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Local Cotton Farmers' Perceptions of Climate Change Events and Adaptations Strategies in Cotton Basin of Cote d'Ivoire

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Abstract

Climate change represents a major potential threat to the viability of rural households' livelihoods in sub-Saharan Africa. This study focused on the perceptions of climate change and adaptation strategies of local cotton farmers in Côte d'Ivoire, identified as particularly vulnerable to climate change. A survey was conducted among 355 smallholder farmers distributed in four departments of the cotton basin of Côte d'Ivoire (Korhogo, Boundiali, Ferkessédougou and Mankono). Using changes in weather pattern as indicators of climate change, the results showed that majority of respondents believe climate change is evident in the study area and has negative effects on their livelihoods. Respondents reported an increase in temperature and decrease in rainfall amount in Korhogo and Boundiali departments, which were consistent with the climate data. The main coping strategies implemented by the farmers were shifting of planting dates and timing of cultural activities, adopting new crop varieties, ploughing before planting, diversifying crops and making specific sacrifices to divine powers depending on the type of belief of the farmer. The farmers' adoption of adaptation strategy depended on their perception of climate change and the available coping strategy. Lack of sufficient knowledge and government support were the major constraints that hindered cotton farmers to adapt effectively, leading to low cotton productivity in the study area. Therefore, policy implications will be crucial to help farmers make better adaptation choices in the face of climate change.

Keywords: climate change, farmers' perceptions, adaptation strategies, cotton crop, Cote d'Ivoire

1. Introduction

Natural disasters caused by climate change phenomena and disturbances have heavy influences on agriculture (Agossou, 2008). Climate change is an increasingly perceptible threat to the viability of rural households' livelihoods in sub-Saharan Africa, particularly where communities depend mainly on the exploitation of natural resources (Kabore et al., 2020). Climate is the main determinant of agricultural productivity and greatly influences food production and the economy as a whole. Therefore, the potential effects of climate change on agricultural productivity are of great concern (Doumbia and Dipieu, 2013). Direct consequences on agriculture are shorter average growing seasons, droughts, reduced productive potential of ecosystems, lower crop yields and expansion of bare areas (Belem et al., 2018; PNIA, 2014; Bambara et al., 2013). In addition, changes such as rising temperatures and changing rainfall patterns are likely to lead to an acute decline in rainfed crop production in some African countries (IPCC, 2013). These climate changes exacerbate the existing vulnerabilities of the poorest people due to their limited adaptive capacities and high dependence on climate-sensitive resources such as water resources and agricultural production systems that rely on semi-subsistence production for survival (Assoumana et al., 2016; Agossou et al., 2012).

Like most developing countries, agricultural production remains the main source of livelihood for most rural communities in Côte d'Ivoire. It plays a crucial role in the country's economic development and contributes significantly to the gross domestic product (GDP). Cotton cultivation is the fourth largest agricultural export after cocoa, rubber and cashew nuts and contributes 1.7% to the nation's GDP (Didi et al., 2018). It is the lung of the economy in the rural north of Côte d'Ivoire, and directly supports 180.000 producers, or about 2.5 million inhabitants (Oudin, 2020). Unfortunately, the agricultural sector is very dependent on climate conditions which are characterized by unreliable and erratic rainfall patterns.

