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Vulnerability of Farms to Climate Variability and Change, and Adaptation Actions in the Tillabéry Department, Niger

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Abstract

In Niger, farms have been facing negative effects of climate change for several decades. The objective of this work is to assess the vulnerability of farms in Tillabery department by proposing an adaptation approach. A five-step method and descriptive analysis were used on a sample of 250 farmers. The degree of damage caused by pests and crop diseases is significant, with respective proportions of 52.50% and 40.40%. It appears that the main climate risk factors for vulnerability are droughts, floods, soil degradation, and pest invasions. Additionally, the average level of exposure to agricultural operations is very high, with an index of 0.6. The sensitivity index remained constant in the range of 0.3 to 0.6 and is significant (reaching an index of 0.8). However, 61.2% of farms have a medium level of vulnerability and 33.3% have a high vulnerability to the effects of climate change. Nonetheless, a concerning trend regarding the vulnerability of farms has been observed. To assist policymakers and development actors in improving the vulnerability level of these production units, four phases of action are proposed: a diagnostic phase, evaluation, estimation of adaptation needs, implementation, and proper monitoring of actions.

Keywords

Vulnerability, Farms, Climate Change, Tillabery, Niger

1. Introduction

The impacts of climate change are among the current challenges that humanity, particularly in rural areas, must and should face. They affect climate-sensitive rural livelihood systems [1]. Countries that contribute the least to the causes of climate change are the most affected and vulnerable to its impacts [2]. Recent studies have shown a possible decrease in rainfall and an increase in temperature [3]. West Africa, one of the most affected regions, especially the Sahel zone, has already experienced a temperature rise of 2˚C since 1950, significant variability in precipitation, and an intensification of extreme weather events [4]. Niger, one of the countries in this region, is among the most vulnerable in the world due to its climatic context, environment, and economy [5]. The latter is primarily based on agriculture and livestock (86% of the population). This economic sector is predominantly managed by family units [6]. Climate risks only exacerbate the vulnerability of the country's socio-economic systems [7]. Given certain constraints related to these risks, the area per agricultural active person could decrease even more than initially projected; it could drop from 1.17 hectares in 2006 to 0.62 hectares by 2050. Agricultural labor productivity could be reduced by 20% compared to CIRAD's central scenario if no additional efforts to increase yields are observed [8]. Thus, farm incomes are negatively affected both by subsequent increases in temperature and decreases in rainfall [9]. Despite all the efforts made in the agricultural sector, the problem persists, and the vulnerability of farms to climate change significantly weighs on the living conditions of farming households [10]. Climate change and its influence on agricultural potentials do not imply the same economic impacts depending on the prevailing sociodemographic context in the region [11]. If significant efforts are not made [12], agricultural economies risk further degradation, rural population instability may increase, and internal as well as cross-border imbalances may intensify [8]. Since the mid-1990s, numerous negative externalities generated by the productive agricultural model have been thoroughly examined by many actors outside agriculture [13]. The department of Tillaberi especially the rural commune of Kourtheye is an area where agriculture (rainfed, irrigated, or flood-recession), livestock farming, fishing, and trade are dominant activities. Currently, these activities occur in a context marked by a resurgence of extreme climatic phenomena, including recurrent droughts, floods, and strong winds. This has had negative consequences on production systems, infrastructure, and public health (especially for farming households). This situation has heightened the vulnerability of households farm's in villages and hamlets that can no longer cope with the multiple shocks they face.

The present study aims to evaluate the vulnerability of farmers' agricultural operations in the face of climate change effects. Specifically, it seeks to: (1) identify the level of vulnerability of farms to the effects of climate change; and (2) propose adaptation options for improvement to policymakers, rural development actors, and the population that could enable farmers to be more resilient to the impacts of climate change.

The research hypothesis formulated for this study is that the level of vulnerability of farms is very high when considering the climate risk factors in the area, which prevents producers from achieving significant agricultural yields.

2. Materials and Methods

2.1. Study Area

The rural commune of Kourtheye is located in the southwestern band of the Tillabéri Department, situated between 13˚45' and 14˚27' North latitude and 1˚30' and 1˚52' East longitude. Geographically, the commune of Kourtheye is bordered to the north by the urban commune of Tillabéri, to the south by the rural commune of Karma, to the southwest by Namaro, to the east by the rural commune of Simiri and the urban commune of Ouallam; and to the west by the rural commune of Gotheye. The climate is Sahelian, characterized by a negative gradient of precipitation from south to north. The average annual rainfall totals range from 250 mm in the north to 400 mm in the south. Temperatures, even at their minimum, remain quite high, averaging between 18˚C and 45˚C throughout the year. This climate is characterized by three distinct seasons: a dry and cool season from November to February, a dry and hot season from March to June, and a rainy season from June to October.

2.2. Data Collection Steps and Sampling

Three survey mechanisms were implemented to achieve the objectives. The first survey involved "an investigation in the field" (I); the second allowed for discussions with farmers in a "Focus Group" (II); and the third was an individual survey (III) on production factors, the effects of climate change (**Figure 1**). For the first case, the observed indicators are primarily.

