12

PERCEPTION AND CHARACTERIZATION OF INTEGRATED SOIL FERTILITY MANAGEMENT STRATEGIES AS A TECHNIQUE FOR ADAPTATION TO CLIMATE CHANGE IN NORTHERN OF BENIN

Bambani C. Roger, Vodouhe G. Fifanou, Alaye Eustache and **Yabi A. Jacob**

Laboratory of Analysis and Research on Economic and Social Dynamics,
Faculty of Agronomy, University of Parakou, BP 123, Benin
Email: rbambanichab@gmail.com

Abstract: *Climate variability and change pose a threat to farmers in northern Benin. As a result, these producers are increasingly forced to adapt their cropping systems to changing climate circumstances. The objective of this research is to characterize the know-how and strategies of farmers in West Atacora in order to help them improve their agricultural productivity in a context of increasingly increased land pressure on arable land and poverty. The data used to carry out this study were collected by individual and focus surveys. groups on a global sample of 1040 individuals from the communes of Boukombé, Matéri, Cobly and Tanguiéta. The results indicate that corn and soybean producers adapt to climate change provided they perceive it to intensify drought, abundance of rains and early cessation of rains and decline in productivity agricultural. Correspondent Factor Analysis (CFA), followed by Ascending Hierarchical Classification (CHA) made it possible to carry out the classification. From the AFC, two groups of strategies emerged. Class 1 is made up of producers who adopt strategies related to the production of drought-tolerant crops, crop diversification through the production of more than two crops, minimal use of chemical fertilizers, crop association, crop rotation, the practice of fallowing and the management of crop residues. As for class 2, it brings together corn and soybean producers who have adopted strategies linked to soil regeneration based on legumes and soil amendment with organic matter. These results highlight the diversity of adaptation choices among agricultural producers, reflecting the different priorities and orientations adopted depending on location, perception of the effects of climate change and level of soil fertility.*

Key words: Perception, Management Strategies, Fertility, Adaptation

Introduction

The impacts of climate change constitute real problems and concerns for the international scientific community. (Ramachandran *et al.* , 2016) This scientific community predicts that climate change has major consequences on coastal ecosystems and poses real development problems. (Alexander, 2013) These impacts are reinforced in sub-Saharan Africa; a region particularly vulnerable to threats of natural resource degradation (Liniger *et al.* , 2011) . Indeed, in the sub-Saharan region of Africa, the decline in soil fertility is a serious problem and a major constraint for agricultural production (Onduru *et al.*, 2001; Vanlauwe *et al.*, 2011; Oduniyi *et al.*, 2021) . It creates a real threat to rural populations. More than 83 percent of Africa's 874 million hectares of arable land (58 percent of global arable land) are said to face serious fertility problems with more than 75 percent of agricultural land classified as very impoverished due to poor practices. (FAO, 2018) Thus, countries whose development is highly dependent on climatic stimuli are increasingly vulnerable. (Savi *et al.*, 2022) . Also, the social construct and the economic constraints which are the basis of inequalities in access to production resources are reinforced by climate change. (Bryan *et al.*, 2009) Several research and development programs have been carried out in rural areas for the sustainable management of the fertility of arable land. This allowed farmers to acquire , in addition to local knowledge, effective knowledge resulting from several years of experience across several generations. (N'guessan *et al.* , 2019) These farmers were able to adapt their agricultural system by developing or adopting new farming practices in order to improve soil fertility. However, research on the characterizations of adaptation strategies to climate change, especially in relation to integrated soil fertility management, remains very little known. Furthermore, several of them have focused on the global, regional or national level. (Challinor *et al.*, 2015) Today, farmers develop and practice different strategies from one farmer to another or from one region to another depending on climatic, social, economic and institutional factors. However, studies relating to the characterization of these strategies are necessary to identify and design the most effective strategies taking into account the feelings of populations regarding climate change. It is imperative to fill this gap in the world of scientific research.

According to (Adekambi *et al.*, 2021) 21 percent of forest areas have been destroyed in 10 years in favor of agricultural land and from another angle, the repetitive putting into production of land under agricultural production causes a drastic drop in the quantity of nutrients and organic matter in the soil, thus leading to the impoverishment of the fertility of the latter. (FAO, 2015) Added to all this are the influences of climate change which manifest themselves through floods, droughts, changes in agricultural calendars, heat waves and low productivity, which constitute the most tangible effects affecting the agricultural households. (FAO, 2016) This study attempts to fill this gap in the world of scientific research and aims to characterize the integrated soil fertility management strategies actually adopted by producers in Northern Benin.

Material and Methods
Choice of Study Area

The present study was carried out in northern Benin, more precisely in the western Atacora region, which includes the municipality of Matéri, Tanguiéta, Cobly and Boukombé (10°40 and 11°20 north latitude and 1°20 and 2° longitude). We chose this zone because the shallow, ferruginous soils have a low water retention capacity and low natural soil fertility (Adegii et al., 1999). Thus, the adoption of agro-ecological production techniques that are less damaging to forest formations and more protective of soils would help mitigate the adverse effects of climate change in the area.