The agro-climatic parameters present constraining features for agriculture, especially in the far north, which sometimes experiences severe droughts (MINESUDD, 2013). Recent studies (Agoh et al., 2021; Dekoula, 2020) have shown that the climate systems of Côte d'Ivoire are characterized by reduction in rainfall trends, reduction in the length of the agricultural season, persistence of negative anomalies and an increase in minimum temperatures. These have modified rainfall patterns and agricultural production systems. Despite the increase in strategic adaptation measures and resources devoted to promoting sustainable land management and increasing agricultural productivity by the government of Côte d'Ivoire, cotton producers still face many challenges, including declining seed cotton yields. A large proportion of cotton farmers in the northern region are already facing the effects of climate change in the form of climatic hazards, declining soil fertility, declining yields and the impact of pests and diseases on the cotton crop (Zagbaï et al. 2006). This phenomenon compromises the development of rain-fed agriculture and therefore makes farmers vulnerable in terms of food security. There is an urgent need to adopt mitigation measures and develop new policies to avoid the worst effects of climate change (Willbanks et al., 2007). Assessing the perceptions of cotton farmers on climate change events and their adaptation strategies could be the first step towards reducing the impacts of climate change on cotton productivity. To achieve this, it is essential to have data on the climate system and to define relevant adaptation measures based on those developed locally. This requires a process based on a comprehensive analysis of the situation, the development of an appropriate action plan that takes into account the perceptions and suggestions of local populations, and the political will to determine the priority of the required actions (Agossou, 2008).

Moreover, studies on the impact, mitigation, and adaptation to climate change in recent time, have been in the spotlight of the media. This is because climate change events have fueled several political and scientific debates, being the subject of many scientific investigations. According to literature, one of the main reasons for the vulnerability to climate change observed in Sub-Saharan Africa is the heavy dependence of their economy on predominantly rain-fed agriculture (Lobell et al., 2008).

Agricultural producers also perceive climate change through its negative impacts on agricultural production and the natural environment. Indeed, West African farmers emphasize that the drop in rains, increase in temperature, more frequent heat waves and strong winds explain between 30 and 50% of the decrease in agricultural production depending on the crops and areas (Mertz et al., 2010). Also, the Sudan savannah region which forms, a vast portion of the northern area of Côte d'Ivoire, is not immune to the reality of this phenomenon, which arises acutely (Adaman, 2016). In response to the harmful consequences of climate change, African farmers have adopted adaptation strategies, the most common of which in Burkina Faso are: varietal adaptation, the use of soil and water conservation techniques, use of organic manure, and modification of sowing dates (Ouédraogo et al. 2010). Indirectly, climate change is also manifested at the level of agricultural labor, the prices of agricultural commodities, and agro-industrial processing units (MEPN, 2008). Taking into account these uncertainties and the enormous threat to the livelihoods of farmer households, producers in vulnerable areas develop in one way or the other strategies to ensure their survival.

As observed by previous study, farmers' practices, the technical choices they make and the changes associated with them in the face of the negative impacts of climate change are only intelligible in terms of their understanding (Ruault, 2007). However, till date, little is known about how local farmers in the cotton basin of Côte d'Ivoire perceive the phenomenon of climate change and the disparities in adaptation skills between farmers, and whether these perceptions are consistent with measured climate observations. A study combining aspects of climate change perception and endogenous adaptation strategies of cotton farmers in the Ivorian cotton basin is needed to fully understand how rural communities in the cotton basin are coping with the adverse consequences of climate change.

Consequently this study is designed to assess to the perceptions of cotton farmers, who are exposed to the adverse effects of climate change on a daily basis, and analyse the local measures they are developing to combat this phenomenon. This study will highlight the limitations in adaptation strategies that prevent cotton producers from adapting effectively.

The objectives of this study are therefore to: (i) analyze the past dynamics of climatic parameters in the study area (ii) assess the perceptions of climate change by local cotton farmers in the cotton basin of Côte d'Ivoire (iii) examine the adaptation strategies of the cotton farmers in the face of climate change.