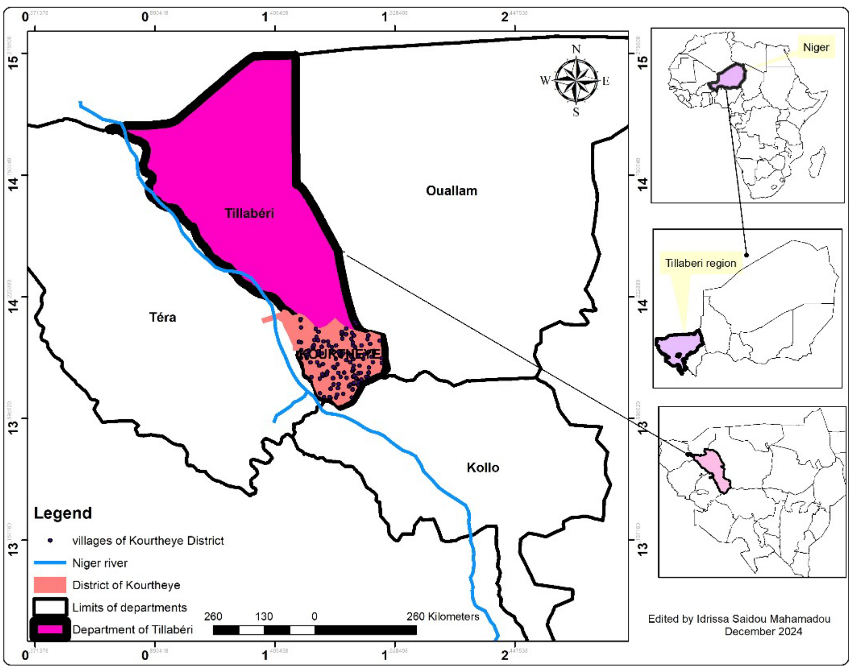

Figure 1. Localization of Tillaberi department.

- The geographical area in which farms are located concerning climate risks (*i.e.*, whether it is in a zone prone to droughts, floods, or rising temperatures).

- A description of the current climate: average rainfall, average temperatures, and general variability. This observation is accompanied by the farmer's perception.
- The types of crops grown and their sensitivities to climate change.
- How farmers utilize natural resources, specifically certain production factors (water, soil).
- The historical climate context through farmers' perceptions: changes in climate in the region (local data: frequency of droughts, rainy periods).
- The impacts of climate change on agricultural production (yield variations).
- The level of investment capacity and technology available to farmers to cope with these challenges.
- The health of farmers in relation to climate variability.

The focus group was conducted using an open questionnaire with a group of stakeholders: local farmers such as family farm heads, traditional leaders, agricultural technicians, and some representatives from farmers' organizations. The aim of this activity is to explore their perceptions, experiences, and strategies developed in response to challenges that threaten the viability of various production units in the area (**Figure 2**).

Figure 2. Localization of Tillaberi department.

The sample size for the survey is set at 250 agricultural households. The following mathematical formulas were used in three steps to determine the final sample size. The first step (1) involves determining the initial sample size (ISS). Its calculation formula is as follows:

$$ISS = \frac{z^2 \cdot P(1-P)}{e^2} \tag{1}$$

where:

- z is the security level regarding the representativeness of the population. A margin of error e = 5% was used, hence z = 1.96;
- P is the homogeneity of the population, found from previous studies, and q = 1 − P.

The second step (2), called adjustment of the sample size, takes into account the number of farmers (ASS). Its calculation formula is: $ASS = \frac{ISS.N}{N + ISS}$ (2)

where:

- N is the total number of farmers.

The third step (3) coincides with the adjustment for the response rate to determine the final sample size (FSS). Its formula is written as: $FSS = \frac{ASS}{RR}$ (3)

where:

- FSS is the final sample size,
- ASS represents the adjusted sample size to ensure a response rate (TR) of 90%.

2.3. Analysis Methods

Vulnerability is considered the susceptibility to being affected by exposure to stresses related to social and environmental changes, in the absence of the ability to adapt [2], or the susceptibility to suffer damage [14]. Its analysis involves various approaches [15]. Thus, the vulnerability of agricultural production systems to climate change can also be viewed as the propensity or predisposition of these farms to be negatively affected by climate change. Vulnerability depends on three key elements: the exposure of the system to climate impacts and hazards (the nature and extent of climate disturbances), sensitivity to disruptions or external constraints (potential damages), and adaptive capacity (the system's ability to adjust to the consequences of disturbances). Vulnerability is complex, evolving, and multi-scalar. Therefore, its analysis must be comprehensive, dynamic, and geographically contextualized [16]. Mathematically, it can be expressed as a function (4):

$$Vulnerability = f\left(Exposure, Sensitivity, Adaptive\ Capacity\right) \tag{4}$$

