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Socioenvironmental Drivers of Farmers' Perceptions of Climate Change Risk in Agroforestry Parklands of West Atacora in Benin (West Africa)

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Abstract

Throughout the world, climate change is threatening the human population. In West Africa, smallholder farmers in indigenous agricultural societies typically hold considerable knowledge. Therefore, this study was conducted in West Atacora of Benin Republic to assess the drivers of farmers' perceptions of climate change risk. We used a random sampling technique to select 360 households' heads who were interviewed regarding different climate change risks perception. Binomial logistic regression was used to assess the drivers of farmers' perceptions of climate change risks. The results showed that the farmers in drier areas had a higher perception of the global risk of climate change than those in humid areas. The same trend was observed for the seven different individual's climate change risk investigated. The study identified also membership of farm organizations as main sociodemographic characteristic that explains farmers' perception of climate change risk perception. These findings are helpful tools to sensitize the local people on climate change risk and cope with the risk in agricultural lands.

Keywords

Climate Change Risk, Local Ecological Knowledge, Socio-Demographic Characteristics, Benin, West Africa

1. Introduction

Smallholder farmers in indigenous agricultural societies typically hold consi-

derable knowledge on natural resources like how to maintain soil fertility [1] [2], why to preserve the trees in their agroforestry parklands [3] [4] [5] and how to use the resources and manage them sustainably. Generally, local knowledge has the potential for empirical observations, pattern recognition, linking knowledge with ecological factors, and predicting future outcomes [6] [7].

Nowadays, the adverse effects of climate change, including extreme floods and drought, are becoming evidence in many parts of the world [8]. In developing countries, climate change has adversely impacted the livelihoods of most farmers [9]. Additional adverse climate change effects include the loss of biodiversity, land degradation in the form of soil erosion, the depletion of vegetation, and the lack of sustenance of ecosystem services. Previous studies in other tropical regions have highlighted that regions with low rainfall and annual irregularities in rainfall distribution are the most vulnerable to climate change adverse effects [8] [10]. Variations in rainfall, strong winds, heat waves, longer dry spells, and seasonal shifts are the main climate change events perceived by producers [11]. According to Katé *et al.* [12], destruction of soil structure and reduced fertility are the perceived direct and indirect effects of CC. However, the main effect of climate change revealed by growers is a decline in soil fertility [13] [14], which negatively influences yield.

Local knowledge of climate change risk is associated with farmers' sociodemographic characteristics, such as access to agricultural information, farm size, age of household head, education level, and income level [15] [16] [17]. Therefore, we hypothesize that farmers' perceptions of the risks associated with climate change depend on multiple sociodemographic characteristics.

In Benin, it was reported that drought, floods, late and heavy rains, strong winds, and excessive heat are among the major risk factors of climate change [18] [19]. The main objective of this research is to: assess local knowledge of the risks associated with CC and the fertilizing role of woody plants in Traditional Agroforestry Systems. Therefore, we expect that drier areas in our study zone will be more vulnerable to climate change risk and, consequently, that local people in drier areas are likely to have a higher perception of climate change risk than those in humid areas. Thus, we hypothesize that 1) farmers in drier localities of the study zone have a higher perception of climate change risk than farmers in humid areas; 2) climate change risk perception is driven by socio-demographic characteristics of farmers.

2. Material and Methods

2.1. Study Area

We conducted the current study in the six communes (**Figure 1**) of West Atacora (Boukoumbé, Cobly, Matéri, Tanguiéta, Natitingou, Toucountouna) in Benin, West Africa. The study area is located in the north of the country in the Sudanian agroecological zone (Zone IV West-Atacora) between 9˚45' and 12˚25' north latitude. This zone is generally characterized by a rainfall of less than 900