2. Material and Methods

2.1 Study Area

The study was conducted in four cotton producting departments of Côte d'Ivoire. These are Korhogo, Boundiali, and Ferkessédougou of the Northern cotton basin and Mankono department of the Central cotton basin (Figure 1). The Northern and Central cotton basins are the two most important cotton production areas out of the five cotton basins of Côte d'Ivoire. The study area is located between longitudes 2- °30'. and 8 °- 30'- West and latitudes 6 °- 50'- and 10- ° 30'. North and covers an area of approximately 201.693 km² out of the country's 322.462 km² (Dekoula, 2019). Two rainfall regimes characterize these zones: the tropical transition regime and the equatorial attenuated transition regime. Three classes of soils are distinguished in this zone: tropical ferruginous soils, and hydromorphic soils (Koné, 2007). The vegetation of the study area is subdivided into three main types namely, (i) the forest zone corresponding to the central western part (ii) eastern part belonging to the Guinean savanna zone, (iii) and the northern part of the cotton zone which belongs to the Sudanian savanna zone. Three of the country's four main rivers: Sassandra, Bandama, and Comoé flow through the Ivorian cotton basin. They flow globally from North to South (Dekoula, 2019). These four departments were selected for the study because the areas are subject to strong climatic variations and have, therefore, been identified as the most vulnerable agro-ecological zones (MINESUDD, 2013). As agriculture in this area had been severely compromised by climatic variations, it was important to conduct the study in the area to help provide the various actors with effective tools for their decision-making.

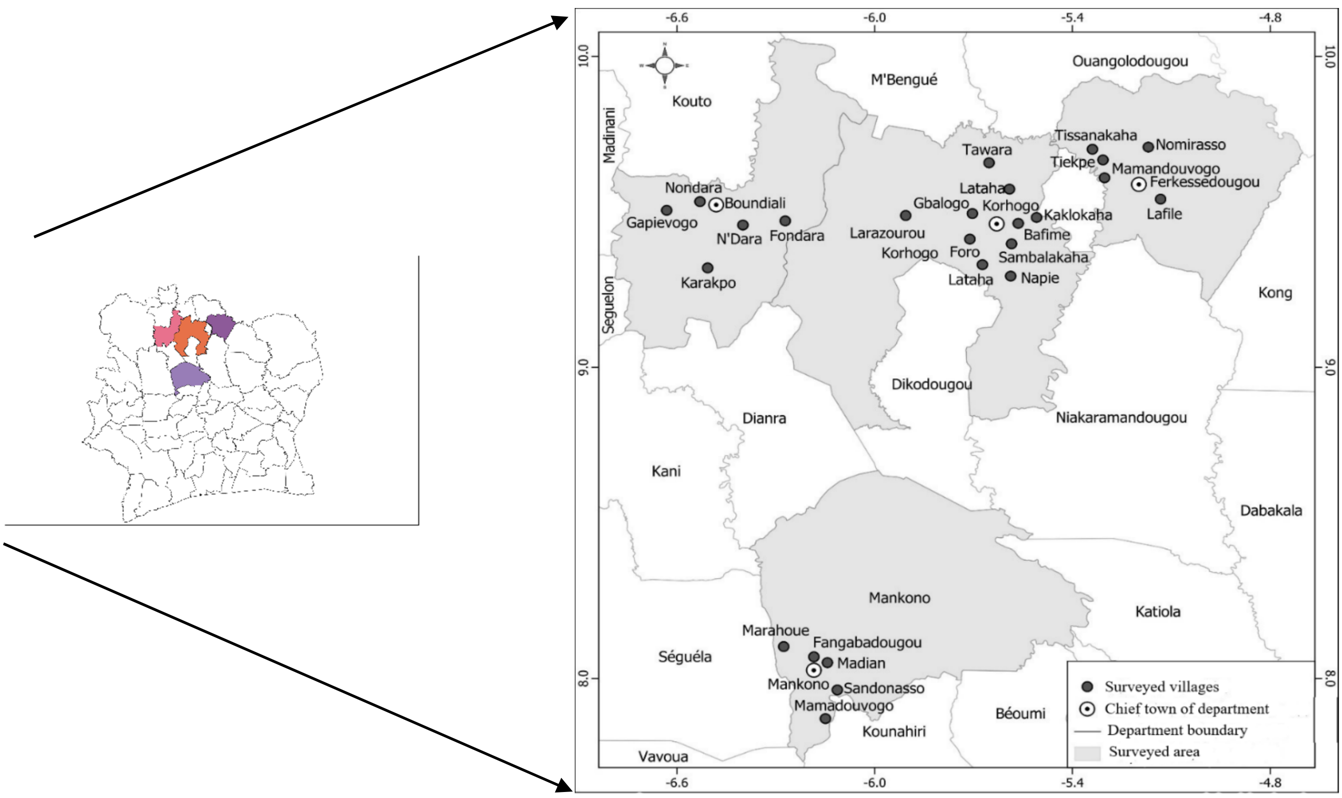

Figure 1. Study area map showing the cotton production basin and location of surveyed villages in Côte d'Ivoire