Vulnerability thus appears as the measure of how susceptible or unable a system is to cope with the adverse effects of climate change, including variability and extreme events. It is a function of the nature, extent, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity [17]. The assessment of this vulnerability depends on the types of methods, approaches, and fields used [18]. Have followed a contextual approach and an income-centered approach in assessing the economic vulnerability of agricultural systems. The article highlights the advantages of these methods but also points out their limitations, particularly concerning social dimensions, dynamic aspects, and long-term trajectories of farms. Two steps are followed: (i) identification of vulnerability indicators (step 1), and (ii) determination of the level of vulnerability by taking into account the specific characteristics of each farm (step 2). The equation for this vulnerability is given by (5):

$$Vulnerability = Exposure \times Sensitivity \times Adaptive\,Capacity \tag{5}$$

In the context of some studies on climate change [19] and risk management, the framework presented conceptualizes vulnerability according to three components: (1) Robustness: a measure of the amount of stress that a system can tolerate before changing state [20]; (2) Sensitivity: the degree to which a system is modified or affected by disturbances [21]; (3) Adaptive Capacity: the ability of a system to adapt to disturbances, mitigate potential damages, and take advantage of opportunities or cope with consequences [2]. The benchmark [22] and the Intergovernmental Panel on Climate Change (IPCC) [23] have been used to create indices from standardized indicators to analyze the vulnerability of farms to climate change. In this case, vulnerability is considered as the difference between adaptive capacity (socio-economic) and sensitivity, with exposure added. In this case, the equation for vulnerability is given by (6):

$$Vulnerability = (Adaptive\,Capacity) - (Sensitivity + Exposure) \tag{6}$$

According to these authors, as a farmer's adaptive capacity increases relative to their sensitivity and exposure, the farmer becomes less vulnerable to climate change risks. Conversely, when a farmer's adaptive capacity decreases relative to sensitivity and exposure, they become more vulnerable. The vulnerability of smallholder farmers to climate change has also been evaluated using three different composite indices [24]: (I) the Livelihood Vulnerability Index, (II) the Livelihood Vulnerability Index—Climate Change Penalty, and (III) the Livelihood Effect Index. Additionally, in 2013, the German Cooperation (GIZ) followed six steps in studying vulnerability: (i) brainstorming on local understanding of climate change, (ii) situational analysis of local agricultural practices and associated issues, (iii) listing and ranking climate risks (calendars/trends, causes and effects), (iv) rating community perceptions on the impacts of climate risks, (v) brainstorming on reasons for vulnerabilities, and (vi) listing adaptation strategies and possible external support (which may lead to adaptation planning).

2.4. Approach Maintained for Measuring the Level of Vulnerability of Farms

The approach maintained for measuring the vulnerability level of farms consists of several steps aimed primarily at defining the very concept of farm vulnerability in the face of a shock (climate). This phase will help clarify the concept. The definition will lead to identifying several components of vulnerability. Each component consists of various indicators. These indicators are determined in the study area by taking into account the knowledge of farmers, the evolution of the landscape, and the farms. A methodological review of vulnerability measurement is then conducted to gain perspective and make a decision on the most appropriate method. Ultimately, all these steps are essential for determining the level of vulnerability of farms (**Figure 3**).

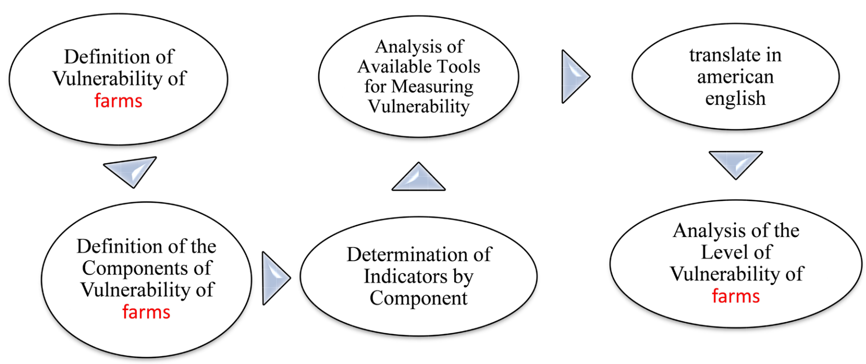

Figure 3. Steps for analyzing the level of farms vulnerability.

2.5. Indicators Selected for Assessing the Vulnerability of Farms to Climate Change Effects

The following table defines six (6) components for measuring the vulnerability of farms. These include climate factors defined by the impacts and hazards of climate (exposure) within farms, the agricultural production obtained, delays in carrying out agricultural activities, the health status of agricultural assets, production factors defining sensitivity, and the various strategies developed by farmers (adaptation of farms) to cope with climate risks. However, it is important to note that climate factors significantly affect the health of farmers. This, in turn, influences agricultural activities and ultimately impacts agricultural production (Table 1).

Table 1. Indicators for measuring the vulnerability of farms.

