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Perceptions of Climate Change Risk on Agriculture Livelihood in Savanna Region, Northern Togo

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Abstract: The agriculture sector in the Savanna region of Togo is especially vulnerable to weather fluctuations, which have an impact on crop production levels. However, farmers' decisions to implement adaptation strategies are directly related to their perceptions of climate change risk. The current study employed a participatory workshop and household survey of 425 farmers to examine the drivers of specific climate change risks of interest (risk of loss of livelihood for farmers) and measure farmers' level of climate change risk perception. A climate change risk perception score (CCRPS), descriptive statistics, principal component analysis, and K-means cluster analysis were used to analyze the data collected. The findings revealed that the most important changes in climate conditions affecting agricultural production in the study area were mainly the increased duration of dry spells, erratic rainfall, and an increase in extreme rainfall events. These climatic variations cause more floods and droughts, which, when coupled with socio-ecological vulnerability drivers, increase the impact of these events on agricultural livelihood, expose more farmers and their farmland, and contribute to the risk of farmers' livelihood loss in the study area. Based on farmers' appraisals of the occurrence of hazards, their exposure, and their vulnerability, farmers' perceptions of climate risk have been classified into three categories: high, moderate, and low. This finding sheds some light on farmers' climate change risk perception, which may influence their adaptation decision. These findings can be used to increase the uptake of adaptation strategies and thus the resilience of Savanna region agriculture to climate change.

Keywords: climate variability; impacts; exposure; vulnerability; farming activity

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1. Introduction

Climate change has adverse effects on rural livelihoods all over the world, especially in West Africa. Climate change is defined by the Intergovernmental Panel on Climate Change as statistically significant variations in climate that persist for an extended time, typically decades or longer [1]. This phenomenon affects and is expected to have the greatest impact on agriculture, and the livelihoods of people in the developing world, particularly in West Africa due to their high dependency on rain-fed agriculture, and also their large dependence on agricultural practices for their livelihoods [2,3].

In Togo, agriculture accounts for approximately 38% of GDP and employs more than 70% of the workforce [4]. The agricultural sector in Togo is particularly vulnerable to the effects of climate change, with huge consequences on agriculture productivity and income [5]. For several consecutive years now, Togo has been subject to climate risks due to an alteration in the distribution of rainfall with extreme droughts and floods events, and a decrease in the number of rainy days across the country, impacting intensively agriculture livelihoods and the agroecosystems on which farmers rely [6–8]. The Savanna region, in Togo, is characterized by extreme climatic variability, including low and erratic precipitation, scarcity of water, frequent droughts and floods, and extreme temperatures [6,8]. The region's climatic conditions have changed over the last few decades, with less rainfall and, in particular, a shorter rainy season and greater variation in rainfall. The uneven distribution of rainfall affects crop and pasture yields, as well as water resources [9]. According to the Ministère de l'Environnement et des Ressources Forestière [10], it is projected that the magnitude of extreme climatic variability will rise compared to the reference situation (1995) in the Savanna region, with the greatest variations in temperature expected in the prefectures of Tône, Tandjoaré, Kpendjal, and Cinkassé, with consequences that would affect production levels of the main crops by 5% by 2025, 7% by 2050, and 10% by 2100.

Based on the observed climate trends and the expected impact of climate change on agriculture, building farmers' resilience through adaptation measures is crucial. However, farmers' decisions to implement climate change adaptation strategies are directly related to their perceptions of climate change, its impacts, and related risks [11]. To improve policy for addressing the challenges that climate change poses to farmers, it is critical to understand farmers' perceptions of climate change, its potential impacts, and associated risks. Nevertheless, a few studies have focused on the assessment of farmers' perceptions of climate-related risks in the Savanna region of Togo [3,4]. Therefore, this study aims to assess farmers' perceptions of climate risk related to the impact of current climate variability on agriculture in the Savanna region. Specifically, this study was set to answer the following questions:

1. What are the perceived key drivers of climate change risk in agriculture?
2. How do climate change risk perceptions vary among farmers' households?

2. Materials and Methods

2.1. Study Area

This study was conducted in fifteen (15) different localities across the Savanna region's seven prefectures (Figure 1). The Savanna region is located more than 600 km from the coast in the northern part of Togo. It extends between 0° and 1° east longitude and 10° and 11° latitude north, covers an area of 8533 km^2 (15% of the national territory), and is watered by the Oti River and its tributaries. It is bordered to the north by Burkina Faso, to the east by Benin, to the west by Ghana, and to the south by the Kara region. The research area has a tropical climate with a dry season from November to March and a rainy season from April to October. The annual rainfall ranges between 900 and 1400 mm, with August being the rainiest. The average temperature ranges from 26 to 28 degrees Celsius. The population is mainly rural, and their dominant activity is agriculture, which employs nearly 90% of the population [12]. The average population density in the Savanna region is estimated at 90 inhabitants per square kilometer and it is characterized by the highest poverty level in the country (65% of the population in 2017), food insecurity (53.3% of the population in 2010), and high population growth rate [13]. The study area's cultural diversity allows for the identification of nine ethnic groups, such as Gourma, Mossi, Yanga, Mamproussi, Koussassé, Boussanga, Bissa, Anoufo (Tchokossi), and Konkomba. The various ethnic groups form communities based on multiple traditional structures with relatively similar customary practices.