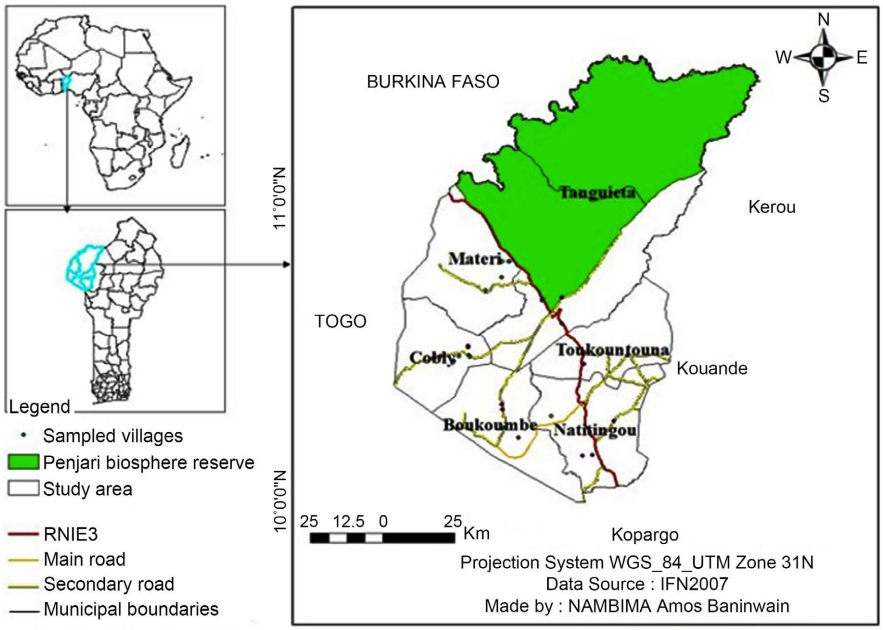

Figure 1. Map of the study area showing the location of sampled villages and study communes.

mm per year and a temperature of 24˚C to 41˚C. Air humidity varies from 18% during the Harmattan to 99% in August [20] [21]. West Atacora has been particularly subject to the degradation of agricultural land within Sub-Saharan Africa, leading to declining farm yields and incomes. It is often cited as an agroecological zone of great poverty [22] [23]. In particular, the agricultural production systems and cultivation techniques practiced in the mountainous areas in the northwest of Atacora have had a negative impact on the natural environment, including low soil fertility and a greater vulnerability to climate change and food insecurity.

Moreover, the presence of mountain ranges leads to a high frequency and abundance of rainfall in some communes at high altitudes [24]. The rainfall in the municipality of Matéri is lower compared to the other communes. The effects of climate variability have led to changes in the climate (warming dry spells, strong wind). The zone is made up of savannas and gallery forests with smaller trees covering the ground slightly. Evapotranspiration is around 1600 mm. Slash-and-burn agriculture is the mode of land reclamation frequently observed in this area.

2.2. Sampling and Data Collection

The farm surveys took place in each of the six communes of West Atacora from May 23 to August 12, 2022. A random sampling technique was applied to select the heads of households. The minimal sample size n per commune was determined by the normal approximation of the binomial distribution of Dagnelie [25] based on the proportion of farmers perceiving at least a risk of climate change:

$$\frac{U^2 \times P(1-P)}{d^2} \quad (1)$$

where n_i is the sample size in village i of each commune; $p = 0.19$ is the proportion of farmers perceiving at least a risk of climate change and was set at 20%; $u = 1.96$ is the value of the normal random variable, and $d = 10\%$ is the margin error of the estimate, which was set at 10% to allow a larger sample size of the local population. The value of n_i was estimated to be $n_i = 59.12$ per commune.

Data were collected through semi-structured interviews with 360 household heads. Additionally, field observations and focus group discussions were implemented to validate some of the information obtained. Two focus group discussions per municipality were performed, and 5 to 8 random people participated in each focus group discussion. During the interviews, we recorded the socio-demographic characteristics of each respondent, the environmental characteristics of the farm location, the climate change risk perception. Thus, the following main question was asked to each respondent: 1) Do you know that climate change has risks? 2) Which climate change risks do you perceive? When respondents named a risk of climate change, we collected data on the severity of the risk as a value ranging from 1 to 4 on the severity scale. We georeferenced the interviewed households and recorded their altitudes, latitudes, and longitudes. Additionally, the coordinates of the interviewed households' locations were used to download online bioclimatic data from the WorldClim website (https://www.worldclim.org/data/cmip6/cmip6climate.html). The bioclimatic data related to rainfall and temperature was added to the altitude and latitude to characterize the environmental characteristics of the studied household's locations.

2.3. Data Analysis

The data were extracted and organized for processing. We used a canonical analysis to characterize the studied household's environments in relation to latitude and altitude. A principal component analysis (PCA) was performed to assess the relationships between latitude and bioclimatic variables on the one hand and between altitude and bioclimatic variables on the other hand. Poisson regression was used to assess the variation of climate change risk perception in the studied households. A stepwise selection based on the Akaike information criterion (AIC) difference used by Burnham and Anderson (2004) was considered. PCA was used to assess the relation between major variables that explained the variation in different climate change risks. A part of the global risk, seven individual's climate change risks were identified and used in this study as follows:

R1: Flooding by rainwater.