Vulnerability	Components	Indicators	Measuring
Exposure climate impacts and hazards	Climate factors	➢ Temperature variation	(Scale of 1 to 5)
		➢ Wind frequency	(Scale of 1 to 5)
		➢ Flooding	(Scale of 1 to 5)
		➢ Duration of drought pockets	(Scale of 1 to 5)
		➢ Locust invasions in farms	(1 Yes, 2 No)
		➢ Soil degradation in farms	(1 Yes, 2 No)
		➢ Irregularities in rainfall	(1 Yes, 2 No)
		➢ Storm frequency	(Scale of 1 to 5)
		➢ Caterpillar invasions in farms	(1 Yes, 2 No)
		➢ Short duration of winter	(Scale of 1 to 5)
		➢ Heavy rainfall intensity	(Scale of 1 to 5)
		➢ Dust intensity	(Scale of 1 to 5)
Sensitivity disruptions or external constraints	Agricultural production	➢ Agricultural production	*Continue*
		➢ Coverage period of productions	Number in months
	Agricultural activities	➢ Delay in planting period	Average number of days
		➢ Delay in fertilizer application	Average number of days
		➢ Delay in tilling and weeding	Average number of days
		➢ Delay in transplanting	Average number of days
		➢ Delay in soil preparation	Average number of days
	Health of farmers	➢ Management of illnesses	Cost in FCFA
		➢ Days lost per person	Number of days
		➢ Prevalence of household morbidities	Percentage
		➢ Known active individuals stopping work for health reasons.	Number of people

Continued

Sensitivity disruptions or external constraints	Production factors	➢ Intermediate consumption	Cost in FCFA
		➢ Equipment goods	Cost in FCFA
		➢ Labor	Cost in FCFA
		➢ Area (land area)	*ha*
Adaptation adjustment capacity of the system (farms)	Adjustment factors	➢ Fertilization	(1 Yes, 2 No)
		➢ Planting date	(1 Yes, 2 No)
		➢ RNA/Planting	(1 Yes, 2 No)
		➢ Non-agricultural income	(1 Yes, 2 No)
		➢ Variety choice	(1 Yes, 2 No)
		➢ Collective prayers	(1 Yes, 2 No)
		➢ Recourse to competent authorities	(1 Yes, 2 No)
		➢ CES/DRS activities	(1 Yes, 2 No)

The level of vulnerability of farms is determined by applying the following formulas and steps:

Step 1: Calculation (7) of the individual vulnerability of farms.

$$V_{ifn} = \frac{\sum_j^k x}{x_i} \tag{7}$$

V_i Individual vulnerability of farms for n climate factor;

x Indicator of vulnerability Factors;

Step 2: Calculation (8) of the vulnerability of sensitivity, exposure, and adaptation of farms.

$V_n = \frac{\sum_j^k x}{\max(x_i)}$ (8) i, sensitivity, exposure, and adaptation.

Step 3: Determination of the vulnerability index (13) of farms.

$$V_G = \frac{\sum_j^k x}{\max(x_A)} - \left(\frac{\sum_j^k x}{\max(x_S)} + \frac{\sum_j^k x}{\max(x_E)} \right) \tag{9}$$

$$\text{Sensitivity Index} = nb.si\left(serie\text{7}_S; indice\ Vs\right) \tag{10}$$

$$\text{Exposure Index} = nb.si\left(serie\text{7}_E; indice\ Ve\right) \tag{11}$$

$$\text{Adaptation Index} = nb.si\left(serie\text{7}_A; indice\ Va\right) \tag{12}$$

$$Index\ of\ Vulnerability = Adaptation\ Index - \left(Exposure\ Index + Sensitivity\ Index\right) \tag{13}$$

A = adaptation of farms, S = sensitivity of farms, and E = exposure of AEs to the effects of climate change.

Step 4: Assessment of the level of vulnerability of farms to climate shocks.

It should be noted that during the calculation of vulnerability indicators, a negative value was assigned to both exposure and sensitivity. The justification is that households that are highly exposed to climate shocks are more sensitive to risks and damages. Following the calculations, the table below provides the different classes of indices for assessing the level of vulnerability of farms (Table 2) according to a scale of 0 (very low) to 1 (very high).

Table 2. Classes of vulnerability index.

Assessment of farms' vulnerability	Index classifications
Very low	0 ≤ Vulnerability index < 0.2
Low	0.2 ≤ Vulnerability index < 0.4
Medium	0.4 ≤ Vulnerability index < 0.6
High	0.6 ≤ Vulnerability index < 0.8
Very high	0.8 ≤ Vulnerability index ≤ 1

3. Results

3.1. Socio-Economic Characteristics of Farms

The average household size of a family farm is estimated to be about nine (09) people. The average number of agricultural workers in these farms is 5, with a standard deviation of 3. The study reveals that the average area cultivated per family is 1.67 hectares. For irrigated crops, the average area is 0.52 hectares with a standard deviation of 0.3, while for rainfed crops, it is 1.12 hectares. The analysis of results also shows that farmers in these farms spend an average of 129876.8 FCFA on agricultural activity-related expenses. Changes over time and space in climate and its variability led farmers to experience delays in agricultural activities. Indeed, regardless of the activity concerned, especially those heavily dependent on the rainy season (such as transplanting, plowing, weeding, and fertilizing), an average delay of 13 to 14 days is observed in farms, except for activities related to soil preparation. Other important factors include the prevalence of illnesses, with an average rate of 70%. (Table 3)

Table 3. Characteristics of farms.