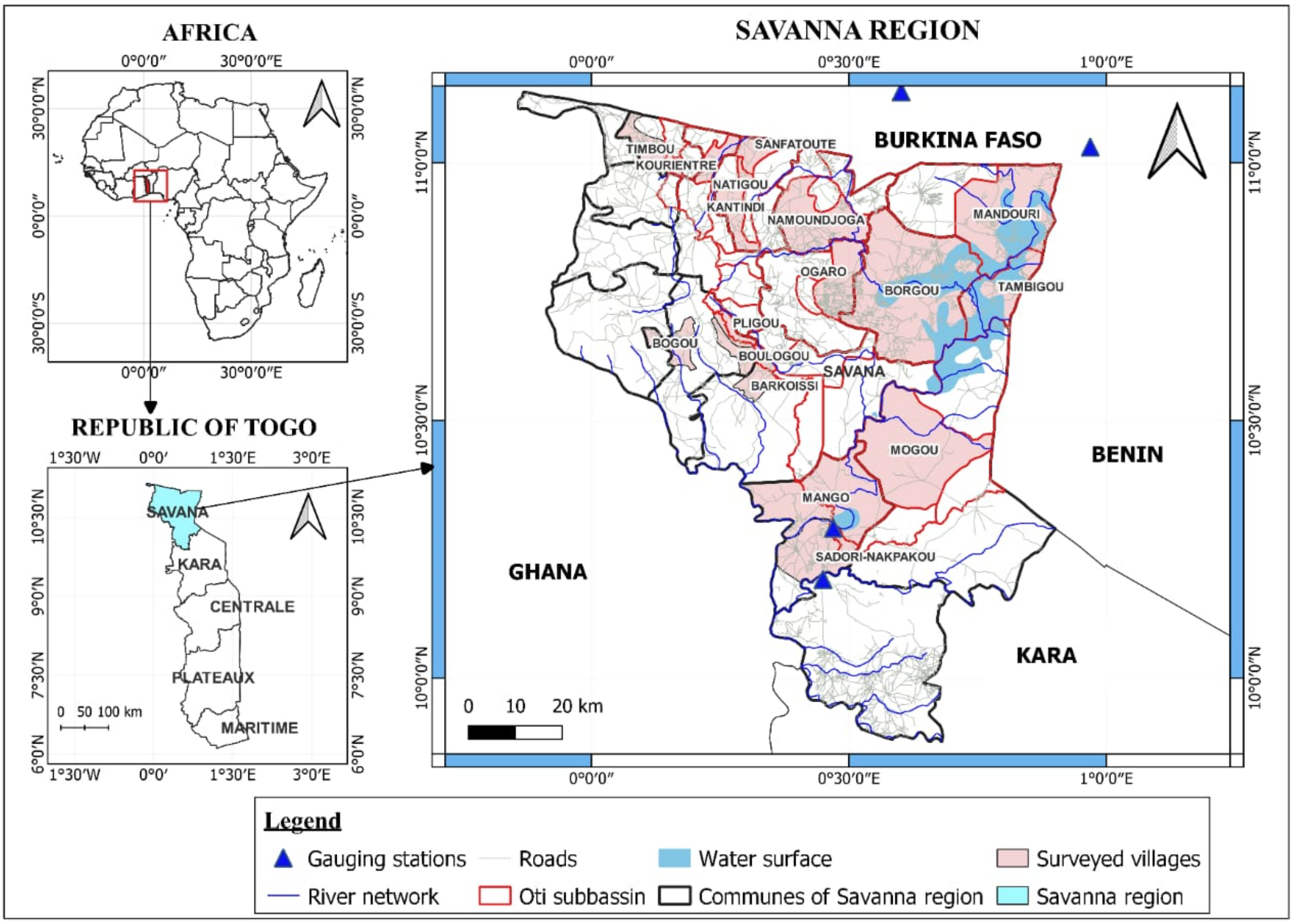

Figure 1. The geographical location of the study area.

2.2. Data Collection

2.2.1. Participatory Workshop

A local stakeholders' workshop was held in January 2022 to qualitatively identify the key drivers of the risk of climate-related impact on agriculture. The workshop involved 21 participants (men and women) from key local NGOs (working in the field of climate change and sustainable agriculture), agricultural local public institutions, community leaders, and farmers' organizations to broaden their knowledge. Those local stakeholders were identified in each of the seven districts of the study area under the assistance of extension agents based on their experience and technical expertise in the field of climate change and agriculture. The workshop was conducted entirely in French. It began with introductory talks during which the climate risk concept and its components (hazards, exposure, and vulnerability), as well as climate impact, were clarified by using the Intergovernmental Panel on Climate Change (IPCC) AR5 approach of risk. According to IPCC (2014), the concept of climate change risk is a function of hazard, exposure, and vulnerability [14]. Following that, a specific climate risk of interest was unanimously selected (risk of loss of livelihood for farmers) by the participants, based on their observations of the last 20 years. Afterward, the participants were divided into three groups of seven. Each group was made up of members of non-governmental organizations (NGOs), community leaders, farmer organizations, and agricultural local public institutions. Each group was asked four questions: (1) What are the major changes observed in the climate conditions and their related hazards affecting farmers' livelihood during the last 20 years? (2) Which major impacts related to the identified climate hazards affected farmers' livelihood during the last 20 years? (3) Which major social and ecological factors contribute to the risk of loss of livelihood for farmers in the study area? (4) What are the major exposed elements at risk? The top-ranked answers provided by each group for each of the four questions were considered to develop the household survey questionnaire.

2.2.2. Household Survey

With the assistance of local stakeholders, 15 localities in the Savanna region were purposefully chosen for a household survey based on their agricultural importance and the severity of past climatic events' (e.g., droughts and floods) impacts in terms of agricultural loss. The survey questionnaire was designed using the information gathered during the participatory workshop. The data were collected through a structured questionnaire using a simple random sampling technique. Face-to-face interviews were conducted in this survey. The questionnaire contained several questions based on the information collected during the local stakeholders' workshop session. The questions included: (1) the demographic and livelihood strategies of the respondents and (2) farmers' perceptions of climate change. The respondents were requested to appraise their view on the identified changes in climate parameters based on the extent to which they influence their agricultural livelihood. A five-point ranking scale was adopted to estimate their perception levels. The ranking scale ranged from 0 (no perception) to 4 (very high perception). (3) Perception of impacts deriving from changes in climate parameters and hazards on agriculture. The respondents were asked to identify climate-related impacts affecting their agricultural production based on the information gathered from the participatory workshop. (4) Perception of key factors determining vulnerability and exposure to the risk of loss of livelihood for farmers. The respondents were asked to give their views based on the subjective degree of agreement for each factor related to hazard, exposure, and vulnerability identified during the participatory workshop. Hence, a five-point Likert scale, ranging from strongly disagree (1) to strongly agree (5), was adopted to estimate households' perception levels.

Before starting the household survey, the interviewers were properly trained. Under the supervision of the researcher, the data of 60 farmers were pre-tested. Eligible interviewees were the head (male or female) of an agricultural household in the survey area who had lived there for at least 20 years before the survey. A total of 425 farm households were surveyed following Cochran's formula, with 60 households in each locality.

$$S = \frac{Z^2 PQ}{E^2} \tag{1}$$

where S = sample size per locality; Z = deviation set at 1.96 corresponding to a confidence level of 95%; P = the number of households in the locality; Q = 1 − P; and E = margin of error, which was equal to 5%.

To eliminate the language barriers between the interviewers and farmers, the interviews were carried out in local languages including Moba, Tchokossi, and French.