2.2 Meteorological Data

The two main meteorological data used were rainfall and temperature. The rainfall data relate to data from the Airport, Aeronautics, and Meteorological Exploitation and Development Company (SODEXAM). This meteorological data is a secondary source of data because it was collected by agents present at the meteorological stations which cover the study region. These were supplemented by those from the database of the Central Soils, Water and Plants Laboratory (LCSEP) of the National Agronomic Research Center of Cote d'Ivoire (CNRA). The data has a sufficiently long series to show the evolution of rainfall over a long period and the intra-seasonal rainfall descriptors. The temperature data was downloaded from Google engine (ERA5 Copernicus ECMWF). The climate data spans the period 1970 to 2020.

2.2.1 Methods of Demonstrating Climate Change

Tests for the detection of breaks in rainfall and temperature series were developed to demonstrate climatic variability within a chronological period (Fossou et al., 2014). Indeed, a break is defined as a change in the probability law of random variables whose successive realization define the time series studied (Servat et al., 1998). In this study, for the detection of ruptures, we applied the Pettitt test. The Pettitt test is non-parametric and derives from the Mann-Whitney U test. The absence of a break in the series (Xi) of size N constitutes the null hypothesis. The implementation of the test assumes that for any time t between 1 and N, the time series (Xi) from i=1 to t and from t+1 to N belong to the same population. The variable to be tested is the maximum absolute value of the variable$U_{t,N}$. Pettit's variables (U) are defined by the following equation:

$$\mathrm{U} = \sum_{i=j}^{t} \sum_{j=t+1}^{N} D_{ij} \tag{1}$$

where: Dij = sgn (xi-xj) with sgn (x) = 1 if x> 0, 0 if x = 0 and -1 if x <0.

The probability (Prob) of exceeding a value k is defined and makes it possible to assess the importance of the break. Prob (kn> k) ≈ 2 exp / Prob (kn> k) ≈ 2 exp ($-6 k^2 / n^3 + n^2$) the absence of a break in the series of size N constitutes the null hypothesis. If the null hypothesis is not rejected, an estimate of the date of the rupture is given at this moment, defining the maximum in the absolute value of the variable U.

2.3 Survey of Farmers' Perception and Adaptation Strategies

2.3.1 Sample Size

In total, a sample size of 355 respondents (farmers) was drawn from 27 villages in the four departments of the study area (Table 1).The target populations for this study were cotton farmers in the department of (Korhogo, Boundiali, Ferkessédougou and Mankono) cotton basin of Cote d'Ivoire. The sample size (n) proportion from each department was determined using the equation developed by Krejcie & Morgan, (1970) as follows:

$$\mathrm{n} = \frac{x^2 N p(1-p)}{e^2(N-1)+x^2\ p(1-p)} \tag{2}$$

where n represents the sample size, N represents the population size, e is the acceptable sampling error, X^2 represents the chi-square of the degree of freedom 1 at a confidence of 95% (which is 3.841) and p is the proportion of the population (which 0.5 if unknown).

2.3.2 Data Collection Procedure

The study used both quantitative and qualitative information. A structured questionnaire with closed questions was administered to respondents on smartphones via the "KoboCollect" application to collect information. Data were collected in 2021 through a field survey by face-to-face interviews with cotton farmers. Data and information collected include perceptions of changes in rainfall amount, length of growing season, temperature, wind strength, socio-demographic characteristics of climate change and farmers' adaptation strategies over the past 30 years. The indicators of the phenomenon of climate change are the meteorological parameters whose evolution over time reflects climate change over the last 50 years.