Characteristic variables	Mean value ± standard deviation.
Age (years of farmers)	58.0 ± 14.7
Household size (number)	9.9 ± 3.9
Agricultural workers (number)	4.7 ± 2.6

Continued

Millet yield (kg/ha)		248.62 ± 151.6
Cultivable area per family (ha)		1.67 ± 2.4
Sorghum yield (kg/ha)		235.59 ± 310.2
Rice production (kg)		3737.60 ± 6862.6
Rice area (ha)		0.52
Months of production coverage (number of month)		4 - 5 mois
Delay in agricultural activities (number of days lost)	Soil preparation	0.4 ± 1.7
	Transplanting	14.6 ± 8.6
	Plowing & weeding	13.6 ± 9.4
	Fertilizer application	13.1 ± 8.6
Total number of days delayed		40.5 ± 24.8
Prevalence of illnesses in the household (%)		0.7 ± 0.2
Individuals who experienced work stoppage		7.0 ± 3.2
Agricultural work stoppage in the household (days)		18.8 ± 14.4
Cost of agricultural expenses (in FCFA)		129876.8 ± 112672.2

3.2. Mains Climate Risks in the Farms

The main climatic risks in the farms, in order of importance, are droughts (consequences: Frequent and prolonged dry spells reduced water availability for crops and livestock), floods (consequences: intense rainfall events caused localized flooding, destruction of crops, loss of soil fertility, and displacement of farmers., soil degradation (consequences: enhanced erosion from heavy rains and wind and declining soil fertility exacerbated by climate variability), and pest invasions (consequences: Rising temperatures and erratic weather patterns favored the spread of pests and crop diseases; Increased vulnerability to locust invasions and other outbreaks) (**Figure 4**).

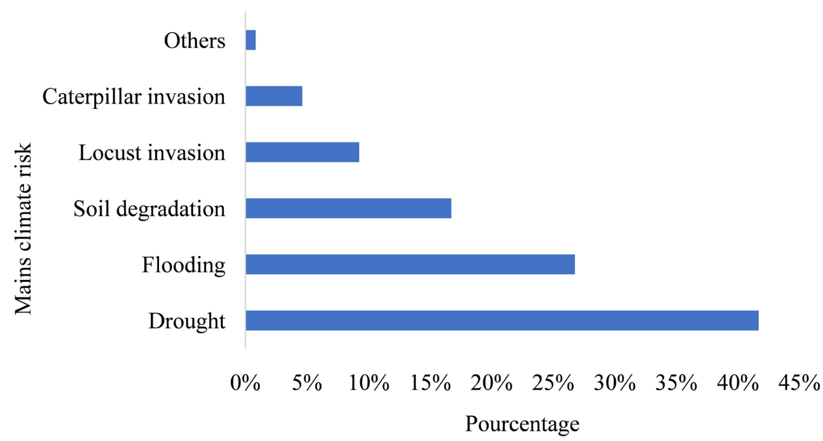

Figure 4. Mains climate risks in the farms.

3.3. Climate Constraints Related to Crop

Pests are of paramount importance as they help prevent or reduce direct or indirect crop losses caused by bio-aggressors. The following figure illustrates the frequency distribution of crop pests in farms in terms of damage caused by diseases and pests (measured by estimated degrees). It emerges that the degree of damage caused by pests and crop diseases in farms is significant, with respective proportions of 52.50% and 40.40% (**Figure 5**).

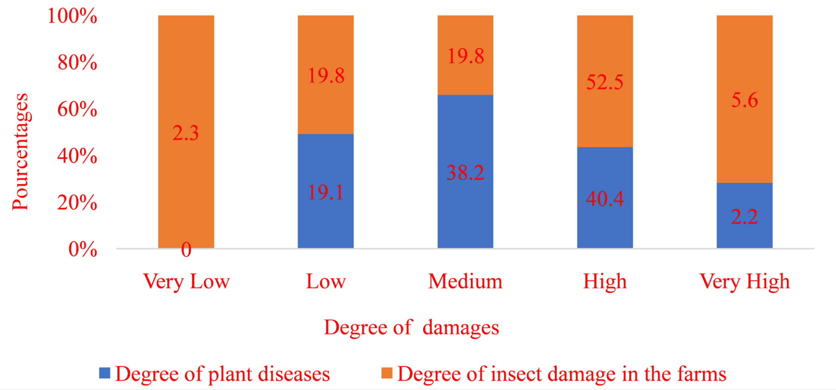

Figure 5. Degrees of damage from crop pests.