2.3. Data Analysis

2.3.1. Climate Change Risk Perception Index for Farmers

The Standardized Climate Change Risk Perception Index (SCCRPI) was used in this study to determine the most influential changes in climate parameters on agriculture production and livelihood based on farmers' perceptions. In various studies on climate change risk perceptions, the standardized climate change risk perception index (SCCRPI) has been widely used [15–19] to gain a better understanding of how farmers perceive climate change risks. The SCCRPI is a metric or index that combines the probability or likelihood of risk events with the severity of risk event consequences [20,21]. The respondents were asked to rate the extent to which the major changes in climate parameters had an impact on their agricultural production and livelihood. For ease of analysis, we denoted values to respective perception scales in increasing order, such as 0 for no perception, 1 for low perception, 2 for medium perception, 3 for high perception, and 4 for very high perception. The Standardized Climate Change Risk Perception Index (SCCRPI) was calculated using the following equation from [15].

$$\text{SCCRPI} = \frac{\text{CCRP}_\text{n} \times 0 + \text{CCRPl} \times 1 + \text{CCRP}_\text{m} \times 2 + \text{CCRP}_\text{h} \times 3 + \text{CCRP}_\text{vh} \times 4}{\text{Respective highest CCRPS value}} \times 100 \quad (2)$$

where SCCRPI is the Standardized Climate Change Risk Perception Index; CCRP_n is the number of respondents having no perception; CCRPl is the number of respondents having low perception; CCRP_m is the number of respondents having medium perception; CCRP_h is the number of respondents having high perception; and CCRP_vh is the number of respondents having very high perception. The total CCRPS value was calculated by multiplying the respective perception values with the total perception frequency against each statement, and the respective highest CCRPS value was calculated by dividing the total CCRPS value by the highest maximum boundary value and multiplying it by 100.

Since we had 425 respondents, the Climate Change Risk Perception Score (CCRPS) for any identified change in climate condition could range from 0 to 1700, with 0 being the minimum and 1700 being the maximum, where 0 indicates a minimum level of risk perception and 1700 indicates a maximum level of risk perception. The analyses were conducted using Excel software.

2.3.2. Measuring Farmers' Climate Change Risk Perception Level

The current study used PCA, a widely used data dimension reduction technique, to identify the variables that explain the variability in farmers' perceptions of climate risk. The standardized component scores derived from PCA were used to run K-means cluster analyses (KCA) to classify households into different climate change risk perception groups. Hyland et al. [22] identified different types of farmers based on their perception of climate change using PCA and cluster analysis.

Principal component analysis (PCA) is a data exploration tool based on ordination that converts a set of potentially correlated variables into a set of uncorrelated variables that capture the variability in the underlying data. PCA is a non-parametric analysis that is unaffected by any hypothesis about the probability distribution of the data [23]. PCA employs orthogonal linear transformation to identify a vector in N-dimensional space that accounts for as much of the total variability in a set of N variables as possible in the first principal component (PC), where total variability within the data is the sum of the variances of the observed variables after each variable has been transformed to have a mean of zero and a variance of one [24]. A second vector (second PC) orthogonal to the first is then sought to account for as much of the remaining variability in the original variables as possible. Each subsequent PC is linearly uncorrelated to the previous ones and accounts for as much of the remaining variability as possible [25]. PCA was used as a data reduction tool in this study to identify relationships between variables and the components to be kept. Varimax rotation was used as the type of orthogonal rotation in this analysis. In addition, the Kaiser–Meyer–Olkin (KMO) adequacy measure was used to determine the appropriateness of applying PCA and Bartlett's test of sphericity to test for the presence of correlation between the variables [26]. A KMO value greater than 0.5 and a significance level for Bartlett's test less than 0.05 indicate that there is a significant correlation in the data. To gain a better understanding of the components or factors received, the factors corresponding to eigenvalues ≥ 1 are suggested [27]. The Varimax rotation method was used to perform an orthogonal rotation.

K-means cluster analysis (KCA) is a clustering method that divides n observations into k clusters, with each observation assigned to the cluster with the closest mean. Iteratively, it works until the sum of squares from points to the assigned cluster centers is minimized. The value of k is determined by repeated exploratory uses of K-means clustering (i.e., k = 2 to 10) [28]. Before running the K-means cluster, the hierarchical cluster was run to determine how many clusters should be considered in the KCA. The analyses were conducted using SPSS version 26.

3. Results

3.1. Socio-Economic Characteristics of the Respondents

The results of the analysis presented in Table 1 show that the majority of respondents were males (73%). Concerning age, 76% of the respondents were within the active working age of 36–50 years. Literacy rates among respondents hovered around 45%. The most common livelihood strategy of the households was crop farming activities (99%), with food crops accounting for 95% of all significant cultivated crops on an average farm size of 4.96 hectares. The respondents had an average of 26 years of farming experience, with an average labor force of approximately 5 people. Half of the respondents (50%) were members of farming associations and had access to extension services.

Table 1. The socio-economic characteristics of respondents (data refer to the sample of farmers).

Variables and Category	Frequency	Mean
Age		
20–35	44 (10%)	
36–50	321 (76%)	
50+	60 (14%)	
Gender		
Male	310 (73%)	
Female	115 (27%)	
Education		
Illiterate	234 (55%)	
Literate	191 (45%)	
Type of crop		
Food crop	395 (95%)	
Cash crop	272 (66%)	
Agricultural Group membership	213 (50%)	
Extension services	212 (50%)	
Farming experience	425	26
Farm size (hectare)	425	4.96
Labor force	425	4.71

3.2. Local Stakeholders' Perceptions of the Key Drivers of Climate Change Risk

Table 2 summarizes the information gathered from the participatory workshop. This includes hazard, exposure, and vulnerability drivers, as well as climate impacts that contribute to the risk of loss of farmers' livelihoods. The workshop participants asserted that five major changes in climate conditions—erratic rainfall, warmer temperatures, an increase in extreme rainfall events, a shortening of the rainy season, and an increase in the duration of dry spells—were responsible for the increase in flood and drought events in the study area. Increased flood and drought events, according to the participants, have a variety of negative impacts on croplands and farmers' livelihoods. These impacts include decreased water availability, decreased soil moisture, increased pests and crop diseases, destruction of crops and farmland, damage to stored agricultural products, increased soil erosion, decreased soil fertility, decreased crop production and yields, and decreased agricultural income.

Table 2. The top-ranked responses to group questions from the participatory workshop with stakeholders.