Figure 01: Map of the Study Area Showing Data Collection Sites
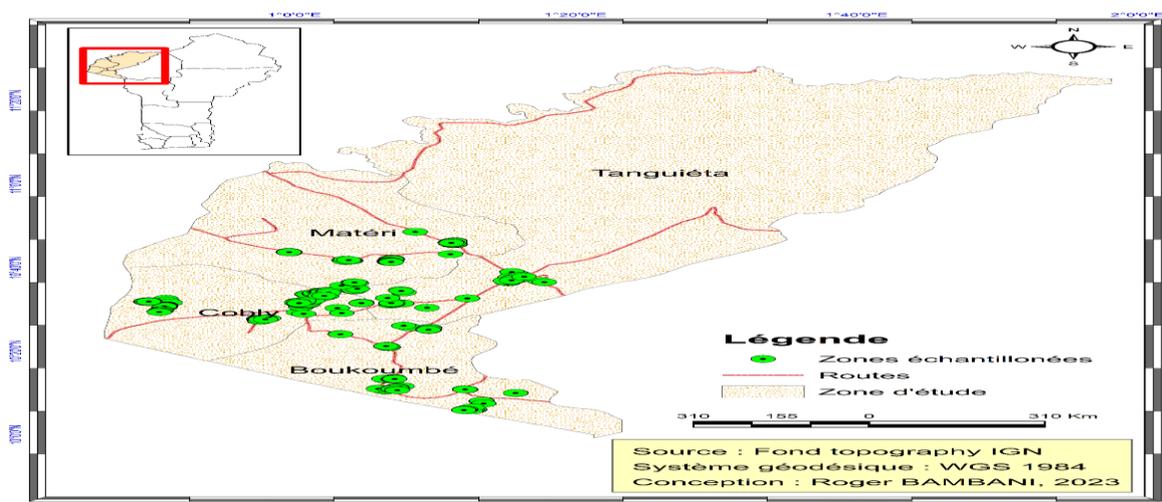
Sampling: There are different methods for determining the size of a research sample, depending on whether the target population is finite or infinite. For the purposes of this research, the size of the target population is not known. It was determined using an approximation of the normal distribution law through the Dagnelie formula (1998). Thus, the sample size n is thus approximately equal to **1040** corn and soybean producers.

Data Analysis: Descriptive statistics were carried out using R software version 4.3.2. Descriptive statistics tools were used to present and analyze data on farmers' perceptions of climate variability and the practices they adopt. In addition, these strategies were characterized using Correspondence Factorial Analysis (CFA). The aim of the present research is to characterize the different integrated soil fertility management strategies. The choice of classification criteria was based on a range of structural and functional variables derived from the data collected (adaptation strategies, etc.). For the hierarchical classification of adaptation strategies, we decided to use an initial level index comprising three (03) distinct classes. The results of variable grouping are strongly influenced by the linking method and distance measure chosen. In order to determine the existence of a relationship of dependence between the various adaptation strategies and the communes surveyed, a chi-square test was carried out under the null hypothesis of independence between communes and climate change adaptation strategies, at a significance level of 5 percent.

Results

Perceptions Related to the Effects of Climate Change by Producers in the Study Area

Those who perceive changes hypothetically adopt one or more agricultural practices to reduce the negative impacts linked to climate change (Nyang'au et al., 2021) . In order to analyze the different strategies adopted in the area in the face of climate, it is necessary to know farmers' perception of climatic variabilities. A comparison of current climatic conditions was made with those of 10 years ago and made it possible to identify certain effects of climate change. Table 1 presents the results that farmers have on the perception of climate in the study area. Overall, these results prove that farmers have perceived the effects induced by climate change over the last 10 years. The analysis of the likelihood ratio test for the overall correlation of the error terms between the different perceptions (chi2 (9) = 736.42; $p < 2.2e\text{-}16$) is significantly different from zero at the threshold of 1 percent and allows us to reject the independence of the different perceptions from one municipality to another. Indeed, in the area of abundance of rain, the Boukoumbé region displays the highest percentage with 90.83 percent, highlighting a

pronounced awareness of this climatic variation in this locality. However, the non-significance of the chi-square test suggests that, although this perception is dominant in this area, the variations between regions are not statistically significant. On the other hand, the increase in temperature shows more marked differences. Thus, Boukoumbé and Cobly are the areas where farmers are most aware of this trend, with percentages of 84.58 percent and 56.57 percent respectively, while those of Tanguiéta weakly perceive this aspect. This significant divergence is supported by the chi-square test ($p < 0.05$), indicating a notable and uneven awareness of temperature changes between these regions. Likewise, the disturbance in the intensity of the cold also presents a strong significance at the 5 percent threshold ($p < 0.05$). The results thus highlight marked divergences between regions. Farmers in Cobly and Tanguiéta, in particular, seem to be more sensitive to this change. Furthermore, the decrease in temperature shows significant differences ($p < 0.05$) between zones, indicating that some farmers are more inclined to perceive this change than others. This could influence decisions about which types of crops to favor.