3.4. Exposure Level of Farms to the Effects of Climate Change

The following variables were considered to determine the exposure level of farms: temperature variation, wind frequency, flooding, duration of drought pockets, locust invasions, soil degradation observed in farms, irregular rainfall patterns, storm frequency in farms, caterpillar invasions in farms, short winter duration, and high intensity of rainfall and dust. Following the calculations, it was found that the level of exposure is very significant with an index of 0.6. The maximum level of exposure to the effects of climate change is high, with an index of 0.7 (**Figure 6**).

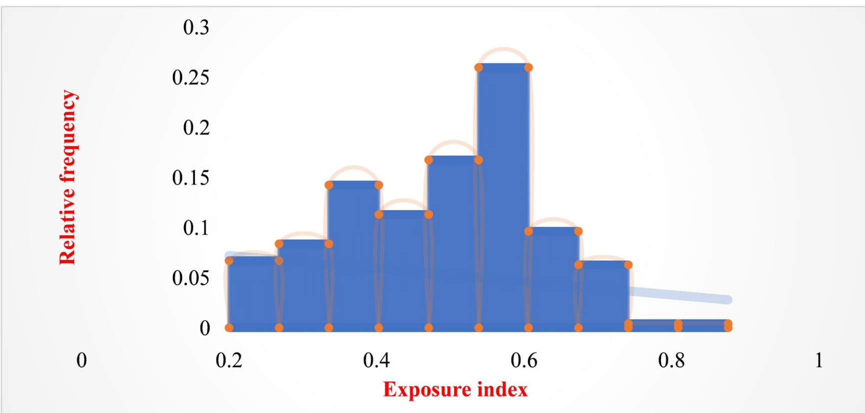

Figure 6. Exposure index of farms to the effects of climate change.

3.5. Sensitivity Level of Farms to the Effects of Climate Change

Regarding the measurement of sensitivity in these farms, four components were evaluated: agricultural production, farmer health, delays in agricultural activities, and costs related to production factors. A significant increase in sensitivity is observed in farms, showing a rather alarming trend. The sensitivity index has remained constant within the range of 0.3 to 0.6 and has reached a significant level (reaching an index of 0.8) (Figure 7).

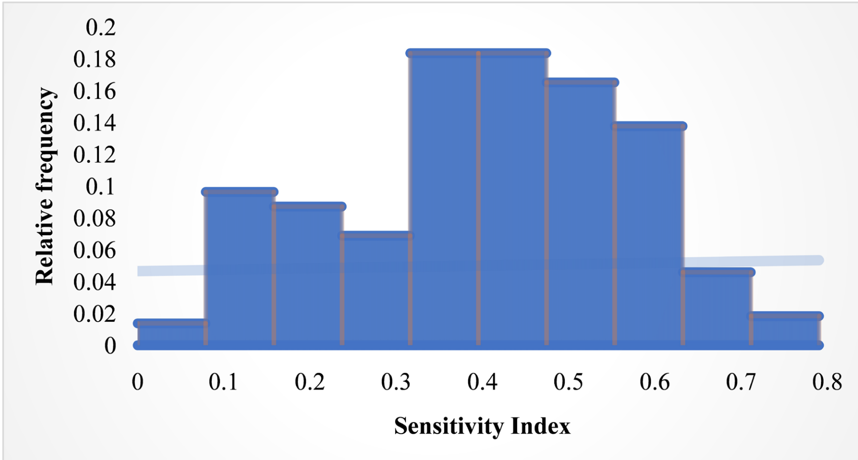

Figure 7. Sensitivity of farms.

3.6. Vulnerability Level of Farms to the Climate Change Effects

The overall level of vulnerability of farms has been assessed based on vulnerability indices. This evaluation indicates that 61.2% (with a vulnerability index between 0.4 and 0.6) of the farms in the study area have a medium level of vulnerability to the effects of climate variability and change. However, it is noteworthy that 33.3% of these farms experience a high level of vulnerability to these effects (with a vulnerability index between 0.6 and 0.8). These results are presented in the following **Table 4**.

Table 4. Vulnerability level of farms.

Level of vulnerability of farms	Vulnerability index class	Percentage (%) of farms
Very low	0 ≤ Index V < 0.20	0.1
Low	0.2 ≤ Index V < 0.40	4.2
Medium	0.4 ≤ Index V < 0.60	**61.2**
High	0.6 ≤ Index V < 0.8	33.3
Very high	0.8 ≤ Index V ≤ 1	1.2

3.7. Trend of Farms Vulnerability

The figure shows a rather concerning trend regarding the vulnerability of farms. Indeed, it can be observed that with climate change, the predicted vulnerability of farms tends to increase over time, as indicated in the following **Figure 8**.