	What Are the Major Changes Observed in the Climate Conditions and Their Related Hazards?		Which Major Impacts Related to the Identified Climate Hazards Affected Farmers' Livelihoods during the Last 20 Years?	Which Major Social and Ecological Factors Contribute to the Risk of Loss of Livelihood for Farmers?	What Are the Major Exposed Elements at Risk?
	Changes in Climate Conditions	Climate-Related Hazards			
Group 1	• Erratic rainfall • Warmer temperatures • Increase in extreme rainfall events	• Increased drought events • Increased flood events	• Decrease in soil moisture • Increase in the rate of soil erosion • Soil fertility decline	• Loss of ecosystem services provided by cropland for farming • Strong dependency on agricultural income • Unsustainable farming practices • Lack of access to sufficient farm labor	• Cropland • Farmers
Group 2	• Shortening of the rainy season • Warmer temperatures • Increase in extreme rainfall events	• Increased drought events • Increased flood events	• A decline in crop production and yields • Increased incidence of pests and crop diseases • Cropland and farm destruction	• Increased cropland degradation • Lack of knowledge of sustainable land management practices • Lack of improved seeds • Lack of access to climate information	• Cropland • Farmers
Group 3	• Increase in the duration of dry spells • Erratic rainfall • Increase in extreme rainfall events	• Increased drought events • Increased flood events	• Decrease in water availability • A decline in agricultural income • Damage to stored agricultural products	• Lack of access to irrigation • Cultivated land size • Lack of access to agricultural assets • Lack of access to financial safety net	• Cropland • Farmers

Additionally, relevant drivers determining the vulnerability of the social-ecological system (SES) were identified. Four main drivers were deemed especially important in each of the three groups. In total, 12 social and ecological vulnerability drivers were identified. The drivers include loss of ecosystem services provided by cropland for farming, increased cropland degradation, cultivated land size, strong dependency on agricultural income, unsustainable farming practices, lack of access to sufficient farm labor, lack of knowledge on sustainable land management practices, lack of improved seeds, lack of access to climate information, lack of access to irrigation, lack of access to agricultural assets, and lack of access to the financial safety net. For example, the stakeholders highlighted that as the population of the study area is increasing, agricultural practices have changed, with the disappearance of fallow land, conversion of forested land, the reduction of crop residues returned to the soil, and the cultivation of land that is too poor or degraded. The combination of these practices results in a decrease in soil cover and a decrease in the rate of organic matter in the soil, accentuating the phenomenon of soil erosion and the degradation of soil fertility, resulting in lower crop production and yields.

Furthermore, according to the participants, these vulnerability drivers may have an influence on the identified impacts of increased drought and flood events on cropland and farmers' livelihoods, which may increase the exposure of farmers and their croplands in the study area. This finding indicates that, in general, local stakeholders have a good understanding of the drivers of the risk of loss of farmers' livelihoods as a result of climate change.

3.3. Farmers' Perceptions of Climate Change, Hazards, and Impacts on Agricultural Livelihood

Approximately 97.2% of household respondents reported perceiving a change in temperature and rainfall over the last 20 years. In our study, we used the Likert scale to assess farmers' perceptions of the influence of those changes on their agricultural livelihood based on their own experience. To gain a better understanding, the SCCRPI was calculated using frequency analysis from Equation (2) on the five major changes in climate conditions identified during the participatory workshop (Table 2). According to the SCCRPI, the values ranged from 49.18 to 92.12 (Table 3), demonstrating the influence of all five major changes in climate conditions on agricultural livelihood perceived by farmers in the study area. After calculating the respective index value for each climatic change, we ranked them based on the highest index from 1 to 5 for better understanding and interpretation (Table 3). Farmers ranked the increased duration of dry spells highest among climatic changes considered, followed by erratic rainfall, an increase in extreme rainfall events, a shortening of the rainy season, and warmer temperatures.

Table 3. Perception of change in climate conditions affecting agricultural livelihood.

Perceived Changes in Climate Parameters	Very High Perception (4) (5)	High Perception (3)	Moderate Perception (2)	Low Perception (1)	No Perception (0)	SCCRPI	Rank
Increased duration of dry spells	348	37	12	15	13	92.12	1
Erratic rainfall	330	50	15	17	13	91.00	2
Increase in extreme rainfall events	255	17	14	126	13	73.71	3
Shortening of the rainy season	221	29	16	146	13	69.47	4
Warmer temperatures	102	11	32	267	13	49.18	5

Furthermore, farmers perceive that those changes have serious consequences on the occurrence of drought and flood events that severely affected agricultural livelihood in the study area. Figure 2 shows that both drought and flood hazards were perceived to have become more intense, frequent, prolonged, and severe over the last 20 years.

Moreover, 96% of those perceiving the changes in climate conditions claimed that they had experienced the impact of these changes on their agricultural livelihood. Figure 3 reveals that among the impacts identified during the participatory workshop (Table 2), the most significant impact perceived by farmers was a decrease in agricultural income (99%), followed by a decrease in crop production and yields (93%), soil fertility decline (92%), decrease in water availability (90%), an increased rate of soil erosion (88%), crop and farmland destruction (80%), decrease in soil moisture (76%), damage stored agricultural products (74%), and increased incidence of pest and crop disease as the most prominent impacts of climate change on agriculture.

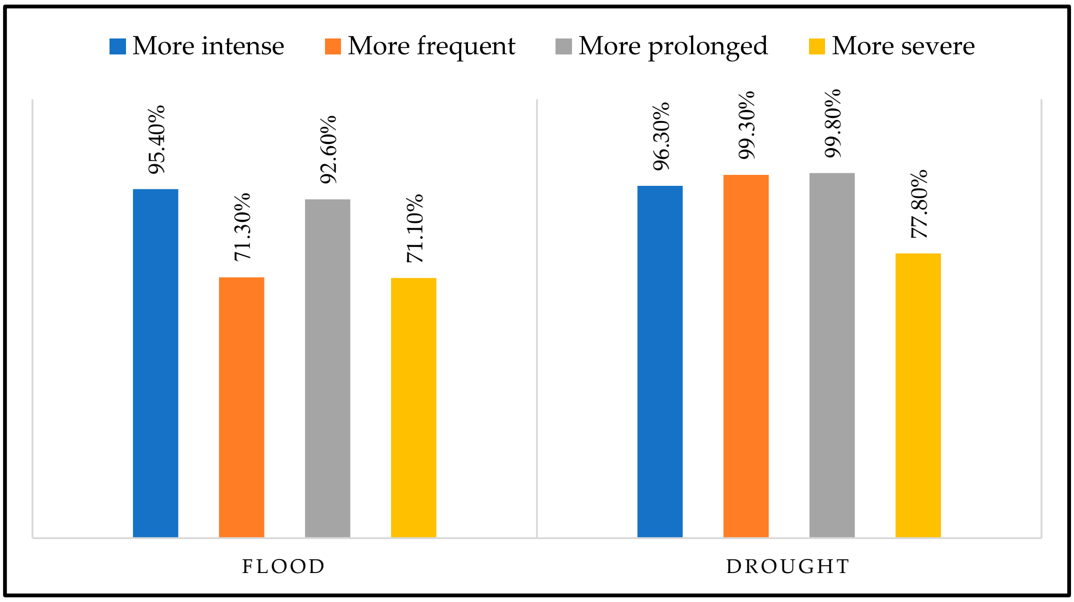

Figure 2. Farmers' perceptions of the occurrence of flood and drought hazards.

