	Assessment	
1	1	0–49 %	Low
2	2	50–79 %	Medium
3	3	80–100 %	High

Source: authors’ research.

Similarly, the weighted performance of strategies depends on the assessment. According to De Doria et al. (2009), successful adaptation is an adjustment that reduces the risks associated with climate variability, without compromising economic, social and environmental sustainability. Thus, the evaluation of the success of adaptation strategies is based on the balance of the triptych: social-economic-ecological. Table 4 illustrates this situation.

Table 4

Assessment of the sustainability of adaptation strategies

Sustainability	Weighting, %	Interpretation
Social	80–100	Strategy is said to be «high sustainable»
Economic	80–100	
Environmental	80–100	
Social	70–80	Strategy is said to be «sustainable satisfactory»
Economic	70–80	
Environmental	50–70	
Social	70–80	Strategy is called «acceptable sustainability»
Economic	70–80	
Environmental	50–70	
Social	0–60	Strategy is said to be «degrading»
Economic	0–60	
Environmental	0–60	

Source: authors’ research.

Presentation of evaluation findings. The Excel-based tool presents the results in two (02) types of forms: tables or/and charts. The tables present the weights of the variables and indicators of the sustainability dimensions.

Sampling and data collection. The selection of the study areas is based on three (03) criteria, which are as follows:

- The area is subject to high climate variability between 1990 and 2020 (Yanogo & Yaméogo, 2023);
- In order to cope with this situation, farmers have mobilised several strategies over several decades;
- The rural populations most affected are those who have tree species such as shea and African locust in their agricultural fields.

The populations studied in this study are the managers of trees in agricultural fields. In this study, the sample size required for the study was estimated using the

following formula (Kothari, 2004):

$$n = \frac{z^2 \cdot p \cdot q \cdot N}{e^2 (N - 1) + z^2 \cdot p \cdot q} \quad (1)$$

where n – sample size (target population);

N – size of the total households: 480;

z – margin coefficient (determined from the confidence level);

e – margin of error;

p – proportion of the populations assumed to have the desired characteristics. If no value for this proportion is available, it will be set at 50 % (0.05);

$q = 1 - p$;

$p = 0.5$. Then, $q = 1 - 0.5 = 0.5$;

$Z = 1.96$ et $e = 0.05$.

There are therefore 104 target households to be surveyed using the formula. In each commune, the selection criteria were three villages: Basgouema, Kao and Kassila. The distribution of respondents in the study villages was based on the security context. The distribution of respondents by study village is shown in the Table 5 below.

Table 5

Target populations sampled in the study sites

Samba rural municipality	Total number of households	Target population
Study villages:		
Basgouema	143	24
Kao	135	30
Kassila	104	50
Total	382	104

Source: General Census of Population and Housing, 2019.

Data sources and collection methods. Two types of data were used in this study. The primary data came almost exclusively from the field surveys, which were conducted from December 2021 to January 2022 in the three (3) villages. The questions were mainly about coping strategies and their sustainability. The secondary data came from the literature review, which focused on sustainability issues.

Data analysis method. Descriptive statistics such as sum, percentage were used. In addition, the Excel logic test, with the formula (IF (SUM (start cell: end cell) = 0;0; (AVERAGE (start cell: end cell))). Next comes the evaluation. The latter is calculated by still using the logical test of Excel following the formula as follows: = SI (\$E30 = "" ;0; (SI(\$E30 <> 0; SUM (initial cell: final cell; initial cell: final cell; initial cell: final cell; initial cell: final cell) /SUMM (initial cell: final cell; initial cell: final cell; initial cell: final cell) ;0)) was used to have the average of the weighting both at the level of the respondents and at the level of the scientists.

The relative importance of adaptation strategies to climate variability was therefore calculated based on the index formula proposed by Uddin et al. (2014):

$$ISA = A_{sn} \times 0 + A_{sl} \times 1 + A_{sm} \times 2 + A_{sh} \times 3 \quad (2)$$

where ISA – Adaptation Strategy Index;

Asn – Frequency of farmers who consider that the coping strategy is not important;

Asl – Frequency of farmers who consider the coping strategy to be of little importance;

Asm – Frequency of farmers who consider the coping strategy to be of moderate importance;

Ash – Frequency of farmers who consider the coping strategy to be important.

ISA is ranked from highest to lowest.

In the context of this study, a threshold has been accepted to retain important strategies. Thus, when ISA is equal to or greater than 100, this strategy is important and should be taken into account. This is because 100 corresponds to 30 % to 50 % of the research sample. However, when strategies are combined, then ISA must be equal to or greater than 180 to be considered. Strategies below these thresholds are rarely practised by respondents, as they are only taken into account by 5 % to 10 % of the research sample. It is therefore useless to evaluate strategies that are not massively used by managers. The calculations were made in the Excel 2020 spreadsheet.