Furthermore, despite the fact that certain perceptions, such as the reduction of rains, the disappearance of species of trees and animals, and the delay in the onset of rains, present differences between regions, the results of the Chi-square test does not show obvious statistical significance. This suggests that although variations exist, they are not pronounced enough to be considered significant. In the communes of Matéri and Boukombé , producers, almost all of the people interviewed highlighted the early end of the rains (91 percent) and the increase in pockets of drought (86.25 percent). However, the results of the chi-square test do not show obvious statistical significance. This suggests that, although these trends are higher in these municipalities, the majority of producers have the same perception of these two phenomena throughout the study area. Indeed, the majority of farmers in all areas perceive that climate change has an impact on social well-being, with particularly high proportions in Matéri (99.63 percent), Boukoumbé (85.83 percent) and Cobly (69.7 percent). As for the perception of agriculture, the results vary depending on the types of perceptions examined although the difference is not significant ($p < 0.05$). The increase in prices of agricultural commodities (APDA) shows a trend, with the Boukoumbé region reporting the highest percentage at 85 percent. This suggests increased awareness of this economic concern in this area. The decline in agricultural yields (BReA) also shows variations with higher awareness in the Boukoumbé and Tanguiéta regions . Although the significance is not as strong, these results highlight potential concerns regarding agricultural productivity. On the other hand, the drop in agricultural income (BRvA), the difficulty in meeting the financial needs of the family (DSBFF), the inability to meet market demand (IRDM), and the persistence of famine (PF) do not do not present significant differences between zones, according to the results of the chi-square test. The results concerning the perception of future climate changes reveal a significant disparity in farmers' knowledge of future consequences. The chi-square test ($p < 0.05$) indicates an extremely significant difference between respondents. A large majority, or 73.23 percent, say they are unaware of the future consequences of climate change, with notable variations between zones.

In conclusion, these results highlight the complexity of farmers' perceptions of the impacts of climate change. While some concerns, such as rising agricultural commodity prices and falling yields, appear to be more significant in some regions, other aspects of social welfare related to agriculture do not show statistically significant differences between areas. These nuances underline the importance of considering local realities in the development of climate change adaptation and mitigation strategies. Furthermore, the poor knowledge of the majority of producers on the future impacts of this phenomenon highlights the need to intensify

education and awareness efforts, with emphasis on the future consequences of climate change, particularly in areas where ignorance is most widespread. This approach could help strengthen the adaptive capacity of farmers by providing them with the knowledge necessary to anticipate and mitigate potential impacts on their agricultural practices.

Climate Change Adaptation Strategies

The results of the adoption of integrated soil fertility management strategies (SGIFS) in the face of climate change reveal marked trends, with significant disparities between the municipalities studied. The extremely low probability of the chi-square test (p = 1.08e-204) confirms a significant dependence between the choices of adaptation strategies and the localities. Indeed, in Boukombé , crop diversification through the production of more than 2 crops (DCPP2C) largely dominates with a high adoption rate of 89.17 percent, illustrating a strong inclination of farmers in this municipality towards a diversified approach. The association of crops or mixed cultivation (AC) (58.75 percent), crop rotation and crop rotation (58.33 percent) are also significantly adopted in Boukombé. Farmers in this region also favor crop residue management (CRM) with a notable rate of 65.00 percent. In Cobly, farmers mainly opt for soil regeneration with legumes (RSL) with an adoption rate of 55.89 percent. The use of organic materials (UMO) and the minimum use of chemical fertilizers (UMFC) are also adopted at significant rates of 43.10 percent and 48.82 percent respectively. This trend suggests a particular sensitivity to organic soil management in this locality. On the other hand, in Matéri , crop diversification through the production of more than 2 crops (DCPP2C) is the predominant strategy with an adoption rate of 95.19 percent, indicating a strong preference for a diversified approach in this region. Drought Tolerant Crop Production (PCTS) and Utilization of Organic Materials (UMO) are also significantly adopted at rates of 78.15 percent and 49.63 percent respectively.

Likewise, in Tanguiéta, crop diversification by producing more than 2 crops (DCPP2C) is also the most adopted strategy with a rate of 86.22 percent. In addition to this strategy, production of drought tolerant crops (PCTS) is also favored in this locality with an adoption rate of 42.52 percent. However, like other municipalities, these producers also make little use of chemical fertilizers (UMFC) (49.61 percent). The disparities observed highlight the need for a differentiated approach in the development of agricultural policies and adaptation strategies, in order to respond effectively to the specific needs and realities of each municipality. However, an overall analysis of these rates indicates that the most adopted strategies are crop diversification by producing more than 2 crops (DCPP2C), production of drought tolerant crops (PCTS), and minimal use of fertilizers. chemicals (UMFC). These results highlight farmers' general preference for diversified and resilient approaches, while strategies such as fallow practice (PJ), use of organic matter (UMO) and crop association or mixed cropping (AC) are adopted by a minority of farmers.