The majority of the questions involved items or statements designed in a closed format where respondents had multiple-choice answers to select as applicable while a few of them were open-ended questions. Thus dichotomous, multiple-choice, and five-point Likert-scale formats were employed in designing the closed-ended questionnaire. The adopted dichotomous closed-ended questioning format was in the form of 'Yes' or 'No' response type and the Likert scale format provided a response scale in which respondents specify their level of agreement to a statement with five options: (1) Strongly disagree; (2) Disagree; (3) Neither agree nor disagree; (4) Agree; (5) Strongly agree. These questioning methods were employed to reduce the number of responses by limiting the respondents and to produce data that could easily be statistically analyzed. Moreover, the Likert-scale questionnaire type allows testing of the reliability and validity of the key constructs of the study (Dawes, 2008; Sachdev & Verma, 2004; Saleh & Ryan, 1991). During the survey, the perceptions of individual farmers with similar socio-economic conditions, belonging to the same social network, or having farms within a given landscape unit were measured. This type of perception measurement takes into account lived experiences or future expectations and is related to the goals, wants, and needs of the farmer (Agossou, 2008).

Before the actual survey, the questionnaires were pre-tested using 50 respondents with a similar socio-economic background to the respondents of the study to test for validity and reliability of the data collection instrument. This led to minor modifications of the questionnaire to improve understanding and capture perceptions not included in the initial questionnaire.

Table 1. Distribution of respondents in the different department of the study area

Department	Villages	Number of villages surveyed	Number of cotton producers
Mankono	Marahoué	5	20
	Sandonasso		17
	Mamadouvogo		20
	Midian		17
	Fangabadougou		10
Korhogo	Tawara	10	20
	Lataha		20
	Kaklokaha		7
	Bafime		6
	Sambelakaha		3
	Fahala		4
	Foro		11
	Larazourou		13
	Gbalogo		10
	Napie		4
Boundiali	N'Dara	6	15
	Ponondougou		12
	Fonondara		10
	Nondara		10
	Karakpo		16
	Gapievogo		16
Ferkessedougou	Tandokaha	6	17
	Dekokaha		17
	Momirasso		16
	Tiekpè		14
	Mamadouvogo		15
	Tiassanakaha 2		15
Total		27	355

2.3.3 Ethical Consideration

Ethical approval was sought from the School of Graduate Studies Board Ethics Committee of the Kwame Nkrumah University of Science and Technology, Kumasi to conduct the study. Permission was sought from the Management of the cotton companies operating in the study sites. The purpose and importance of the study were disclosed to the authorities and participants. Oral consent was sought from participants before the study started and respondents were assured of the confidentiality of the information they provided. Participants were not financially induced or coerced to take part in the study as it was explained to them that their participation was purely voluntary. Thus, the study was being guided by the Belmont guideline (Belmont, 1979) concerning fairness in the selection of participants, consent to participate in studies, and efforts were made to reduce risks or harm to participants.

2.4 Statistical Analysis

The XLSTAT statistical software, (version 2021.5) was used for detection of breaks in the rainfall and temperature series. The valid responses gathered at the end of the survey period were extracted and analyzed quantitatively in line with the research objectives. Descriptive and inferential analytical methods were employed to analyse the data with SPHINX (Ver.5.1) software at a statistical significance of 5 % error (0.05), i.e. at 95% confidence level. We used descriptive statistics to analyse the socio-economic profile, farmers' perception of climate change and adaptation strategies of the surveyed households. The internal validity of the Likert-scale results was tested with Cronbach's alpha reliability ($\alpha = 0.69$). This suggests that the data collection instrument is 69% reliable and will produce the same results if the study is repeated. The percentages and distributions of the characteristics of the smaller holder cotton farmers were determined with the univariate and bivariate analysis. Pearson's chi-square was used to test and describe the relationship between the independent socio-economic and demographic categorical variables. The cross-tabulation obtained by calculating the mean and standard deviations allowed the analysis of local perceptions of climate change and adaptation strategies.