Results and discussion. *Adaptation strategies and their prioritization by the respondents.* Several strategies were carried out by the managers in the study villages. These were grouped into three (03) levels as follows: proactive strategy, reactive strategy and silvicultural technique strategy. Each strategy has several types of strategy associated with it.

According to the field surveys, the proactive strategy group is widely used by the respondents in the commune of Samba. It is followed by the reactive strategy and the silvicultural techniques strategy. To assess the importance of the respondents' coping strategies, the index of the importance of coping strategies established (Table 6).

This Table shows that in the proactive strategy group, reforestation of fruit trees (ISA = 309) is ranked first, followed by a ban on wood cutting (ISA = 258), then a ban on bush fires (ISA = 255), and finally awareness raising (ISA = 254). This means that the respondents favor the reforestation of trees (especially fruit trees and, secondarily, non-fruit trees). However, the other strategies (prohibition of bush fires, abusive wood cutting and awareness raising) are more combined by the managers in the same field. In the case of the reactive adaptation strategy group, soil conservation methods (dyke method, stone barriers) are promoted more. In the case of the silvicultural strategy, grafting and pruning of trees is more common. Reforestation and the combination of strategies (prohibition of bush fires, wood cutting, awareness raising) are important in the commune of Samba. Their ISA is over 200.

In most studies, many authors state that strategies in the context of climate variability are reactive (Dumenu & Obeng, 2016), preventive or anticipatory (Mogotsi et al., 2013), and combined (Carr et al., 2022).

Evaluation of the adaptation strategies selected in the commune of Samba. The importance index of the strategies made it possible to classify the strategies according to their importance. Thus, in the group of proactive strategies, four (04) types of strategies such as reforestation, bushfire ban, timber cutting ban, and awareness raising

are taken into account by the respondents, as their ISA > 200.

Table 6

Importance of the strategies deployed by the villages surveyed in the commune of Samba (Basgouema, Kao, Kassila)

Coping strategies		Asn	Asl	Asm	Ash	ISA (Type of strategy)	Combination strategy	Rank (Type of strategy)	ISA (group of strategy)	Rank (group of strategy)
Proactive strategy group	Reforestation of fruit trees	0	1	2	306	309	-	1 st	1076	1 st
	Awareness raising	0	5	12	237	254	xxx	4 th		
	Ban on wood cutting	0	10	20	228	258	xxx	2 nd		
	Prohibition of bush fires	0	10	20	225	255	xxx	3 rd		
Reactive strategy group	Dyke method	0	41	40	27	108	xxx	1 st	214	2 nd
	Stone cordon	0	30	14	9	53	xxx	2 nd		
	Fallow practice	0	14	10	3	27	-	3 rd		
	Use of organic fertilizer	0	15	2	9	26	-	4 th		
Forestry technique strategy	Grafting of trees	0	30	32	30	92	-	1 st	170	3 rd

Note. - – no combination; xxx – combination of strategies in agricultural fields.

Source: field surveys, December 2021 – June 2022.

Not all strategies are taken into account for the evaluation, in this case, the strategy of silvicultural techniques, as its ISA is lower than 180 points. This means that about 3% of the research sample practices this strategy. This is too small a proportion to be evaluated, hence the rejection of this strategy for this study.

Proactive adaptation strategy (Reforestation of fruit trees):

• *Social*

In the villages studied, reforestation of fruit and non-fruit trees is the important strategy. Fruit species dominate non-fruit species. Thus, 70% of the respondents have reforested fruit trees (mango, guava, papaya) and 30% non-fruit trees (eucalyptus, *acacia nilotica*). According to 90% of respondents, reforestation brings significant social benefits. The assessment of the social impact of reforestation was based on the following variables: food, health, education, security. Thus, the weighting of the food variable shows a high level of appreciation among the respondents and on the scientific basis (Table 7). The opinion of the respondents is P = 2.3 on average and that of the scientists P = 2 on average. This would mean that the assessments are average. We note

that the evaluations/weights are otherwise high. This is because the species used for reforestation provide food for the respondents. Moreover, from a scientific point of view, it appears that fruit species have important food contributions for people. Indeed, papaya, guava and mango are very rich in minerals and vitamins.