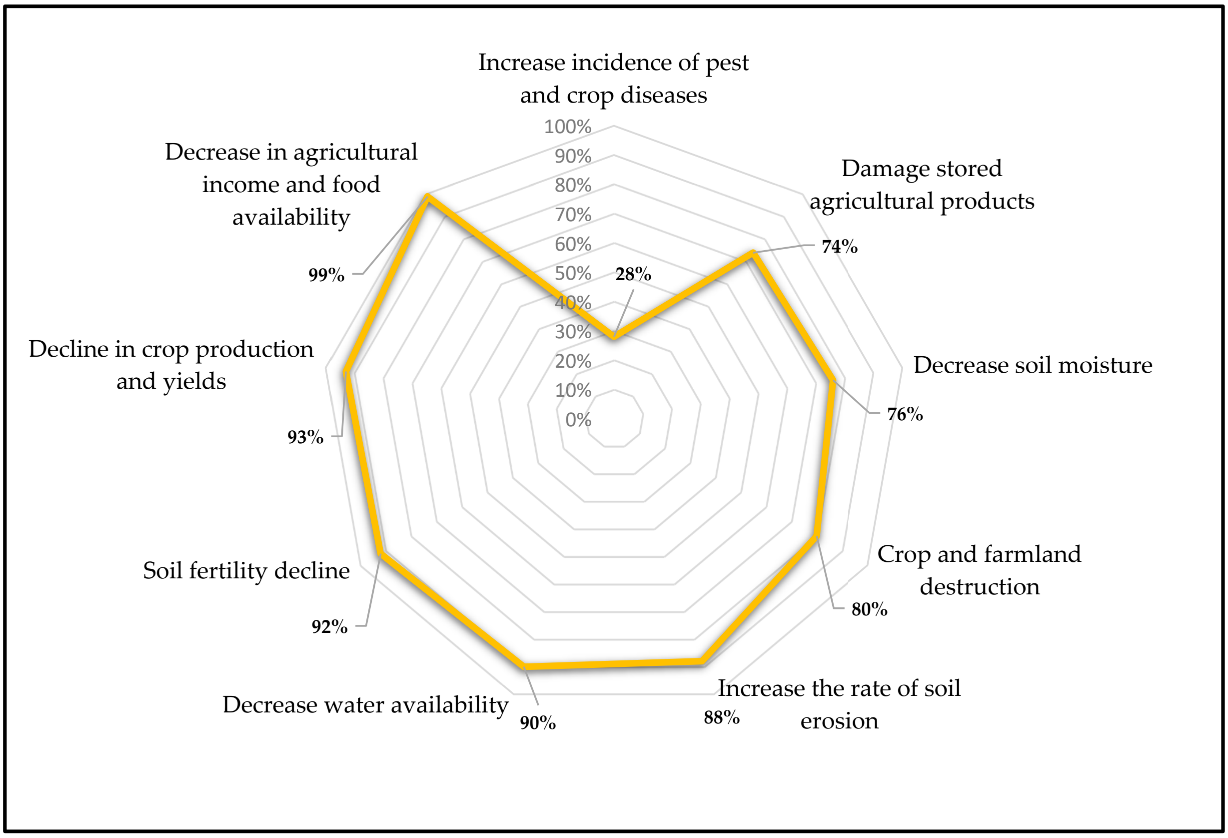

Figure 3. Farmers' perceptions of the major climate impacts in the agriculture sector.

3.4. Evaluation of Farmers' Climate Change Risk Perception

In this section, the study measured the level of climate risk (risk of loss of farmers' livelihoods) perception among farmers who reported perceiving change in climate conditions based on hazard, vulnerability, and exposure drivers identified during the participatory workshop (Table 2) using PCA and K-means cluster analysis. A total of 16 items were considered. Each farmer gave a subjective degree of agreement for each of 16 statements based on 5 Likert scale points, where 5 points stood for "strongly agree," 4 for "agree", 3 for "neither agree nor disagree", 2 for" disagree", and 1 point for "strongly disagree".

Principal component analysis (PCA) was used as a data reduction tool to identify relationships between variables and the components to be kept. The evaluation of the data assumptions for PCA is shown in Table 4. It includes the Kaiser–Meyer–Olkin (KMO) value, which is used to determine whether the PCA is useful for these variables. According to the results, the KMO value was 0.726, indicating that PCA is appropriate. Furthermore, Bartlett's test was used to determine whether or not there was an interrelationship between variables. The result shows that the p-value for Bartlett's test of sphericity was less than 0.01; thus, the requirement for variable interrelationship is met in this study.

Table 4. Evaluation of the data assumptions for principal component analysis.

Test of the Correlation between Variables.	Results	Conclusion
Kaiser–Meyer–Olkin (KMO)	Value = 0.726	Satisfied. PCA is appropriate for the analysis of these variables.
Bartlett's Test of Sphericity:	Chi-Square = 1058.407; df = 120; p-value = 0.000 *	Satisfied. Variables are correlated.

* actual p-value is less than 0.01.

One method to determine whether variables are significant for principal component analysis is to examine their Measure of Sampling Adequacy (MSA). It is suggested that an MSA value of less than 0.50 is unacceptable and has to be excluded from further analysis because the correlations between Xi and the other variables are unique, meaning that they are unrelated to the remaining variables outside of each simple correlation. The Anti-Image Correlation Matrix is shown in Appendix A. The overall MSAs of the individual variables are displayed on the matrix's main diagonal. It can be observed that the MSA values for the 16 variables are all greater than 0.50, making them acceptable for the final analysis of the data.

The Varimax rotation method was used to determine how many components should be retained. There are a total of 16 variables loaded into specific components. The components were chosen based on the total eigenvalue ≥ 1 criterion, as well as the variance explained by the factors when they were combined. The first 7 components were retained, accounting for 75% of the variance in the data (Appendix B). Table 5 shows the variables grouped into their respective factors and renamed according to their collective representation: (1) Climate-related hazards; (2) Exposed elements at risk; (3) Cropland sensitivity; (4) Social sensitivity; (5) Sustainable agriculture barriers, (6) Lack of access to agricultural facilities, and (7) Lack of access to financial protection and climate information (Table 4). The first principal component, "Climate-related hazards", comprises two variables: increased drought events and increased flood events. This describes the households' perception of climate hazards affecting their agricultural livelihood. It accounted for 15.95% of the total variance. The second component, "Exposed elements at risk", includes two variables: exposed farmers and exposed croplands, which accounted for 13.675% of the total variance. The third component, "Cropland sensitivity", accounted for 12.10% of the total variance. It comprises the loss of ecosystem services provided by land for farming activities and cropland degradation and describes the perception of households on their cropland health. The fourth component, "Social sensitivity", is made up of three variables: unsustainable farming practices, and strong dependency on agricultural income and cultivated land size. It describes the perception of households on the pressure they put on their cropland. This factor accounted for 10.75% of the total variance. The fifth component, "Sustainable agriculture barriers", is comprised of two variables: lack of knowledge of sustainable land management practices and lack of access to improved seeds. It accounted for 9.29% of the total variance and describes the sustainable agriculture capacity of households. "Lack of access to agricultural facilities", the sixth component, is made up of three variables: lack of access to agricultural production assets, lack of access to sufficient farm labor, and lack of access to irrigation. This describes the farming capacity of a household and accounted for 8.09% of the total variance.