Table 01: Producers' Perception of the Effects of Climate Change

Variables	Perception	Study zone (percent)					khi-square test
		Boukombe	Cobly	Material	Tanguiéta	Grand total	
Climate Change	**Climate change over the last 10 years**	**100 percent**	**100 percent**	**100 percent**	**100 percent**	**100 percent**	
	Abundance of rain	90.83 percent	7.07 percent	48.15 percent	37.80 percent	43.83 percent	$X2 = 7.351$; P = 0.061
	Early end of rains	84.58 percent	57.24 percent	91.85 percent	89.76 percent	80.02 percent	$X2 = 3.558$; P = 0.313
	Temperature increase	84.58 percent	56.57 percent	47.78 percent	9.45 percent	49.39 percent	$X2 = 8.871$; P = 0.031*
	Increase in droughts	86.25 percent	55.22 percent	28.15 percent	40.16 percent	51.74 percent	$X2 = 4.4037$; P = 0.221
	Disruption of cold intensity	15.00 percent	53.87 percent	36.67 percent	4.33 percent	28.84 percent	$X2 = 15.027$; P = 0.001**
	Decrease in the dry season	67.50 percent	4.71 percent	23.33 percent	28.74 percent	29.41 percent	$X2 = 7.157$; P = 0.067
	Decrease in temperature	50.83 percent	4.38 percent	36.67 percent	6.30 percent	23.56 percent	$X2 = 8.519$; P = 0.036*
	Decrease in Rain	99.17 percent	80.81 percent	97.78 percent	95.67 percent	92.84 percent	$X2 = 2.409$; P = 0.491
	Disappearance of tree species and animals	39.58 percent	54.21 percent	77.04 percent	18.50 percent	48.16 percent	$X2 = 7.497$; P = 0.057
	Disruption of the rainy calendar	41.25 percent	65.99 percent	40.74 percent	13.39 percent	41.38 percent	$X2 = 2.797$; P = 0.424
	Flood	3.75 percent	0.00 percent	0.00 percent	0.00 percent	0.85 percent	$X2 = 3.007$; P = 0.390
	Delay in onset of rains	60.42 percent	52.19 percent	91.85 percent	85.43 percent	72.10 percent	$X2 = 5.566$; P = 0.134
Impacts of climate change on social well-being	No	14.17 percent	30.30 percent	0.37 percent	57.48 percent	25.54 percent	$X2 = 104.15$; P = 2.2e-16***
	Yes	85.83 percent	69.70 percent	99.63 percent	42.52 percent	74.46 percent	
	Perception about agriculture	**100 percent**	**100 percent**	**100 percent**	**100 percent**	**100 percent**	
Perception about agriculture	Increase in agricultural commodity prices (APDA)	85.00 percent	44.44 percent	38.89 percent	37.80 percent	50.61 percent	$X2 = 7.185$; P = 0.066
	Fall in agricultural yields (BReA)	81.67 percent	36.70 percent	98.89 percent	41.73 percent	63.90 percent	$X2 = 5.4734$; P = 0.140
	Fall in agricultural income (BRvA)	82.08 percent	52.86 percent	71.48 percent	38.98 percent	60.89 percent	$X2 = 1.689$; P = 0.639
	Difficulty meeting your family's financial needs (DSBFF)	34.58 percent	53.54 percent	89.26 percent	40.16 percent	55.14 percent	$X2 = 6.441$; P = 0.092
	Inability to meet market demand (IRDM)	35.00 percent	35.35 percent	48.52 percent	39.37 percent	39.59 percent	$X2 = 2.298$; P = 0.512
	Persistence of famine (PF)	33.33 percent	50.17 percent	47.78 percent	38.58 percent	42.98 percent	$X2 = 4.110$; P = 0.249
Future climate change	No	96.25 percent	57.24 percent	83.70 percent	59.06 percent	73.23 percent	$X^2 = 57.069$ P = 2.485e-12***
	Yes	3.75 percent	42.76 percent	16.30 percent	40.94 percent	26.77 percent	

Source: Survey results, May 2023

Table 02: Climate Change Adaptation Strategies

SGIFS	Boukoumbe	Cobly	Material	Tanguiéta	Grand total
DCPP2C (Crop diversification by production of more than 2 crops)	89.17 percent	15.49 percent	95.19 percent	86.22 percent	69.37 percent
UMFC (Minimum use of chemical fertilizers)	80.00 percent	48.82 percent	52.59 percent	49.61 percent	57.02 percent
PSPT (Early/late sowing practice)	7.92 percent	49.83 percent	96.67 percent	83.86 percent	60.41 percent
RSL (Soil regeneration with legumes)	6.67 percent	55.89 percent	45.56 percent	18.50 percent	33.18 percent
PCTS (Production of Drought Tolerant Crop)	40.00 percent	7.74 percent	78.15 percent	42.52 percent	41.28 percent
UMO (Use of organic materials)	12.92 percent	43.10 percent	49.63 percent	16.93 percent	31.67 percent
AC (Crop association or mixed culture)	58.75 percent	0.34 percent	45.19 percent	23.23 percent	30.44 percent
USCCC (Use of certified seeds/short cycle seeds)	7.50 percent	19.53 percent	45.56 percent	38.98 percent	28.09 percent
ARC (cropping and crop rotation)	58.33 percent	20.20 percent	45.56 percent	38.98 percent	39.77 percent
GRR (Crop Residue Management)	65.00 percent	17.85 percent	45.19 percent	42.91 percent	41.47 percent
PJ (Fallow practice)	10.00 percent	3.03 percent	44.44 percent	40.16 percent	24.03 percent
Dependency relationship between adaptation strategies and municipalities					
Probability (p) of chi-square test			1.08e-204***		

Source: Survey data analysis results, 2023

Identification of groups

In order to carry out a hierarchical classification of adaptation strategies, the study opted for the use of an initial level index comprising three (03) distinct classes. The results of the grouping of variables are significantly influenced by the link method and the distance measurement selected, carried out using the R software. The Ascending Hierarchical Classification (CAH) was deployed for this approach, making it possible to identify two (02) distinct groups of producers based on the strategies they adopted, as visualized in the following Figure 1.