Table 7

Assessment-weights/average performance of reforestation’s contribution to the social dimension

Food	Weighting of respondents	Weighting based on scientific data (expert)	Evaluation/Weighted performance, % (E)
Food			
Ensuring access to food	3	2	80
Ensuring the nutritional quality of food	3	3	85
Ensuring food security	3	2	82
Promote food sovereignty	3	2	80
Average weighting: food	3	2	78
Health			
Improve and maintain the health status of the population	3	3	85
Ensure access to health services	2	1	75
Promote preventive health actions, healthy environments and the adoption of healthy lifestyles	1	1	25
Average weighting: health	1.7	1.6	72
Safety			
Creating a sense of food security	1	1	25
Average weighting: safety	1	1	75
Education			
Providing basic education	1	1	43
Average weighting: education	1	1	68
Gender			
Participation in activities regardless of gender	2	2	70
Average weighting: gender	2	2	76
Average weighting: social dimension	2.3	2.0	76

Source: processing of field survey data, December 2021 – June 2022.

From this Table, it can be seen that respondents’ opinions are strong on food, with fruit species helping them to overcome food insecurity and significantly improve their nutritional status. In rural areas, the diet consists more of vegetables and cereals. As a result, the diet of rural people is deficient in minerals and vitamins. Financial resources from fruit trees enable them to go to health facilities in case of illness (75% of respondents). Food stability allows 90% of the respondents to affirm that they are secure in their situation of feeding their children. Women and men

participate/participated in reforestation, maintenance and fruit harvesting activities

•*Economic*. The economic evaluation of the reforestation strategy was made on economic bases such as: responsible production (adequacy between needs and goods and services produced), economic viability (economic sustainability of the product), work (promotes the occupation of people, fair remuneration of work), and wealth and prosperity (income (financial benefit induced by the activity)). 90 % of the respondents observe that the reforestation of fruit trees responds to the negative effects of climate variability and that the products from these trees help to deal with food problems. However, the latter (90% of respondents) state that they are not concerned about the sustainability of the production. However, only 25% of them claim to produce with economic viability in mind.

Moreover, the scientific literature notes that responsible production involves two (02) expressions, namely: “responsible” (producer-centred responsibility) and “production” (production-centred responsibility) (Liu et al., 2021). This would mean that production should take into account the producer's responsibility towards the environment. According to the United Nations Sustainable Development Goals, the goal of responsible production is to “do more and better with less”. However, surveys and observations in the field reveal an interest in improving living conditions without worrying about producing less to satisfy needs. In view of these results, the weightings on the basis of scientific data are low. In contrast, work and wealth and prosperity are taken into account by the managers. As a result, the weights are medium. From the literature we can understand that any production model, in order to be sustainable, has to include financial benefits, in order to make many people adhere to it. Therefore, the economic character of this production model must be understood. Table 8 below gives the weights of the respondents, scientists and evaluations of the reforestation strategy.

Table 8

Average assessment weights/performance of the economic dimension themes for the reforestation strategy

Reforestation strategy	Weighting of respondents	Weighting based on scientific data (expert)	Evaluation/Weighted Performance (E/PP)
Responsible production			
Ensuring the match between needs and goods and services produced	1	1	75
Promoting sustainable industrialisation	1	1	40
Average weighting: responsible production	1	1	63
Economic viability			
Economic sustainability of the product	1	1	25
Average weighting: economic viability	1	1	25

Continuation of Table 8

Work			
Keeping people employed	3	3	88
Ensuring a fair value for people's work	3	2	85
Medium weighting: labour	3	1	86
Wealth and prosperity			
Income generated (RG)	2	1	78
Average weighting: wealth and prosperity	2	1	78
Average weighting: economic dimension	1.8	1.3	71

Source: processing of field survey data, December 2021 – June 2022.

From this Table it can be seen that the overall weights are low for responsible production and economic sustainability, and high for work and wealth and prosperity. As the assessments are differentiated, performance varies between variables.

•*Ecological.* The ecological contribution of the strategy was assessed on the basis of variables such as: ecosystem, biodiversity, resources, land use. The link between reforestation and ecology is weakly observed by the respondents. The latter therefore find that reforestation does not have a significant link with the environment of the area. Therefore, the type of species that are reforested is based on food and financial interests. The literature shows that reforestation is likely to change the biodiversity of the landscape, since the introduction of new species to a landscape inevitably leads to changes. In the case of the study area, shea and African locust bean trees are the dominant species. These are reduced (tree fall) due to the strong winds of the monsoon, and are not replaced. The mango, guava and papaya trees that are planted will progressively replace the spontaneous species (*Vitellaria paradoxa*) and thus act as a substitute for their disappearance from the landscape in the long term. Because of these facts, the scientific weighting is very low (Table 9).