The seventh and last component, "Lack of access to financial protection and climate information", consists of two variables: lack of access to financial safety nets and lack of access to climate information. It accounted for 5.21% of the total variance.

The results from the PCA were used to classify households into different risk perception categories using cluster analysis. Table 6 depicts the classification of cluster households. Based on the component scores, the households that perceived changes in climate conditions were divided into three risk perception groups (clusters). Clusters 1, 2, and 3 accounted for 65.9%, 21.4%, and 12.7%, respectively. These three clusters were labeled as Cluster 1 "high climate risk perception households", which included farmers who perceived a high or very high perception of the influence of changes in climate conditions on their agricultural livelihood; Cluster 2 "moderate climate risk perception households", which included farmers who perceived a moderate perception of the influence of changes in climate conditions on their agricultural livelihood; and Cluster 3 "low climate risk perception households", which included farmers who perceived a low perception of the influence of changes in climate conditions on their agricultural livelihood. The F values of the component "Sustainable Agriculture barriers" have a greater influence in deciding the clusters (291.898), followed by "Cropland sensitivity" (58.412), "Exposed elements at risk" (12.337), and "Social sensitivity" (3.768), while the least important factor influencing the clusters was "Lack of access to agricultural facilities" (3.086).

The households in Cluster 1 (high climate risk perception households) are those with a high perception of the least access to a sustainable agricultural system, the least access to agricultural facilities, and the highest cropland and social sensitivity (Figure 4).

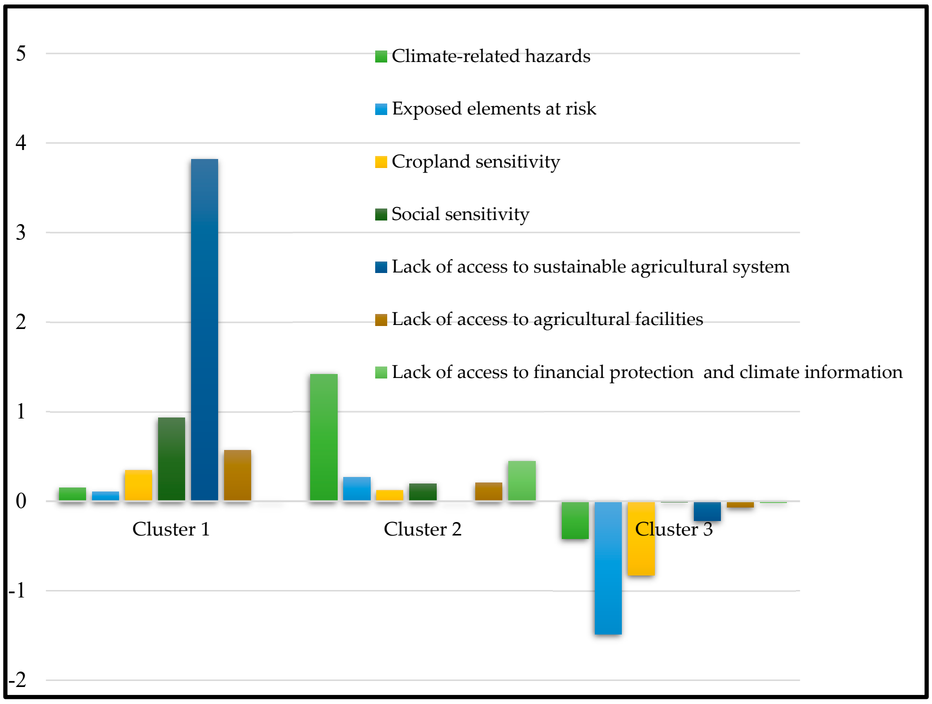

Figure 4. Cluster centers based on component/factor scores.

Table 5. The rotated component matrix: factor analysis for farmers' perceptions of the drivers of climate risk.

No.	Drivers of Climate-Related Risk (Risk of Food Insecurity Due to Lower Income and Food Availability)	Principal Components						
		Climate-Related Hazards	Exposed Elements at Risk	Cropland Sensitivity	Social Sensitivity	Sustainable Agriculture Barriers	Lack of Access to Agricultural Facilities	Lack of Access to Financial Protection and Climate Information
X1	Increased drought events	0.864	0.077	0.112	−0.036	−0.013	0.060	0.006
X2	Increased flood events	0.852	−0.027	0.030	−0.020	0.045	0.081	−0.015
X3	Exposed farmers	−0.006	0.791	−0.021	−0.028	0.048	0.062	−0.051
X4	Exposed cropland	0.061	0.790	0.094	−0.026	−0.017	0.074	0.020
X5	Loss of ecosystem services provided by cropland for farming	0.006	0.056	0.597	0.043	−0.001	−0.198	0.473
X6	Increased cropland degradation	0.087	−0.007	0.846	−0.092	0.000	−0.001	0.050
X7	Unsustainable farming practices	0.050	0.136	0.019	0.878	0.134	0.152	−0.037
X8	Strong dependency on agricultural income	0.178	0.049	0.085	0.800	0.146	0.009	0.060
X9	Cultivated land size	0.129	0.033	−0.007	0.779	0.240	−0.035	0.077
X10	Lack of knowledge of sustainable land management practices	0.044	0.016	0.057	0.092	0.906	−0.079	0.093
X11	Lack of access to improved seeds	−0.392	−0.021	0.225	−0.131	0.544	0.361	−0.272
X12	Lack of access to agricultural assets	0.075	−0.040	0.039	−0.082	−0.024	0.577	−0.041
X13	Lack of access to sufficient farm labor	0.111	0.255	0.323	0.230	−0.098	0.800	0.301
X14	Lack of access to irrigation	0.049	0.050	0.069	0.062	0.047	0.814	0.011
X15	Lack of access to financial safety net	−0.010	0.294	−0.037	−0.029	0.083	0.064	0.662
X16	Lack of access to climate information	−0.112	0.112	0.234	−0.167	0.237	0.181	0.580

Table 6. Characterization of individual clusters based on component scores.