Figure 01: Hierarchical Tree
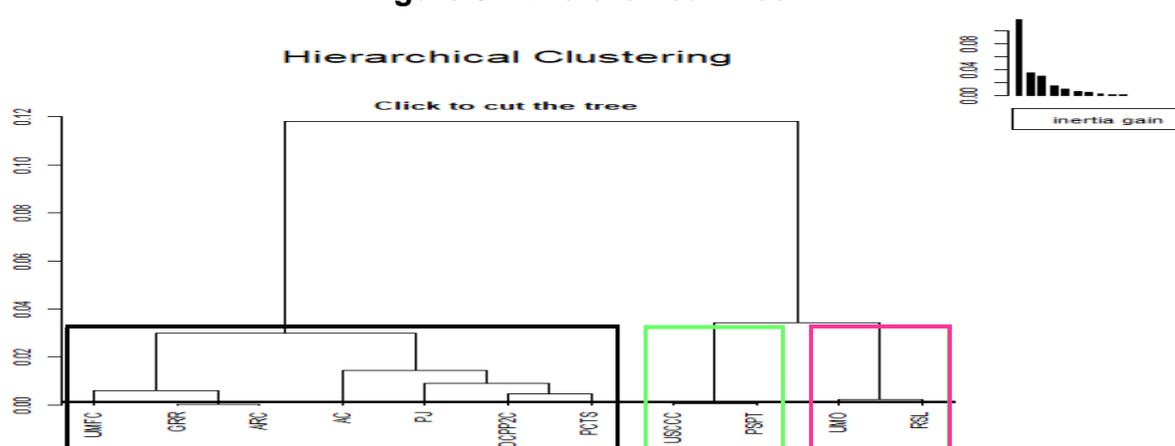
Class 1 is characterized by the grouping of producers adopting diversified strategies, notably the production of drought-tolerant crops (PCTS), crop diversification by producing more than 2 crops (DCPP2C), minimal use of chemical fertilizers (UMFC), crop association or mixed cropping (AC), crop rotation and crop rotation (ARC), fallow practice (PJ) and crop residue management (GRR). **Class 2** is represented by the adoption of strategies relating to soil regeneration with legumes (RSL) and the use of organic matter (UMO).

Figure 01: Ascending Hierarchical Classification of Climate Change Adaptation Strategies Climatic Changes
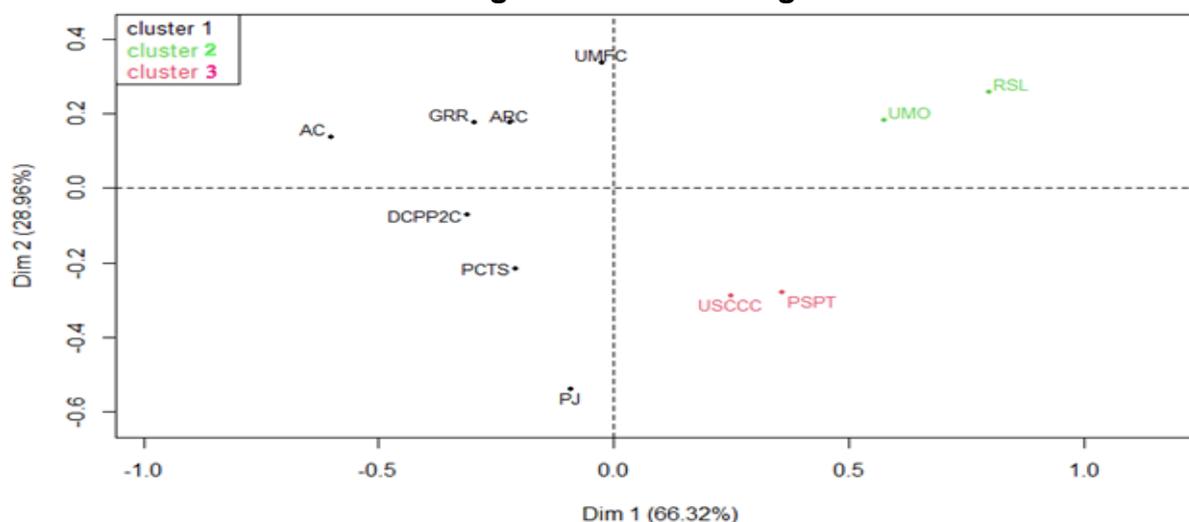
Discrimination of Different Classes of Strategies

The analysis of the discrimination of different classes of strategies highlights disparities marked by the adoption of these approaches between the municipalities studied. Class 1 particularly stands out with notable values in Boukombé (21.59) and Matéri (-3.60), highlighting a significant difference in the use of strategies within these two localities ($p < 0.05$). The averages for the use of strategies in this class in Boukombé (29.92 ± 21.61) and Materi (34.08 ± 35.86) exceed the general average (21.61), indicating significant adoption of these strategies in these specific municipalities. Similarly, class 2 stands out with high values in Cobly (17.23) and Tanguieta (-8.36), with a significant difference in the use of strategies within these two municipalities ($p < 0, 05$). The averages for the use of strategies in this class in Cobly (42.73 ± 17.27) and Tanguieta (13.08 ± 25.26) exceed the general average (17.27), highlighting a significant adoption of these strategies in these specific localities. As for class 3, no municipality differentiates the adoption of class 3 strategies. This would indicate a low adoption of strategies throughout the study area.