Table 9

Average assessment weights/performance of the ecological dimension themes for the reforestation strategy

Reforestation strategy	Weighting of respondents	Weighting based on scientific data (expert)	Evaluation/Weighted Performance, %
Ecosystems			
Develop knowledge about ecosystems and the species that depend on them	1	1	5
Preserve park ecosystems	1	1	15
Limit biological, chemical and physical degradation of soils	1	1	10
Set targets for restoration of degraded ecosystems	1	1	7
Average weighting: ecosystems	1	1	9

Continuation of Table 9

Biodiversity			
Promote the protection of biodiversity	1	1	10
Protect rare, threatened and endangered species	1	1	15
Valuing species with symbolic value	1	1	2
Medium weighting: biodiversity	1	1	9
Resources			
Conserve resources essential to sustain life in ecosystems	1	1	15
Choose resources with the least impact	2	1	50
Plan for wise use of renewable resources	1	1	32
Plan for wise use of non-renewable resources	1	1	22
Average weighting: resources	1.3	1.3	34
Land use			
Optimise land use	1	1	35
Limit conflicts of use	1	1	40
Maintain landscape diversity	2	2	62
Medium weighting: land use	1.3	1.3	50
Medium weighting: ecological dimension	1.1	1.1	27

Source: processing of field survey data, December 2021 – June 2022.

From this figure it can be seen that the performance of the ecological dimension is very low. In sum, after the weightings and evaluations, it can be seen that in the proactive strategy, the reforestation of fruit trees is high in the social and economic dimensions and very low in the ecological dimension (Figure 7).

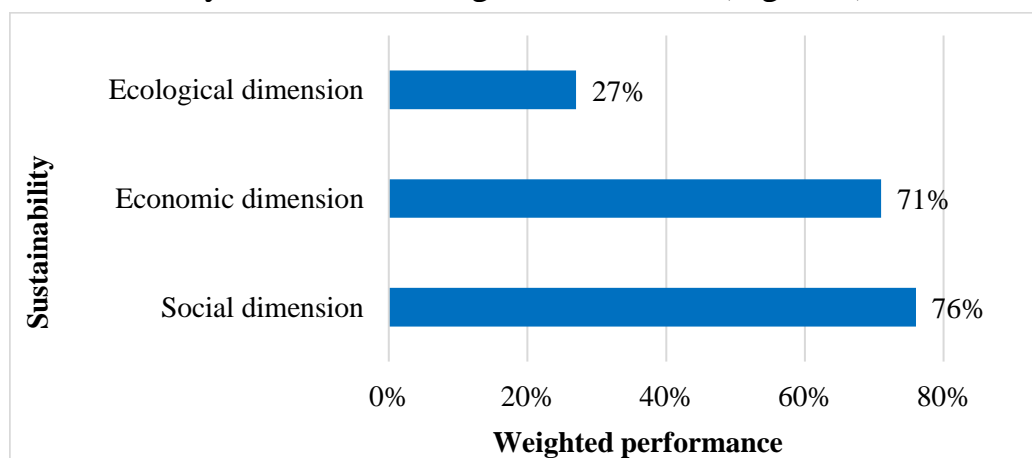


Figure 7. Tree reforestation strategy and the dimensions of sustainability

Source: processing of field survey data, December 2021 – June 2022.

This graph shows that the strategy is less sustainable, as the performance of the ecological dimension does not vary between 30% and 50%.

Combined strategy (bushfire ban, logging ban and awareness raising).

•**Social.** It is used by 75% of respondents. As a result, this strategy was maintained. Thus, for the social dimension, the respondents have a good perception of the strategies on their living conditions. Indeed, for the latter (80% of respondents), the combined practices of banning bush fires, cutting shea and African locust bean wood and raising awareness allow the trees to develop properly. This development has the effect of increasing productivity, since according to them (75% of the respondents) a tree that suffers bush fires loses its leaves, grows slowly and produces less.

Moreover, the literature confirms the opinions of the respondents. Indeed, in Burkina Faso, Sanou (2016) notes that bushfires have negative impacts on the growth and productivity of shea. In Mali, they also impact the productivity, distribution and abundance of shea. In view of this situation, the weights seem to corroborate the opinions of the respondents (Table 10).