R2: The poor spatial distribution of rainfall.

R3: The increase in heat.

R4: The decrease in humidity levels.

R5: The prevalence of a Sirocco.

R6: The prevalence of strong winds.

R7: The instability in wind direction.

Binomial logistic regression was used to identify the determinants of the farmers' perceptions of climate change risk. For each model fitting, socioenvironmental variables were included. These variables were commune, latitude, longitude, altitude, sex, marital status, age, ethnicity, religion, education level, activity, experience in agriculture, household size, farm organization membership, cultivated area, perception of climate change risk. The final model was chosen based on a stepwise algorithm. All analyses were performed using R software version 4.1.1 [26].

3. Results and Discussion

3.1. Sociodemographic Characteristics of Respondents

The sociodemographic characteristics of the surveyed farmers are summarized in Table 1. Farmers came from five main sociocultural groups and were mostly animists and illiterate in local and foreign languages.

Table 1. Sociodemographic characteristics of the surveyed farmers.

Characteristics		Number of respondents	Percentage (%)
Sociocultural groups	Ditamari	132	36.67%
	Waama	65	18.06%
	Biali	84	23.33%
	M'Berme	55	15.28%
	Gourmantche	18	5.00%
	Other	6	1.67%
Religion	Animist	237	65.83%
	Muslim	16	4.44%
	Christian	107	29.72%
Sex	Male	312	86.67%
	Female	48	13.33%
Age	Age ≤ 35 years	178	49.44%
	35 < age ≤ 60	154	42.78%
	Age > 60	28	7.78%
Education level	Elementary	66	18.33%
	Basic education	11	3.06%
	High school	5	1.39%
	Secondary	38	10.56%
	Illiterate	240	66.67%

3.2. Environmental Characteristics of the Respondents

The canonical analysis (Figure 2) showed that the farmers from high-altitude locations (communes of Boukoumbé and Natitingou) were located at the lowest latitudes. In contrast, the farmers from high-latitude locations (communes of Matéri and Tanguiéta) were located at the lowest altitudes.

The PCA showed the relationships between altitude and bioclimatic variables on the one hand and latitude and bioclimatic variables on the other hand (Figure 3). The high-latitude environments had greater seasonality and annual temperature variation. They had the lowest rainfall and were drier areas. In contrast, the higher elevation areas had more rainfall and were the least arid.

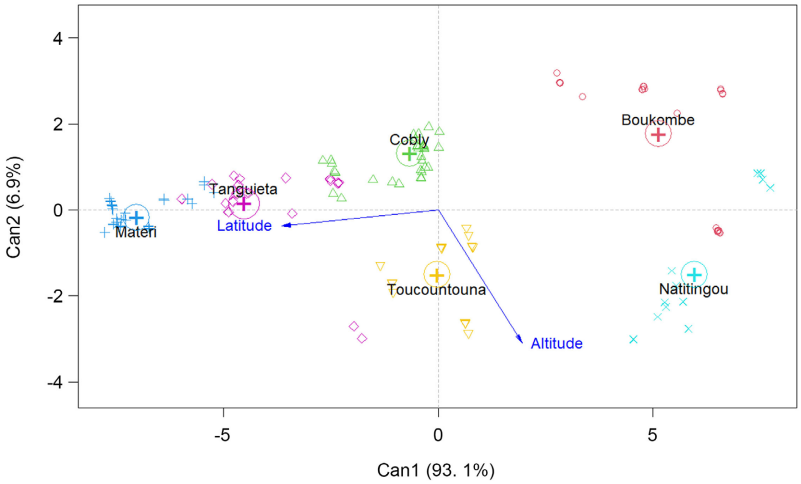

Figure 2. Canonical axes showing the variation of latitude and altitude among the studied farmers.