3. Results

3.1 Socio-Economic and Demographic Characteristics of Cotton Producers

The results of the analysis of the socio-economic and demographic characteristics of the cotton farmers are shown in Table 2. The, parameters were: age, sex, marital status, level of education, experience in cotton cultivation, mode of access to the plot, and the economic activities carried out. The results showed that cotton cultivation is an activity mainly practiced by men, i.e. 99.4% against 0.6% of women in the surveyed areas. The ages of these producers were between 20 and 70 years with an average age of 45 years. The age group between 40 and 50 years was the majority (38%) in this study while almost all of the respondents were married (98.9%).

Table 2. Socio-economic and demographic characteristics of cotton farmers

Variables	Percentage (%)
Age	
Below 20	0.3
20-30	3.7
30-40	26.2
40-50	38.0
50-60	21.1
60-70	9.6
Above 70	1.1
Gender	
Male	99.4
Female	0.6
Marital Status	
Married	98.9
single	30.9
widower	0.3
Education	
No Formal Education	72.1
Primary school	20.9
High school	5.4
Quranic school	1.6
Access to cultivation plots	
Inheritance	59.40
Rental	19.20
Loan	13.50
Donation	7.90
Labour use	
Manual labor	92.4
Animal traction	7.6
workforce used	
Family	72.3
Salaried	55.5
Experience	
Less than 10 years	14.9
10-20 years	24.5
20-30 years	30.1
30-40 years	19.4
40-50 years	8.5
50-60 years	2.3
Above 60 years	0.3

3.2 Endogenous Perception of Climate Change Indicators

3.2.1 Change in Precipitation Indicator

Climate variability is a reality in the Ivorian cotton zones. Local people remember abundant and regular rainfall in the past and long rainy seasons. These rains could last several hours during the day. Currently, cotton producers are seeing a disruption of the rainy season. This can be seen, according to cotton growers, by a shorter duration of the rainy season (99.4%), a decrease in the number of rainy days (98.9%), a decrease in rainfall (98.6%) (Figure 2). Respondents perceived the rainy seasons have a late start (91.3%) while other cotton producers perceived the rainy seasons have earlier onset (7.9%). According to the producers, the changes in rainfall pattern do not manifest themselves in the same way during the year, there were months where the decrease in the number of rainy days was significant. In general, the respondents reported that the decrease in the number of rainy days was pronounced in the period from March to June with a peak in May and June. This observed decrease in the number of rainy days differed from one area to another. For example, in Boundiali, the decrease was more observed in January, February, March, and May while in Ferkessédougou, the months from March to July were the most affected by this decrease in the number of rainy days. In Korhogo, the months of May and June were the most frequently mentioned whereas, in Mankono the month of May alone was affected by the decrease in the number of rainy days. Regarding the decrease in the amount of rainfall, the farmers reported that this was generally observed within the months of April to June although there were variations in the response from one locality to another. The months from April to August were the most frequently mentioned in Boundiali, while in Ferkessédougou, it was rather the months of March and June that were of concern. Finally, in Korhogo and Mankono, the months from May to September were affected by decreasing amounts of rainfall.

3.2.2 Extreme Temperature and Wind Indicators

The cotton famers reported observed changes in temperature (Figure 2). They perceived the increase in temperature through its impact on their cropping activities (93.8%). The high temperatures associated with the months from January to April influenced their site preparation activities for cotton production (ploughing, application of collected herbicides). Again, respondents reported that the presence of strong winds in cotton production was a recent phenomenon. According to 95.5% of famers surveyed, the winds have become more violent and more frequent (Figure 2). They appeared in the form of whirlpools of sand and caused significant damage to crops by breaking the stems of the cotton plants. The strong winds were generally observed in March, April, and October. In Boundiali, respondents indicated that violent winds were rather prevalent in, the months of August and October. While, in Ferkessédougou, the months April, May, and October were associated with violent winds. In Korhogo, farmers observed strong winds in the months of March, August, September, and October whereas the farmers in Mankono observed, the presence of destructive winds from February to April.