Table 10

Average assessment weights of the contribution of the bushfire ban, logging and awareness raising to the social dimension

Combined strategy (Bushfire ban, logging and awareness raising)	Weighting of respondents	Weighting based on scientific data (expert)	Evaluation/Weighted Performance, %
Food			
Ensure access to food	2	2	73
Ensure nutritional quality of food	3	2	80
Ensure food security	2	1	65
Promote food sovereignty	2	1	69
Average weighting: food	2.0	1.5	71
Health			
Improve and maintain the health status of populations	2	2	68
Ensure access to health services	1	1	45
Promote preventive health actions, healthy environments and the adoption of healthy lifestyle habits	1	1	42
Medium weighting: health	1.3	1.3	56
Safety			
Creating a sense of security	2	2	77
Medium weighting: safety	2	2	77
Education			
Providing functional basic education for all	3	3	80
Medium weighting: education	3	3	80
Gender			
Strive for equal rights regardless of gender	2	2	74
Medium weighting: gender	2	2	74
Average weighting: social dimension	2.0	1.8	71

Source: processing of field survey data, December 2021 – June 2022.

The Table shows that the majority of the weights are medium, except for health, which is 1.3 and therefore low. However, the ratings are high. This results in high performance of the variables of the social dimension themes.

•*Economic.* The economic contribution of the strategy was assessed on the basis of variables such as: responsible production (matching needs with goods and services produced, promoting sustainable industrialization), economic viability (ensuring economic viability), work promotes access to employment, fair value for people’s work), wealth and prosperity (income earned). Table 11 below shows themes of the economic dimension.

Table 11

Assessment-weights/average contribution of bushfire ban, logging and awareness raising to the economic dimension

Combined strategy (Bushfire ban, logging and awareness raising)	Weighting of respondents	Weighting based on scientific data (expert)	Evaluation/Weighted Performance, %
Responsible production			
Ensuring that needs are matched with goods and services produced	1	1	35
Promoting sustainable industrialization	1	1	30
Average weighting: responsible production	1	1	33
Economic viability			
Ensuring economic viability	3	3	83
Medium weighting: economic viability	3	3	83
Work			
Ensuring a fair value for people’s work	3	3	85
Medium weighting: labor	3	3	85
Wealth and prosperity			
Income generated	2	2	78
Average weighting: wealth and prosperity	2	2	78
Medium weighting: economic dimension	2	2	78

Source: processing of field survey data, December 2021 – June 2022.

The Table shows that the weight given to responsible production is low, as the respondents’ interests are focused on safeguarding shea and African locust bean and maintaining economic and food profitability. Responsible production is therefore not part of their practices. As a result, variables such as work, economic viability, wealth and prosperity are high. This has an impact on the performance of the thematic variables, as work, economic viability, wealth and prosperity are high.

•*Ecological.* The strategies (bushfire ban, wood cutting, awareness raising) are also evaluated on an ecological basis. The ecological variables selected are ecosystem,

biodiversity, resources, and land use. According to 80% of the respondents, the combination of the bushfire ban, wood cutting, and awareness raising allows the offspring of shea and other species to develop. In addition, shrubs and herbaceous plants also proliferate in agricultural fields. Apart from the disruption of climatic parameters that influence tree productivity, the trees are developing well, with reasonable productivity. The literature (Favier, 2003) on the issue notes that human actions have the effect of degrading forest and savannah resources. Thus, the weightings at both the respondent and scientific levels vary from medium to high (Table 12).

Table 12

Assessment-weights/average contribution performance of the bushfire ban, logging and environmental awareness

Indicators	Weighting of respondents	Weighting based on scientific data (expert)	Evaluation/Weighted Performance, %
Ecosystems			
Develop knowledge about ecosystems and the species that depend on them	2	2	75
Preserve park ecosystems	3	3	80
Limit biological, chemical and physical degradation of soils	1	1	37
Set targets for the restoration of degraded ecosystems	2	1	50
Average weighting: ecosystems	2	1.8	66
Biodiversity			
Promote the protection of biodiversity	3	3	88
Protect rare, threatened and endangered species	3	3	90
Valuing species with symbolic value	3	3	88
Medium weighting: biodiversity	3	3	89
Resources			
Conserve resources essential to sustain life in ecosystems	2	2	78
Choose resources with the least impact	2	2	72
Plan for wise use of renewable resources	3	3	87
Plan for wise use of non-renewable resources	2	2	72
Average weighting: resources	2.3	2.3	78
Land use			
Optimise land use	1	1	45
Minimise conflicts of use	2	2	65
Maintain landscape diversity	3	2	70
Medium weighting: land use	2	2	64
Medium weighting: ecological dimension	2.1	2.0	75

Source: processing of field survey data, December 2021 – June 2022.

The Table shows that the biodiversity variable is strongly taken into account by the respondents. Overall, the variables of the themes that have medium weights are strong.

Figure 8 shows that biodiversity is the variable that performs best in relation to the other themes of the ecological dimension.

In contrast, for the combined strategy (banning bushfires, logging and awareness raising), the three (03) dimensions, social, economic and ecological, are high (Figure 8).