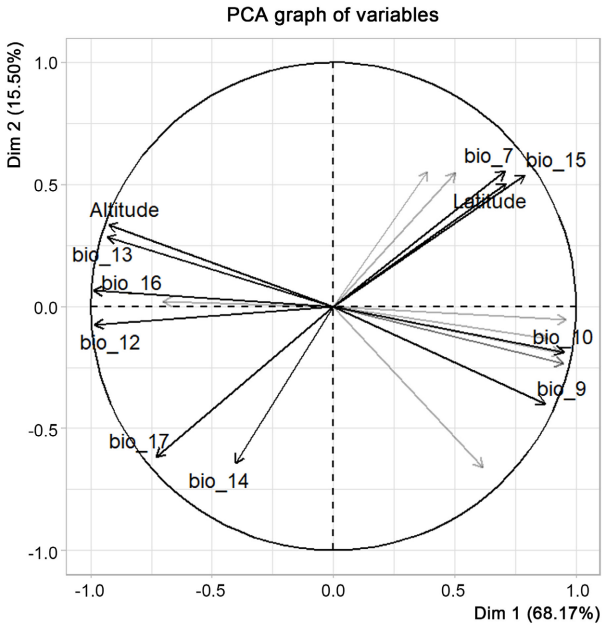

Figure 3. Principal component analysis (PCA) showing the relationships among bioclimatic variables and latitude and altitude.

We concluded that the farmers from the communes of Boukoumbé and Natitingou were located at high altitudes, low latitudes, and in the most humid zones. The farmers from the communes of Matéri and Tanguiéta were located at low altitudes, high latitudes, and in the drier areas. The farmers from the communes of Cobly and Toucountouna had intermediate values for the considered environmental variables.

Bio_7: Temperature annual range; Bio_9: Mean temperature of driest quarter; Bio_10: Mean temperature of warmest quarter; Bio_12: Annual precipitation; Bio_13: Precipitation of wettest month; Bio_14: Precipitation of driest month; Bio_15: Precipitation seasonality; Bio_16: Precipitation of wettest quarter; Bio_17: Precipitation of driest quarter.

3.3. Climate Change Risk Perception

3.3.1. Global Climate Change Risk Perception

The perception of the risks of climate change depended significantly on the altitude, latitude, farm organization membership, and the preservation of woody fertilizers (Table 2). These variables were the significant drivers of climate change risk perception by farmers.

The farmers at low altitudes had a higher perception of the risks of climate change than those located at high altitudes. The respondents at high latitudes had a higher perception of the risks of climate change than those located at low latitudes. Regarding farm organization membership, farmers who did not belong to a farm organization had a higher perception of the risks of climate change than those belonging to a farm organization. Respondents who perceived the importance of preserving woody fertilizers were more aware of climate change risk than those who did not.

In the study area, the risks of climate change were perceived less by farmers located at the highest altitudes (Boukoumbé, Natitingou), whereas there was a higher perception of these risks in the drier environments (Tanguiéta, Matéri).

3.3.2. Individual Climate Change Risk Perception

For all seven climate change risk factors investigated individually, variation was either latitude- and altitude-dependent or one of latitude- or altitude-dependent. Climate change risk perception was also heavily associated with the degree of aridity at the farmers' location (Table 3).

Table 2. Determinants of the perception of the climate change (CC) risk by farmers in West Atacora, Benin.

Variables		Odds ratio	*P*
Altitude		0.99 (0.98, 1.00)	0.014
Latitude.100		1.23 (1.11, 1.53)	0.004
Farm organization membership	No	Reference	
	Yes	0.03 (0.00, 0.16)	<0.001
Woody fertilizer preservation	No	Reference	
	Yes	26.74 (5.39, 205.40)	<0.001

Table 3. Poisson regression for the climate change risk factors' variation results.

Response	Variable	Estimate	Std. Error	z value	Pr (>|z|)	
R1	Intercept	−2.698	2.092	−1.289	0.197	
	Latitude	0.385	0.196	1.968	0.049	*
	Altitude	−0.002	0.000	−6.053	<0.001	***
R2	Intercept	−2.929	1.499	−1.955	0.051	.
	Latitude	0.398	0.143	2.789	0.005	**
R3	Intercept	1.452	0.071	20.404	<0.001	***
	Altitude	−0.001	0.000	−3.299	<0.001	***
R4	Intercept	1.292	0.086	14.962	<0.001	***
	Altitude	−0.001	0.000	−3.821	<0.001	***
	Farm organization membership yes	0.185	0.062	2.966	0.003	**
R5	Intercept	−5.078	2.264	−2.242	0.025	*
	Latitude	0.579	0.211	2.737	0.006	**
	Altitude	−0.001	0.000	−3.420	<0.001	***
R6	Intercept	1.407	0.072	19.647	<0.001	***
	Altitude	−0.001	0.000	−2.826	0.005	**
R7	Intercept	−3.522	1.579	−2.230	0.026	*
	Latitude	0.445	0.150	2.957	0.003	**

R1: Flooding by rainwater; R2: The poor spatial distribution of rainfall; R3: The increase in heat; R4: The decrease in humidity levels; R5: The prevalence of a Sirocco; R6: The prevalence of strong winds; R7: The instability in wind direction.