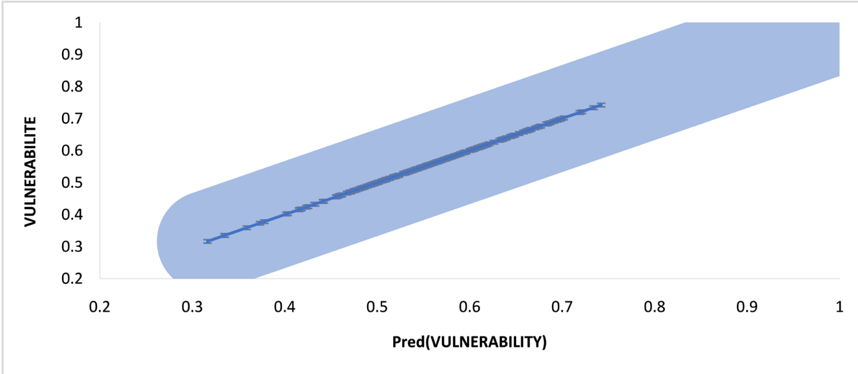

Figure 8. Trend of farms vulnerability level.

3.8. Strategy for Reducing the Farms Vulnerability to the Climate Change

This strategy aims to identify the farm's vulnerability factors and select appropriate measures to mitigate them. Four (4) essential phases are outlined (Figure 9).

Phase 1: Conducting a diagnosis at the farm level in the context of climate change

This involves understanding the impact on agricultural practices, production factors, farmer productivity, yields, and long-term sustainability of the farm. It could identify the various climatic factors that affect production by establishing a cause-and-effect relationship, while also considering other related factors that may indirectly impact the agricultural production unit.

The following steps can be followed:

- **Climate data analysis:** It is crucial to examine recent and future climate trends for the area based on local climate models. This includes temperature variations, changes in precipitation, drought periods, and heat waves.
- **Identification of climate risks in the area:** Identify and prioritize climate shocks (droughts, floods) and their extreme intensification related to crops and livestock.
- **Analysis of current practices:** Evaluate current practices regarding irrigation, water management, and land use in the context of climate change. Some agricultural practices may be vulnerable to climatic variations.
- **Resource management:** Identify how natural resources (soil, water, biodiversity) are managed. Sustainable management can enhance resilience against climate change.
- **Past yields and trends:** Analyzing yields from different crops in previous years helps detect any climate-related anomalies, such as production decreases, irregular yields, or total failures in some cases. Trends can be observed using yield modeling tools based on projected climate scenarios to predict areas most likely to be affected by climate changes.
- **Risk management systems:** Understand whether the farm has adaptation strategies (e.g., insurance against climate risks, water storage) and emergency plans for natural disasters.

- **Adaptation measures:** Assess available strategies for adapting to climate change. For this study, this mainly includes selecting varieties resistant to climatic conditions, integrated water management, and activities for recovering degraded lands.
- **Profitability of the farm:** Evaluate the economic effects of climatic conditions on the profitability of the farm (e.g., increased costs related to production factors, reduced yields, adaptation costs).

Phase 2 allows for an evaluation based on the analysis from Phase 1, with the aim of defining the level of vulnerability of the farms. This level can be very low, low, medium, high, or very high depending on the degree of impact. Following this, the correct implementation and proper monitoring of these actions are essential.

Phase 3 is crucial for identifying and understanding the risks to which these farms are exposed. This enables the establishment of appropriate risk management strategies to ensure their sustainability.

Phase 4: The implementation and monitoring of actions addressing the vulnerabilities of farms are critical steps in agricultural risk management. This phase aims to ensure that the strategies developed to mitigate identified risks are effectively applied and adapted over time.

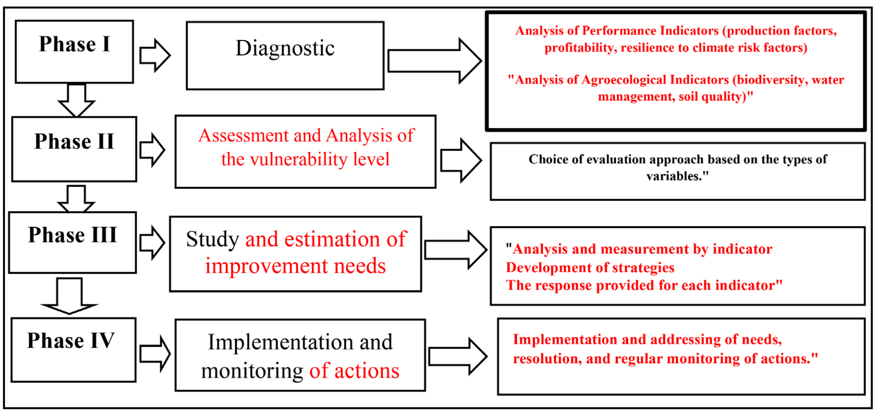

Figure 9. Model for improving the synchronic analysis of the vulnerability of agricultural operations.