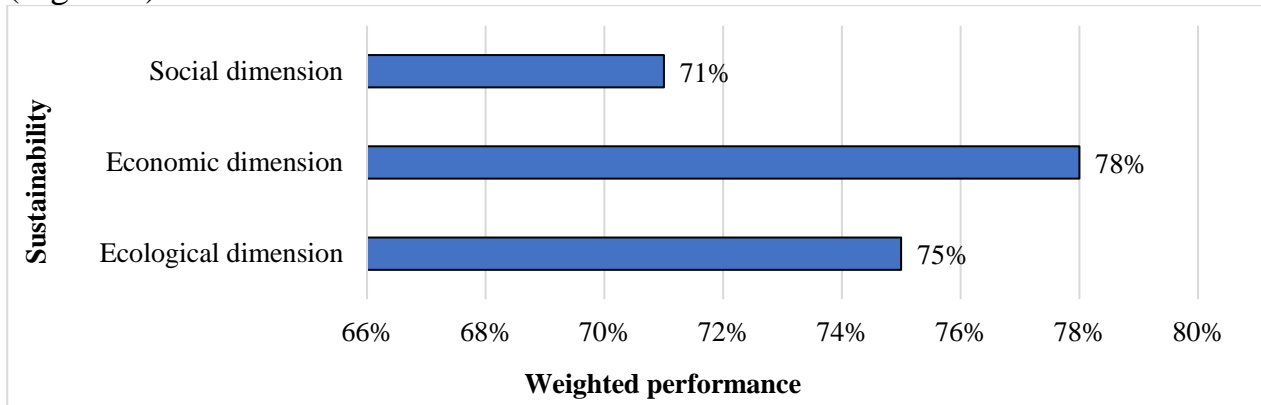


Figure 8. Combination strategy (bushfire ban, logging and awareness raising) and sustainability dimensions

Source: processing of field survey data, December 2021 – June 2022.

According to this graph, it can be said that this strategy is “satisfactorily sustainable”, since the three dimensions of sustainability have more than 70%, and the economic dimension is strong, followed by the ecological dimension and finally the social dimension. Under these conditions, it can be seen that the proactive strategy is sustainable when the types of strategy that make it up are combined, and less sustainable when the types of strategy promoted are not combined.

The proactive strategy (reforestation of fruit trees) is “less sustainable”, since the ecological dimension is less than 30%. However, when the strategy is proactive and combined, sustainability is acceptable. Thus, the proactive strategy gives different results when it is a proactive strategy mobilized alone. Conversely, when the strategy is proactive and combined, sustainability is sufficient. These results seem to differ from those of Perrels et al. (2022), who note that proactive adaptation always leads to higher profits, as it is more efficient to avoid losses and exploit opportunities. L. Berrang-Ford et al. (2010) add that the sustainability of the proactive strategy comes from the fact that it allows the potential benefits of climate variability to be reaped. It is therefore less costly (lower ecological, social, and economic costs) than the reactive strategy (Smit & Pilifosova, 2003). The results of the previous authors are based on the comparison with reactive strategies. This created a gap between their results and those of the study.

Reactive adaptation strategy (dyke methods).

- Social.* Respondents also promote reactive strategies. However, only the bund strategy has an ISA above 100. The other strategies such as stone barriers, following,

and the use of organic fertilizer (manure) are below 100. Therefore, the assessment of the sustainability of the strategy will only concern the bunding methods. Thus, Table 13 below shows that the bunding strategy has a low impact on the social dimension of sustainability.

Table 13

Weighting of the average assessment/performance of the contribution of clustered methods to the social dimension

Dyke methods	Weighting of respondents	Weighting based on scientific data (expert)	Evaluation/Weighted Performance, %
Feeding			
Ensuring access to food	2	2	65
Ensuring the nutritional quality of food	1	1	42
Ensuring food security	2	2	63
Promote food sovereignty	1	1	40
Average weighting: food	1.5	1.5	56
Health			
Improve and maintain the health status of populations	2	2	59
Ensure access to health services	1	1	28
Promote preventive health actions, healthy environments and the adoption of healthy lifestyle habits	1	1	25
Medium weighting: health	1.0	1.2	43
Safety			
Creating a sense of security	1	1	42
Medium weighting: safety	1	1	42
Education			
Providing functional basic education for all	1	1	25
Medium weighting: education	1	1	25
Gender			
Strive for equal rights regardless of gender	3	3	87
Medium weighting: gender	3	3	87
Medium weighting: social dimension	1.5	1.5	56

Source: processing of field survey data, December 2021 – June 2022.