Table 05: Discrimination of Climate Change Adaptation Strategies in Different Municipalities

| Groups	Features	V test	Internal (percent)	Overall (percent)	P. value
Class 1	Boukoumbe	21.59	29.92	21.61	2.29e-103
	Material	-3.60	34.08	35.86	3.14e-04
	Cobly	-17.11	10.47	17.27	1.25e-65
Class 2	Cobly	17.23	42.73	17.27	1.58e-66
	Tanguieta	-8.36	13.08	25.26	6.42e-17
	Boukoumbe	-11.21	6.83	21.61	3.51e-29
Class 3	-	-	-	-	-

Source: Survey data analysis results, 2023

Exploration of Clusters of Agricultural Strategies Facing Climate Change in The Context of GIFS

Analyzing proportions of strategy adoption among producer groups provides detailed insight into specific preferences and directions for adaptation to climate change. These results, resulting from the evaluation of agricultural practices in two distinct groups, highlight the strategic choices adopted by farmers to face climatic challenges. Indeed, for Group 1,

producers adopt a diverse range of adaptation strategies to climate change. The most predominant strategy in this group is DCPP2C (crop diversification by producing more than 2 crops), representing approximately 23 percent of all strategies adopted. The PCTS (drought-tolerant crop production) and UMFC (minimum use of chemical fertilizers) strategies are also significantly adopted, contributing to approximately 19 percent and 13 percent of Group 1 practices, respectively.

Figure 02: Adoption Rate of Different Strategies by Producer Group
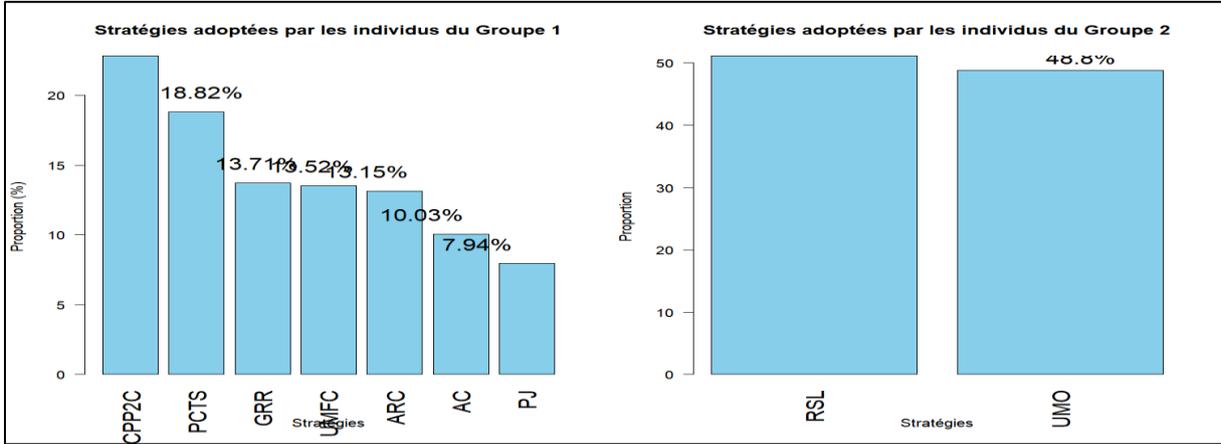
Agronomic Performances of The Groups According to the Strategies Adopted in the Context Of GIFS

After the classification of the different producers according to the strategies adopted, the general characteristics of the producers of **groups 1 and 2** according to the inputs used are as follows:

- there **class 1** made up of producers who adopt strategies linked to the production of drought-tolerant crops (41.28 percent); crop diversification by production of more than 2 crops (69.37 percent), minimal use of chemical fertilizers (57.02 percent), crop association or mixed cropping (30.44 percent), rotation and crop rotation (39.77 percent), the practice of fallowing (24.03 percent) and the management of harvest residues (41.47 percent). These producers use on average 178.64 [a] (±346.48) Kg of NPK in corn production; 103.17 [b] (± 652.1) Kg of Urea on an average area of 1.02 [a] (± 1.07) ha and obtain an average production of 1543 [b] (± 2194.99) Kg. As for soya , producers plant an average area of 0.65 [a] (± 0.90) ha and obtain an average yield of 620.75 [b] (± 953.06) Kg.

- **Class 2** brings together producers who adopt strategies relating to soil regeneration with legumes and the use of organic matter amendments. They use on average in the production of corn 223.78 [b] (± 271.3) Kg of NPK; 71.74 [a] (± 90.61) Kg of Urea on an average area of 1.55 [a] (± 1.99) ha and obtain an average yield of 1484.21 [a] (± 2220.6) Kg. Elsewhere, these producers planted an average area of 0.62 [a] (± 0.98) ha and harvested an average of 501.75 [a] (± 975.8) kg.

In summary, the corn cultivation results reveal significant differences between the two strategic groups, highlighting distinct trends in agricultural practices. In Group 1, farmers use an amount of NPK of 178.64 kg, while in Group 3, this amount reaches 223.78 kg. A similar dynamic is reflected in the use of urea, where Group 3, with 71.74 kg, takes a different approach from Group 1 which uses 103.17 kg. However, despite these variations, Group 1 stands out for higher harvest results, with a quantity of corn harvested of 1543 kg, compared to that of Group 2, which amounts to 1484.21 kg. In addition, the figures reveal nuances in

harvest management. Although Group 1 has a slightly higher self-consumed quantity (610.17 kg) compared to Group 2 (589.63 kg), Group 2 stands out in the sale of corn, with 1092.46 kg, exceeding the 723, 22 kg. from Group 1. The difference in the amount given or lost is also notable, showing a more conservative trend in Group 2 (15 kg) compared to Group 1 (91.15 kg). These results highlight the complexity of agricultural choices, where divergent strategies can influence productivity, personal consumption and marketing of the corn crop.