4. Discussion

Agricultural systems are currently undergoing rapid changes due to the global environmental change context [25]. Agriculture is one of the most important sectors in the area and a primary activity for the population of Tillaberi. It is also one of the sectors most sensitive to climate change, and any degree of climate change has the potential to significantly impact agricultural production and related processes. Furthermore, this will inevitably have a huge impact on agricultural production in the future [26]. Millet, sorghum, and rice are respectively the main rainfed and irrigated crops in the region, both in terms of cultivated area, production, and their contribution to food security. Despite the privileged position of these crops, the region has become structurally deficient due to its climatic characteristics marked by periodic but increasingly frequent droughts over nearly decades. Results from farms reveal a critical environmental issue in the area in terms of insects or pests' damages.

Climate change has had both direct and indirect impacts on these farms. Directly, it affects significant climatic factors such as droughts (irregularity and insufficiency of rainfall, as well as inadequate distribution in space and time), floods. Indirectly, these factors have health impacts at the household level in general and on agricultural workers in particular [25]. Indicating that the direct impacts of climate, including atmospheric carbon dioxide (CO_2) concentrations, affect agricultural systems through effects on plant development, cereal productivity, and mortality. Projections show that climate change in agricultural regions will be characterized by slow, long-term changes in average conditions punctuated by acute extreme events. These impacts have rendered farms vulnerable to certain levels, as several constraints have been noted: delays in agricultural activities (averaging 14 days per activity) due to a shift from the normal activity period (such as soil preparation, transplanting, plowing, weeding, or fertilizer application). In Niger, farmers typically sow millet with the first useful rain, which occurs within a range of 15 to 20 mm. However, the arrival of rains is often delayed while the length of the rainy season continues to decrease [27]. However, the sowing date is a very important parameter that often determines the success of the crop. The destruction of weeds through weeding is the first maintenance operation, which should begin as soon as the plants reach about 10 to 15 cm in height. This indicates that their roots have developed sufficiently to ensure close contact with the soil. The second weeding is generally done 20 to 30 days after the first. A third weeding is sometimes performed for late varieties. Each year, it is necessary to adjust schedules based on weather conditions (for example, transplanting rice is impossible before the first rains that allow for puddling in the rice fields). During the growing cycle, flooding or prolonged drought can lead to reduced yields and may even result in the loss of the entire plot. These delays are directly related to climate variability and change and are indirectly linked to the deteriorating health status of farmers at certain times of the year. This study took several of these factors into account to assess and determine the level of vulnerability of farms [28]… Indeed, these farms are also located in an area characterized by climatic instability as well as sustained population growth [29]. Following calculations, it was found that the level of exposure is very high, with an index of 0.6. The same result was obtained by [27] who found that the exposure index related to intra-annual rainfall variability is slightly higher in the southern basin, with a high index of 0.66, indicating an intensification of vulnerability. The sensitivity index of farms has remained constant within the range of 0.3 to 0.6 and is considered medium. Emphasis has been placed on key production factors such as labor, workforce, and intermediate consumptions, as well as health factors. Furthermore, with limited physical capital, farms do not have substantial means of production, and what little they produce could be subject to pre-harvest and post-harvest losses due to pests (birds, beetles), late harvesting, manual harvesting, poor storage conditions (high humidity), fires, floods, artisanal processing, and sometimes theft [30]. The agricultural production obtained provides food coverage for households for 3 to 4 months. Additionally, results show that 61.2% of farms have a high overall level of vulnerability with a vulnerability index between 0.4 and 0.6. This level can be explained by recurrent droughts, floods in certain areas, soil degradation and poverty, attacks from crop pests, and other indirect health factors. The strategy proposed by the authors is primarily based on four main actions to positively improve vulnerability indicators for farms against the effects of climate change: diagnostic, assessment, rational estimation of needs, and implementation.

5. Conclusions and Recommendations

This study aimed to assess the vulnerability of farms in the department of Tillaberi to the effects of climate variability and change. It was found that there are numerous factors making farms vulnerable to climate variability and change in the area. Among these factors are the insects and pests damages. Although, the research hypothesis that states that the level of vulnerability of farms is very high when considering the climate risk factors in the area has not been confirmed. The level found of these farms to these effects is medium for the majority of them, while one-third of the farms exhibit a high level of vulnerability. To assist policymakers and potential decision-makers in reducing this vulnerability, four adaptation options have been identified that could enable cropping systems and the populations dependent on them to become more resilient to the impacts of climate change. In light of the analysis of the results, it is important to formulate recommendations for the stakeholders (Policy makers, NGOs) in order to combat poverty and food insufficiency for better resilience of communities in the area.

- Support agricultural operations with significant subsidies. This involves providing modern agricultural production equipment and inputs (such as the production and dissemination of improved seeds) that are adapted to the climatic conditions of the area.
- It is also essential to give paramount importance to the various existing agricultural farmer organizations in the area and support them by enhancing their capacities, ensuring they have enough competent technical staff at their disposal.
- Raise awareness among producers about the issues surrounding climate change and its consequences on household health and their agricultural operations.

Also consider training, retraining, and equipping phytosanitary brigadiers, as well as methods for rehabilitating degraded lands for agricultural purposes.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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