Components of Households' Climate Risk Perceptions	Cluster 1 (65.9%)	Cluster 2 (21.4%)	Cluster 3 (12.7%)	F	*p*-Value
	High Climate Risk Perception Households	Moderate Climate risk Perception Households	Low Climate Risk Perception Households		
Climate-related hazards	0.15124	1.41800	−0.4165	3.236	0.000
Exposed elements at risk	0.10438	0.26613	−1.48457	12.337	0.000
Cropland sensitivity	0.34512	0.12442	−0.8263	58.412	0.040
Social sensitivity	0.19574	−0.93161	−0.01049	3.768	0.032
Sustainable Agriculture barriers	3.81686	−0.00717	−0.21883	291.898	0.000
Lack of access to agricultural facilities	0.56685	0.20459	−0.06964	3.086	0.024
Lack of access to financial protection and climate information	0.03392	0.44873	−0.0181	3.710	0.047

The majority of these households have cultivated medium land (67%), small (18%), or large (13%), with most having their household sizes between (6–10) (48%) and (11–15) (41%). Although 79% of these households have no non-farm income, 75% are members of agricultural organizations (Figure 5).

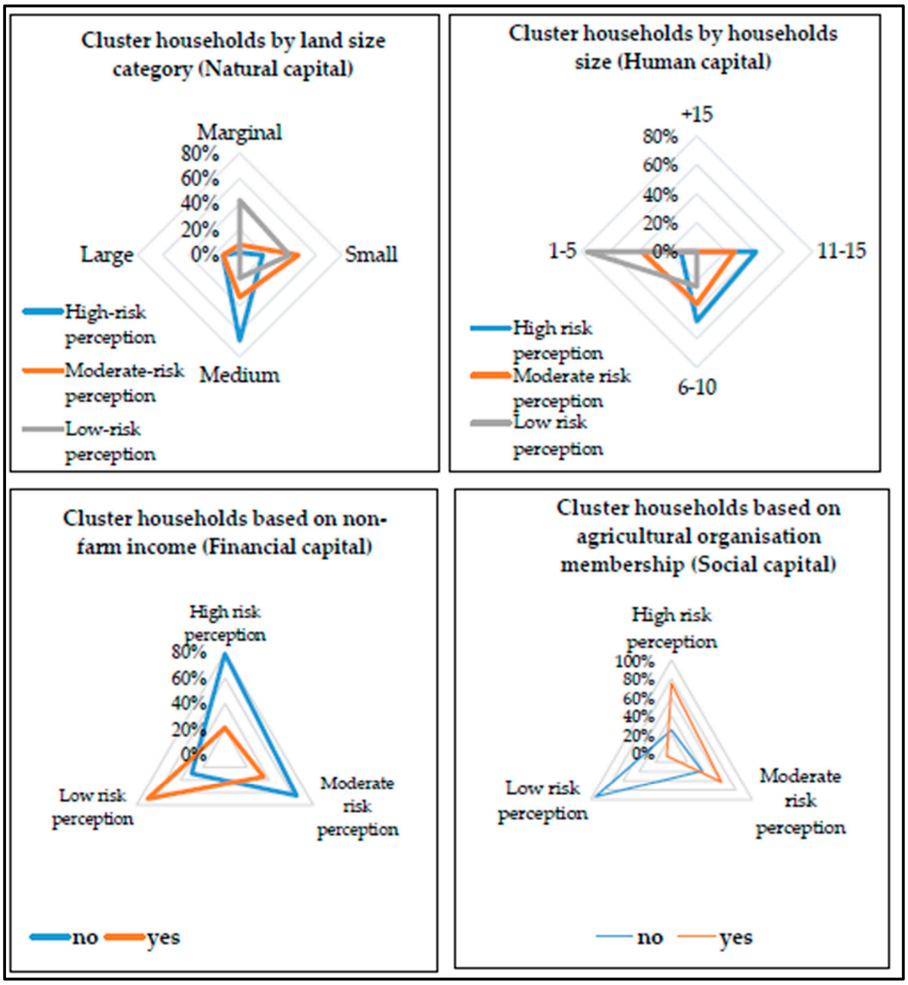

Figure 5. Cluster households' classification based on Natural, Human, Financial, and Social capital. Note: Marginal (<1 ha); Small (1 ha–2.9 ha); Medium (3 ha–7 ha); Large (>7 ha).

Cluster 2 (moderate climate risk perception households) have the greatest perception of climate-related hazards and vulnerable elements, but the least access to financial protection and climate information (Figure 4). These households primarily had small (46%), medium (39%), and large (13%) cultivated land, with the majority of households falling into the (1–5) (38%) and (6–10) (36%) categories. Although 65% of these households have no non-farm income, 62% are members of agricultural organizations (Figure 5)

Households in Cluster 3 (those with low climate risk perception) have the lowest scores on all seven climate risk perception components (Figure 4). They have the most marginal (43%) and small (39%) cultivated land, as well as the smallest range of household sizes (1–5) (76%), with 70% having a non-farm income and 94% not members of agricultural organizations (Figure 5). These findings show that households with a large amount of cultivated land, large household size, and non-farm income perceive more climate risk, and their perceptions increased as their perceived socio-ecological sensitivity, lack of adaptive capacity, and exposure in the study area increased. The greater their vulnerability and exposure to climate-related hazards, the greater their perceived risk of losing their livelihood.

4. Discussion

The first step towards developing an effective risk management system is a proper perception of risk factors [22]. Farmers' understanding and perceptions of climate risks are important because they can influence their management practices and provide a better guide for adaptation responses [29,30]. Various studies [31–33] have shown that farmers' perceptions are important for understanding climate-related risks in agricultural practices because this body of knowledge is built on individual farmers' perspectives, belief systems, and interpretations of climate issues based on experience and local knowledge. In our study, both the qualitative results from the local stakeholders' workshop and the quantitative results from the household survey revealed that farmers, as well as local stakeholders, are aware of the change in climate parameters mainly in rainfall and temperature and the occurrence of their related extreme events. They perceived that the frequency and intensity of extreme weather events, mainly droughts and floods, have increased during the last two decades. Similarly, earlier studies carried out in the study area [3–5] reported that farmers perceived an increasing trend of temperature and changes in rainfall patterns marked by erratic rainfall and an increase in extreme rainfall events in the Savanna region of Togo, causing extreme events such as droughts and floods. A similar study carried out by [34] showed that farmers in Burkina-Faso are aware of changing climatic conditions, including increased temperatures, greater rainfall variability, heavier precipitation events, and delayed onset and premature offset of the rainy season. Another study conducted by [35] in Ethiopia revealed that smallholder farmers face several climate-related hazards, including highly variable rainfall and severe droughts, which can be devastating to their livelihoods. According to [36,37], as the temperature increases and the rainfall pattern changes due to climate change, the likelihood of sudden disasters including floods and droughts will augment and intensify the risk of loss of rural income and livelihood for the most vulnerable populations. Similar findings shown by [38] revealed that farmers in western Nepal reported an increase in the frequency and severity of floods, increased dry spells, and rising temperatures, which lead to a decline in agricultural productivity and yield, and reduced food availability, affecting the food security of communities/small-farm holders who are heavily reliant on agricultural production and sales. All of the previous findings support the perceptions of local stakeholders and farmers in the study area, who believe that an increase in flood and drought events due to climate variability may increase the risk of farmers losing their livelihood.