Table 01: Comparison of The Economic Performances of the Two Groups of Producers for The Production of Corn and Soybeans

	But		Soy	
Culture	Group 1	Group 2	Group 1	Group 2
Quantity of NPK (kg)	178.64 [to] ±346.48	223.78 [b] ± 271.3	-	-
Quantity of Urea (kg)	103.17 [b] ± 652.1	71.74 [a] ± 90.61	-	-
Total sown area (ha)	1.02 [to] ± 1.07	1.55a [±] 1.99	0.65 [to] ± 0.90	0.62 [to] ± 0.98
Quantity harvested (kg)	1543 [b] ± 2194.99	1484.21 [a] ± 2220.6	620.75 [b] ± 953.06	501.75a [±] 975.8
Self-consumed quantity (kg)	610.17 [b] ± 637.79	589.63 [a] ± 1119.33	68.94 [b] ± 109.04	49.56 [a] ± 171.94
Quantity sold (kg)	723.22 [a] ± 1572.9	1092.46 [b] ± 2003.4	520.69 [b] ± 898.21	358.77 [a] ± 635.9
Quantity given/lost (kg)	91.15b [–] ±155.74	15 [to] ±81.68	28.65 [b] ± 64.82	14.47a [±] 80.58
Sale price at harvest (FCFA/Kg)	116.68a [±] 85.93	100.54a [±] 75.95	111.41 [b] ± 113.66	75.61 [a] ± 105.36

Source: Survey data results, 2023

Discussion

The results of this study show that farmers clearly perceive the effects of climate change over the last ten years. However, these results reveal significant disparities in the perception of the effects of climate change among corn and soybean producers in the different municipalities in the area. The description of the statistics shows that the early cessation and Reduction of rains were perceived as climatic phenomena which have increased over the last ten (10) years (80.02 percent and 92.84 percent) of the households surveyed. These results corroborate with those of (Diarra et al., 2021; Faisal *et al.*, 2021) who found that regardless of sex, the majority of farmers were confronted with pockets of prolonged drought and an increased frequency of violent winds. These results are in line with those obtained by (Katé *et al.*, 2014; Ayedegue *et al.*, 2020b; O'Neil *et al.*, 2022) in northern Benin, and which prove that farmers have noticed changes temperatures, the amount of rainwater and the precipitation regime. Overall, the results of this study showed that corn and soybean producers are aware of climatic variabilities, which are mainly manifested by the increase in pockets of drought and the decline in soil fertility which negatively impact these two crops in the area. These results agree with those of (Djohy et al., 2015; Adjovi *et al.*, 2018) , who mentioned that climatic variations constitute limiting factors in the production of corn, sorghum as well as that of soya in northern Benin. Indeed, rainfall deficits or excesses and rising temperatures drop corn yields by around 10-30 percent (Adjovi *et al.* , 2018) . Thus, due to these effects of climate change, many producers have developed several adaptation strategies to cope with the various risks. The results of the present study made it possible to identify nine strategies most adopted by both corn and soybean producers. However, the results of the adoption of these integrated soil fertility management strategies (SGIFS) in the face of climate reveal marked trends, with significant disparities between the municipalities studied. The extremely low probability of the chi-square test (p = 1.08e-204) confirms a significant dependence between the choices of adaptation strategies and the localities. These results confirm those obtained by (Nambima *et al.* , 2023) in the study area and which reveal that sustainable land management practices are practiced according to the climate, soil type, available resources and agricultural practices. current conditions in the locality (Pouya *et al.*, 2013a; Phiri *et al.*, 2022; Antwi-Agyei *et al.*, 2023) .

Indeed, in Boukombé and Matéri, crop diversification by producing more than 2 crops (DCPP2C) largely dominates while in Cobly, farmers mainly opt for soil regeneration with legumes (RSL). These integrated soil fertility management strategies are necessary approaches to ensure sustainable land management on farms in the North of the Benin (Adekambi *et al.*, 2021). Furthermore, these results are in line with the conclusions of (Pouya *et al.*, 2013a; Hermans *et al.*, 2021; Oduniyi *et al.* , 2021; Ifeanyi-Obi *et al.*, 2022) , who all concluded that The adoption of integrated soil fertility management strategies combined with mineral fertilizers contributes to improving agricultural yields and household income.

Conclusion

Just like in the literature, this research proves that climate change is a reality and has negative effects on agricultural production. This research made it possible to identify and characterize nine integrated soil fertility management strategies adopted in western Atacora by corn and soybean producers. These strategies revolve around the practices of crop association, use of organic matter, crop diversification, crop rotation and crop rotation, soil regeneration based on legumes, minimal use of fertilizers. chemicals, fallow practices, crop residue management and production of drought-tolerant crops. The Ascending Hierarchical Classification (AHC) deployed in this study made it possible to identify two (02) distinct groups of producers according to the strategies they adopted. This classification is of interest for the implementation of innovations appropriate to each locality in a context marked by climatic variabilities. These results made it possible to understand that producers in western Atacora combine a multitude of strategies to mitigate the impacts linked to climate change. These results highlight the need for policy makers and agricultural development stakeholders to take into account contextual factors in the process of developing and popularizing climate adaptation strategies.