From this Table, it should be noted that the weights are low. As a result, the assessment/performance is low. The low weights are due to the fact that dyke methods are carried out with the aim of conserving soil in order to increase agricultural productivity. In this context, responsible production is better appreciated by the respondents. In addition, the implementation of bunds requires the participation of all people, regardless of gender. Hence, the favorable opinions of the surveys on food and

gender participation in dike strategy methods. Therefore, the weights are medium for food and high for gender. Variables such as health, education, and security are low, as 92% of the respondents do not perceive the effects of the dyking methods on these areas. The scientific weights also confirm the respondents' opinions. Indeed, studies (Blamah, 2004) note that diking methods aim to slow down the speed of runoff and maximize infiltration. Agricultural crops easily benefit from this, resulting in increased yields. Under these conditions, food availability is assured. However, these anti-erosion measures will not have a direct effect on the variables of health, safety, and education. Given the anti-erosion nature of the strategy, the social dimension is weakly weighted by respondents and by the scientific base. The low weights affect the assessments and performance of the social dimension variables, as only gender performs well compared to the other variables (Table 13).

•*Economic.* The dyke methods are also evaluated according to economic variables (Table 14).

Table 14

Weighting-assessment/low performance of the contribution of dyke methods to the economic dimension

Responsible production	Weighting of respondents	Weighting based on scientific data (expert)	Evaluation/Weighted Performance, %
Responsible production			
Ensuring that needs are matched with goods and services produced	1	1	35
Promoting sustainable industrialization	1	1	17
Average weighting: Responsible production	1	1	26
Economic viability			
Ensuring economic viability	1	1	47
Medium weighting: Economic viability	1	1	47
Work			
Promoting access to employment	3	3	85
Ensuring a fair value for people's work	1	1	18
Medium weighting: work	1.5	1.5	62
Wealth and prosperity			
Income generated	2	2	65
Average weighting: wealth and prosperity	2	2	65
Average weighting: economic dimension	1.2	1.2	41

Source: processing of field survey data, December 2021 – June 2022.

It should be noted in this Table that the weights are low, except for labour and

income. According to 85% of the respondents, the dyke strategy aims at slowing down runoff and allowing agricultural crops to develop in good conditions. According to the majority of respondents, the concept of responsible production is not yet within their reach, as they have to think about feeding themselves at all costs. This is reflected in their weighting of responsible production, which is low.

Furthermore, 90% of them do not perceive the effects of the dike strategy on economic viability and responsible production. However, 72% of them see that income has increased by 13% through the sale of grain, partly due to the bunds that have been installed. They also note that the strategy mobilizes family labour, hence the high gender weighting. Thus, the performance of the labour variable is strong and incidentally average for the wealth and prosperity variable. The fact remains that, overall, the performance of the variables related to the themes of the economic dimension is weak.

•*Ecological.* From an ecological point of view, the dyke strategy reduces soil erosion. This increases soil fertility. Plants and crops will benefit from the infiltration of water into the soil and grow more. Based on this information, the scientific weighting finds that the dikes method strategy will positively impact the ecosystem and land use, as tree and grass species will benefit from the wet conditions.

However, biodiversity and forest resources are less affected, as species can adapt to these conditions or not. The opinions of the respondents are in agreement with the scientific findings. Indeed, 90% of the respondents found that there was a regrowth of herbaceous tissue and shrubs in the agricultural fields with the application of bunds, compared to 10% who did not observe this change. In addition, 85% of them have widened their fields, as the erosion control measures have reduced the continuous degradation of the soil in the fields. Under these conditions, the weights of both the respondents and the scientific base are almost average for the ecosystem and land use variable, and low for the other variables (Table 15).

Table 15

Weighting-assessment/low performance of the contribution of dyke methods to the economic dimension

Dyke methods	Weighting of respondents	Weighting based on scientific data (expert)	Evaluation/Weighted Performance, %
Ecosystems			
Develop knowledge about ecosystems and the species that depend on them	1	2	24
Preserve park ecosystems	2	2	70
Limit biological, chemical and physical degradation of soils	2	1	79
Set targets for the restoration of degraded ecosystems	2	1	72
Average weighting: ecosystems	1.8	1.8	67

Continuation of Table 15

Biodiversity			
Promote the protection of biodiversity	1	1	45
Protect rare, threatened and endangered species	1	1	48
Valuing species with symbolic value	1	1	10
Medium weighting: biodiversity	1	1	34
Resources			
Conserve resources essential to sustain life in ecosystems.	2	2	70
Choose resources with the least impact	1	1	25
Plan for wise use of renewable resources	1	1	48
Plan for wise use of non-renewable resources	1	1	20
Average weighting: resources	1.3	1.3	47
Land use			
Optimise land use	2	2	72
Minimise “conflicts” of use	2	2	70
Maintain landscape diversity	1	1	47
Medium weighting: land use	1.7	1.7	66
Average weighting: ecological dimension	1.3	1.3	57

Source: field survey data processing, December 2021 – June 2022.