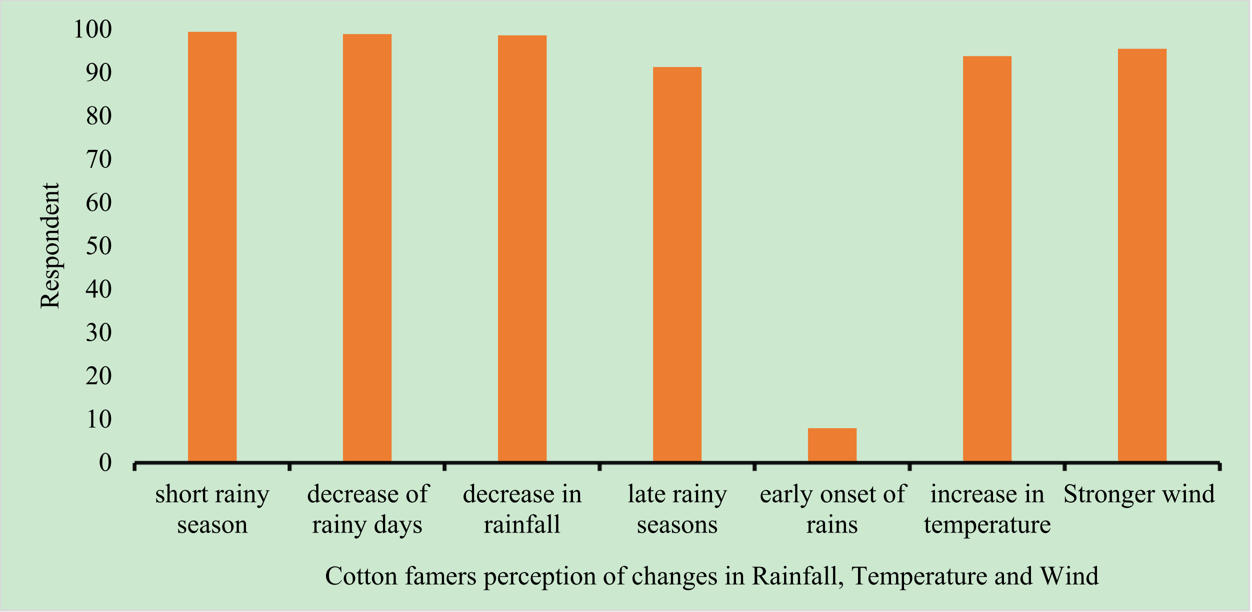

Figure 2. Cotton farmers' perception of changes in rainfall, temperature and strong winds in the study area

3.3 Adaptation Measures of Cotton Producers in the Face of the Effects of Climate Change

Faced with the consequences of climate change, the cotton producers had developed adaptation strategies to cope with the effects of climate change on their livelihoods. The adaptations strategies of the respondents in the face of climate change effects on their livelihoods are shown in Figure 3. The cotton farmers had resorted to the use of new, more adapted short-cycle cotton varieties. Overall, these varieties had been adopted by almost all farmers (87.3%). The respondents reported other adaptation strategies such as use of organic manures to restore the fertility of overexploited soils (80%), ploughing before sowing (30%) and, sacrifices to the divine beings before cultivating their cotton fields (40%). This climatic context also led 36% of cotton farmers to diversify their cotton production by intercropping with groundnuts and maize to guarantee some form of income in the event of cotton crop failure. Crop diversification refers to mixed cropping and aims to increase financial returns from crops so that farmers are not dependent on a single crop to generate their farm income. Diversification of income sources was also a component of the strategies developed by the local people to ensure the sustainability of their livelihoods and their survival.