References

1. Adegii et al., (1999) 'Farmers' Perceptions and Sustainable Land Use in the Atacora, Benin', pp. 1–36. Available at: http://www.iied.org/creed.
2. Adekambi *et al.* (2021) 'Factors determining the adoption of integrated soil fertility management (GIFS) measures in northern Benin: an application of the multivariate probit model to the case of maize producers', *International Journal of Biological and Chemical Sciences* , 15 (2), pp. 664–678.
3. Adjobo *et al.* (2020) 'Socio-Economic Determinants of the Adoption of Cashew Nut Sales Methods in the Communes of Djougou, Tchaourou and Glazoué in Benin', *European Scientific Journal* , 16(19), pp. 313–336.
4. Adjovi, NRA *et al.* (2018) 'Climate variation and food production in South Benin: case of the commune of Bohicon', *Afrique Science* [Preprint].
5. Ajzen, I. (1985) 'From intentions to actions: A theory of planned behavior', in *Action control: From cognition to behavior* . Springer, pp. 11–39.
6. Akoko et al., G. (2021) 'A review of swat model application in Africa', *Water (Switzerland)* , 13(9). Available at: https://doi.org/10.3390/w13091313.
7. Antwi-Agyei *et al.* (2023) 'Typologies and drivers of the adoption of climate smart agricultural practices by smallholder farmers in rural Ghana', *Current Research in Environmental Sustainability* , 5, p. 100223.
8. Ayedegue et al., (2020) 'Typology and Determinants of Adaptation Strategies to Climate Change in Rice Farming in the North and Center of Benin', p. 30.
9. Boudon, R. (2011) 'The general theory of rationality, basis of cognitive sociology', *Cognitive sociology* , pp. 43–75.
10. Bryan, E. *et al.* (2009) 'Adaptation to climate change in Ethiopia and South Africa: options and constraints', *Environmental Science and Policy* , 12(4), pp. 413–426. Available at: https://doi.org/10.1016/j.envsci.2008.11.002.
11. Challinor, AJ *et al.* (2015) 'Crop yield response to climate change varies with cropping intensity', *Global change biology* , 21(4), pp. 1679–1688.
12. Chia *et al.* (2014) 'Adaptive behavior theory and family farming'.
13. De Munck (2013) *Modeling of urban vegetation and adaptation strategies for improving climatic comfort and energy demand in cities.*

14. Diarra et al., (2021) 'Are perception and adaptation to climate variability and change of cowpea growers in Mali gender differentiated?', *ENVIRONMENT DEVELOPMENT AND SUSTAINABILITY* , 23(9), pp. 13854–13870.
15. Djohy et al. (2015) 'Climate variation and food production: maize cultivation in the peri-urban agricultural system of the commune of Parakou in North Benin', *Afrique Science* , 11(6), pp. 183–194.
16. Djohy, GL *et al.* (2022) 'Perception and adaptation of cattle breeders to climate change in the Ouémé Supérieur basin in Benin Perception and adaptation of breeders', *Tropicultura* [Preprint].
17. Doire St-Louis, A. (2010) 'Rational choice theories: Perspectives and implications in institutional design'.
18. Ekue et al., (2004) 'Overview of the ecological distribution and the traditional agroforestry system around ackee (Blighia sapida) in the Sudanese environment in northern Benin', pp. 34–44.
19. Faisal, M. *et al.* (2021) 'Perceptions, Vulnerability and Adaptation Strategies for Mitigating Climate Change Effects among Small Livestock Herders in Punjab, Pakistan', *INTERNATIONAL JOURNAL OF ENVIRONMENTAL RESEARCH AND PUBLIC HEALTH* , 18(20), pp. 10771–10771.
20. FAO (2018) *The multiple roles of soil in the Near East and North Africa* , p. 36.
21. Gandji *et al.* (2021) 'Vulnerability of agricultural production to climate change in the Communes of BANIKOARA and BEMBEREKE in the North of BENIN', *Espace Gégraphique et Société Marocaine* , 1(52).
22. Gomez-Zavaglia, A. *et al.* (2020) 'Mitigation of emerging implications of climate change on food production systems', *Food Research International* , 134, p. 109256.
23. Hermans, T.D. *et al.* (2021) 'Combining local knowledge and soil science for integrated soil health assessments in conservation agriculture systems', *Journal of Environmental Management* , 286, p. 112192.
24. Hinnou et al. (2021) 'Effects of agropastoral systems on the financial profitability of maize production in northern Benin.', pp. 45–56.
25. Ifeanyi-Obi, CC *et al.* (2022) 'Promoting uptake and integration of climate smart agriculture technologies, innovations and management practices into policy and practice in Nigeria', *International Journal of climate change strategies and management* , 14(4), pp. 354–374.
26. Yabi, JA *et al.* (2016) 'Socio-economic determinants of the adoption of cultural practices for soil fertility management used in the commune of Ouaké in North-West Benin', *International Journal of Biological and Chemical Sciences* , 10(2), pp . 779–792.