This Table shows that the evaluations are low for resources and biodiversity, and high for the ecosystem and land use variables. As a result, performance is average for the ecosystem and land use variables. In the evaluation of the dike method strategy, it can be seen that none of the dimensions achieved a weighted performance of 60% (Figure 9).

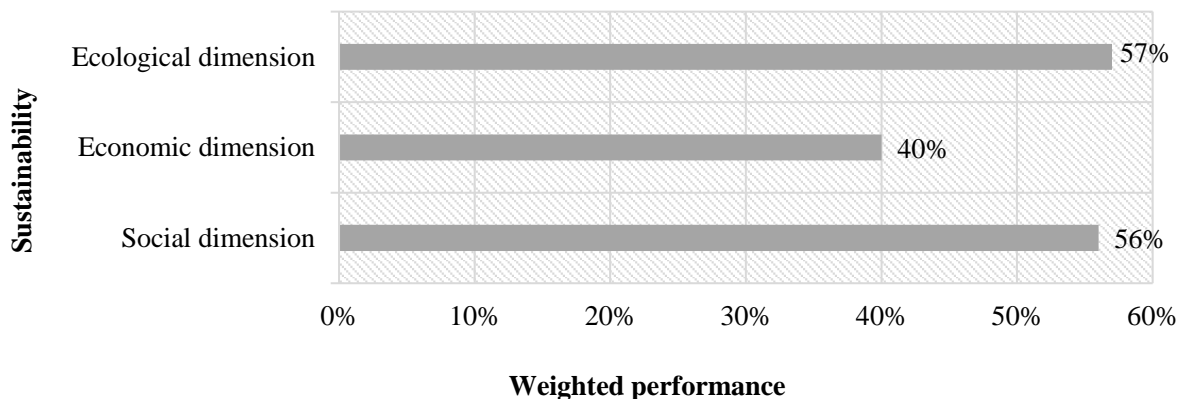


Figure 9. Very low sustainability of the reactive strategy (dike methods)

Source: field survey data processing, December 2021 – June 2022.

This means that we are in a “degrading” strategy. This situation could be explained by the fact that the reactive adaptation of the interviewees focused on the low productivity of agricultural and tree production (shea, African locust bean) in response to rainfall variability. However, in the case of the study area, there is also a continuous increase in wind speed, which annually uproots trees (shea, African locust bean) in agricultural fields, and the occurrence of extreme rainfall, leading to increased

drought and flooding. The combination of these climatic risks (occurrence of wind and extreme rainfall) has therefore rendered the impact of the reactive strategy ineffective. The same conclusion about the reactive adaptation option was reached in the work of Robert & Bergez (2016); Yousefpour et al. (2017); Lempert & Collins (2007). Indeed, in reactive decision making, adaptation does not incorporate anticipation, but rather adapts by progressively incorporating new information, according to Robert & Bergez (2016). Under these conditions, lack of anticipation implies that reactive adaptation must depend on climate risk magnitude (Yousefpour et al., 2017). And if the latter is very high, it could lead to irreversible damage, resulting in ineffective or less sustainable reactive strategies (Lempert & Collins, 2007). This has led some authors (Endrikat et al., 2014; Kim et al., 2018) to argue that proactive strategies lead to better environmental performance, while reactive strategies are associated with worse environmental performance.

Conclusions. This study shows that, in the context of climate variability, farmers who manage trees in agricultural fields mobilise different strategies. These are proactive, reactive, silvicultural and combined strategies. Proactive, reactive and combined strategies are widely used by farmers according to the Adaptation Strategy Index. However, their assessment using the Sustainability Analysis Guide shows that when the proactive strategy is used alone, sustainability is insufficient. On the other hand, when the two strategies are combined, sustainability is acceptable. In the case of the reactive strategy, sustainability is described as less sustainable, as the performance scores for the three dimensions of development are below 60%. There is therefore an urgent need to raise awareness among farmers in Samba commune of the need to use the combined proactive strategy to strengthen their resilience to climate variability.

The limitations of this study lie in the fact that it relies mainly on the opinions of tree managers in agricultural fields. However, respondents' answers on the sustainability of adaptation strategies could be influenced by the economic benefits of these strategies, as they are poor. This may have an impact on their assessment of sustainability. It would therefore be interesting in future research to examine the factors of success or failure of the sustainability of adaptation strategies in rural areas in a context of climatic extremes.

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