The first two axes of the PCA summarized 66% of the main information on climate change risk factors, latitude, and altitude (**Figure 4**). All risk factors' perception increased with the latitude and decreased with the altitude. Because climate aridity increased with latitude and decreased with altitude in the study area, the climate change perception risk was assumed to increase with climate aridity.

The study showed a diversity of perceptions of the risks of climate change among different agricultural areas. Farmers in drier areas (Tanguiéta, Matéri) had a higher perception of the risks of climate change compared to those in humid areas (Boukoumbé, Natitingou). Such results confirmed our first hypothesis and may be supported by the great vulnerability of farmers to climate change in drier areas (Tanguiéta, Matéri). Indeed, in these two communes, the living conditions are difficult, which is explained by the degradation of natural resources (soil, vegetation) and prolonged exploitation of the same land. For instance, the presence of the Pendjari National Park and the mountains occupy a large part of the land at Tanguiéta and Matéri, which leads to a substantial reduction of cultivable land. Moreover, in those drier areas, the great manifestation of climate change by the reduction of rainfall, due to the irregularity of the rainy season, has had a direct adverse effect on farm productivity and explains the ease at

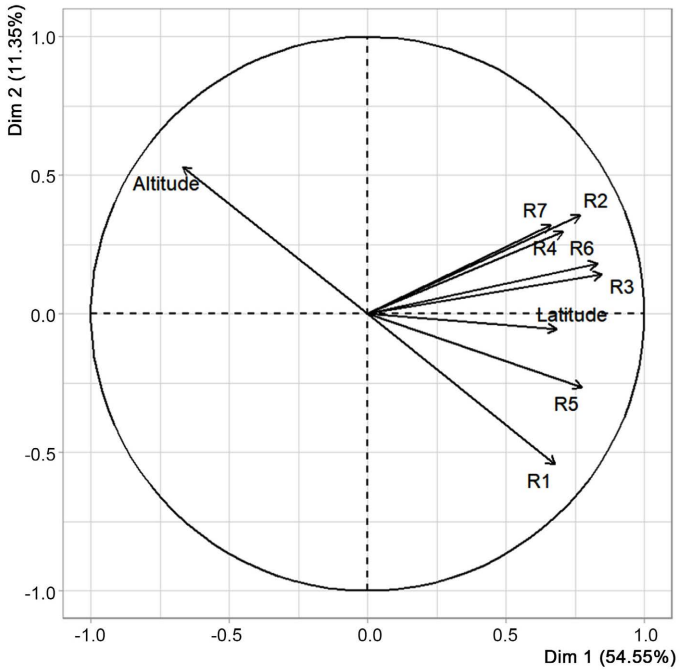

Figure 4. PCA showing the CC risk factors' perception in relationship to latitude and altitude.

which farmers perceived the climate change risk in drier areas. In addition, the absence of vegetation covers in the commune of Matéri, which has a climate similar to that of the Sahel, exposes the farmers to be more sensitive to climate change and, therefore, have a higher perception of the risks of climate change. The current results showing that farmers in drier areas had a higher perception of the risks of climate change suggest that countries located in the Sahel region of Africa have a higher perception of climate change risk and are maybe experiencing more of the climate change manifestations compared to the African coastal countries.

The results are congruent with the findings of other studies according to which the scarcity of water is the main vulnerability driver of climate change risk perception [27].

Although this study identified membership of farm organizations as main sociodemographic characteristics that can explain farmers' perception of climate change risk, other studies highlighted other potential drivers. For instance, Ndamani and Watanabe [28] showed that education level in a rural area of Ghana had a positive influence on climate change risk perception by local people. Experience in agriculture was found elsewhere as predictors of climate change risk perception in semi-arid regions of Brazil [8], Niger [29], and South Africa [30].

4. Conclusion

In conclusion, this study showed that altitude, latitude, farm organization membership, and the preservation of woody fertilizers are the main factors of the

perception of the risks of climate change. This study showed that the farmers located in drier areas had a higher perception of the risks of climate change in West Atacora in Benin. Moreover, socio-demographic characteristics such as membership in a farm organization were potential driver of farmers' knowledge of climate change risk. This study will help to better guide extension strategies in the fight against climate change risk, particularly in high-risk areas.

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Conflicts of Interest

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

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