Several climate impacts on agricultural land and production have been identified in the study area. The prominent impacts perceived were a decrease in agricultural income, a decline in crop production and yields, a decrease in soil fertility, a decrease in water availability, and increased soil erosion. These results are consistent with earlier studies on the impacts and risks of climate change on agriculture [39–42], which showed that because agriculture is so dependent on weather and climate, changes in these parameters can have a significant impact on agricultural production that affects farmers' livelihoods.

In addition, several socio-ecological factors were identified as contributing to farmers' increased vulnerability. Among others, the perceived factors were loss of ecosystem services provided by land, strong dependency on agricultural income, unsustainable farming practices, lack of sufficient farm labor, lack of sufficient agriculture assets, lack of knowledge of sustainable cropland management strategies, lack of access to improved seeds, lack of access to irrigation, lack of access to financial safety nets, and lack of access to climate information. Along the same lines, the studies carried out by [43,44] revealed that smallholder farmers are vulnerable to the effects of climate change due to low levels of technology, high dependence on agriculture for their livelihoods, limited access to climate information, and a lack of other essential agricultural assets, resulting in an increased vulnerability and loss of livelihood.

Furthermore, when measuring farmers' perceptions of climate risk, the findings show that three major factors play a significant role in categorizing farmers as high, moderate, or low climate risk perceivers. Those factors are perceived socio-ecological sensitivity, lack of adaptive capacity, and exposure to climate-related hazards. This means that farmers with a higher risk perception of losing their livelihood due to climate change had a higher perception of their vulnerability and exposure to hazards. This is consistent with the findings of [45], who discovered that farmers in Chiapas, Mexico, with strong perceptions of climate hazards and their vulnerability to those hazards were more likely to appraise climate risk and adapt. The authors of [46] also found that understanding climate-related vulnerabilities and exposure is critical for understanding climate risk perception and improving agricultural practices to increase food production. According to Raghuvanshi and Mohammad [47], measuring farmers' perception of risks associated with climate change is of paramount importance and needs to be assessed so that appropriate adaptation measures can be implemented to mitigate productivity losses. This study demonstrated the importance of local knowledge in understanding the drivers of climate change risk in agriculture.

5. Conclusions

Our study assessed farmers' risk perception towards climate change and its impact on agriculture in the Savanna region of Togo. Five main changes in rainfall and temperature patterns were perceived by farmers. Among those changes, erratic rainfall, an increase in the duration of dry spells, an increase in extreme rainfall events, a shortening of the rainy season, and warmer temperatures were highly perceived as the most observable changes affecting farmers' agriculture production and livelihood (refer to Table 3). Changes in rainfall and temperature were perceived to have serious implications for the occurrence of climate-related hazardous events such as droughts and floods, which are becoming more frequent and severe in the study area (refer to Figure 2). Agroecosystems are impacted by the frequency and severity of drought and flood events. Three categories of climate risk perception levels have been distinguished among farmers: households with high-risk perception, households with moderate-risk perception, and households with low-risk perception (refer to Table 5). This categorization of farmers' households depends strongly on how they perceive their exposure, cropland sensitivity, socio-economic sensitivity, and adaptive capacity to drought and flood events. This demonstrates their comprehension of the challenges they face in the context of climate change and may influence their intention and decision to undertake sustainable farming adaptation strategies. More research into this area is needed to improve the understanding of the links between farmers' perception of climate risk and their decision to implement adaptation strategies focusing on the sustainability of agroecosystems.

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Appendix A. Anti-Image Correlation Matrix

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16
X1	0.671 a															
X2	0.045	0.553 a														
X3	0.179	−0.545	0.570 a													
X4	−0.076	−0.053	−0.004	0.578 a												
X5	0.107	0.037	−0.069	0.077	0.709 a											
X6	0.029	−0.049	−0.083	−0.029	0.016	0.574 a										
X7	0.114	0.030	−0.003	0.148	−0.183	−0.016	0.663 a									
X8	−0.034	0.031	−0.033	0.108	−0.060	−0.035	0.090	0.654 a								
X9	0.021	0.024	−0.005	−0.135	−0.307	−0.011	0.043	−0.328	0.630 a							
X10	−0.040	−0.018	−0.086	−0.098	0.040	0.051	−0.240	−0.124	−0.055	0.704 a						
X11	−0.180	0.029	−0.083	−0.017	−0.012	−0.030	−0.132	0.001	−0.176	−0.187	0.605 a					
X12	0.086	−0.047	−0.020	−0.002	−0.027	0.325	−0.027	−0.012	0.065	−0.115	−0.015	0.541 a				
X13	−0.177	−0.029	0.011	0.063	−0.035	−0.074	−0.054	0.039	−0.047	0.094	−0.095	−0.232	0.515 a			
X14	−0.005	0.006	−0.043	−0.021	−0.034	−0.102	0.023	0.037	0.081	−0.008	−0.500	0.001	0.046	0.600 a		
X15	−0.033	−0.061	0.077	−0.117	−0.313	−0.032	−0.233	−0.189	0.023	−0.052	0.152	−0.038	−0.080	−0.094	0.655 a	
X16	−0.268	0.005	0.009	−0.026	−0.034	−0.114	0.171	−0.067	0.093	−0.066	−0.187	0.011	−0.018	0.037	0.044	0.675 a

a. Measure of Sampling Adequacy (MSA).

Appendix B. Total Variance Explained by Extracted Components Using Principal Component Analysis

Components	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.509	15.949	15.949	3.509	15.949	15.949	2.702	12.280	12.280
2	3.009	13.675	29.624	3.009	13.675	29.624	2.702	12.280	24.561
3	2.662	12.101	41.725	2.662	12.101	41.725	2.694	12.244	36.805
4	2.364	10.746	52.472	2.364	10.746	52.472	2.354	10.702	47.507
5	2.045	9.294	61.766	2.045	9.294	61.766	2.176	9.890	57.397
6	1.780	8.089	69.855	1.780	8.089	69.855	2.069	9.403	66.800
7	1.146	5.208	75.063	1.146	5.208	75.063	1.818	8.263	75.063
8	0.930	4.326	79.389						
9	0.817	4.108	83.497						
10	0.676	3.314	86.811						
11	0.655	2.977	89.788						
12	0.547	2.487	92.275						
13	0.509	2.314	94.589						
14	0.464	2.099	96.688						
15	0.388	1.865	98.553						
16	0.325	1.447	100.000						

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