The staggering of sowing dates and the timing of cropping activities have strong influence on the performance of the cropping system throughout the cycle. The optimal sowing date is determined primarily by the arrival of rains and/or the water regime of the plot. As a result, the farmers indicated that their plots preparation had to be done as early as possible to allow sowing of cotton seeds as soon as the first "useful" rains come. As a practice in the Côte d'Ivoire cotton basin, cotton used to be sown in the first decade (D1: 21-31 May). However, due to climate change, many of the cotton famers (83.1%) sowed their cotton in the second decade (D2: 1-10 June). But the farmers reported that if the rains start very late, sowing of the cotton seeds was done in the third (D3: 11-20 June) or fourth decade (D4: 21-30 June).

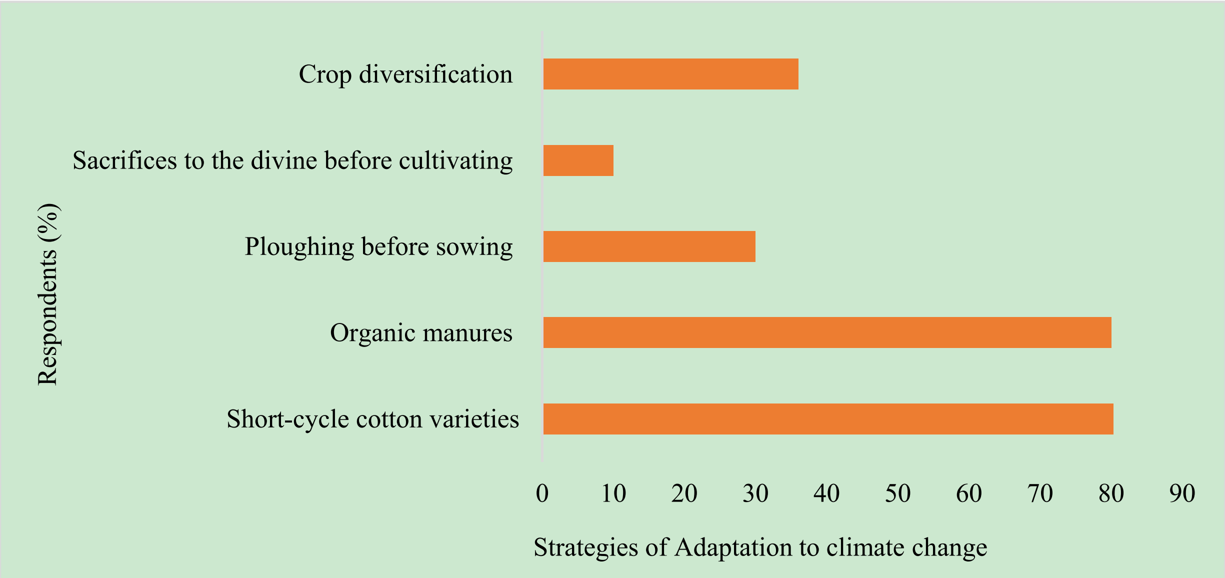

Figure 3. Adaptations strategies of farmers to climate change effects in the study area

3.4 Climatic Disruption and Rainfall Deficits

The results (Figure 4 a, b, c, d) indicates a break in 1998 for the Korhogo station (Figure 4a) and a break in 1999 for the Boundiali station (Figure 4b) at 99% level of confidence for the two stations. The observed drop in rainfall in the stations of the two basin was quantified by calculating the deficits due to the breaks detected in the data series. The rainfall deficits obtained were 9.9% in Korhogo and, 19.60% in Boundiali. However, the Pettitt break test did not show any apparent break in the Ferkessédougou (Figure 4c) and Mankono (Figure 4d) rainfall series.

3.5 Climatic Disruption and Temperature Increases

With respect to temperature analysis, the Pettit test showed apparent breaks in the temperature series in the four departments of the study area (Figure 5 a, b, c, d). The temperatures ranged from 28.67°C to 31.21°C with an average of 29.94°C. The temperatures were therefore below the damaging thresholds, which is around 35°C. However, the temperature increases by an average of 0.7°C per decade and showed a break in 2002 for the Korhogo station (Figure 5a), 2001 for the Boundiali station (Figure 5b), 2005 for the Ferkessédougou station (Figure 5c) and 2001 for the Mankono station (Figure 5d).

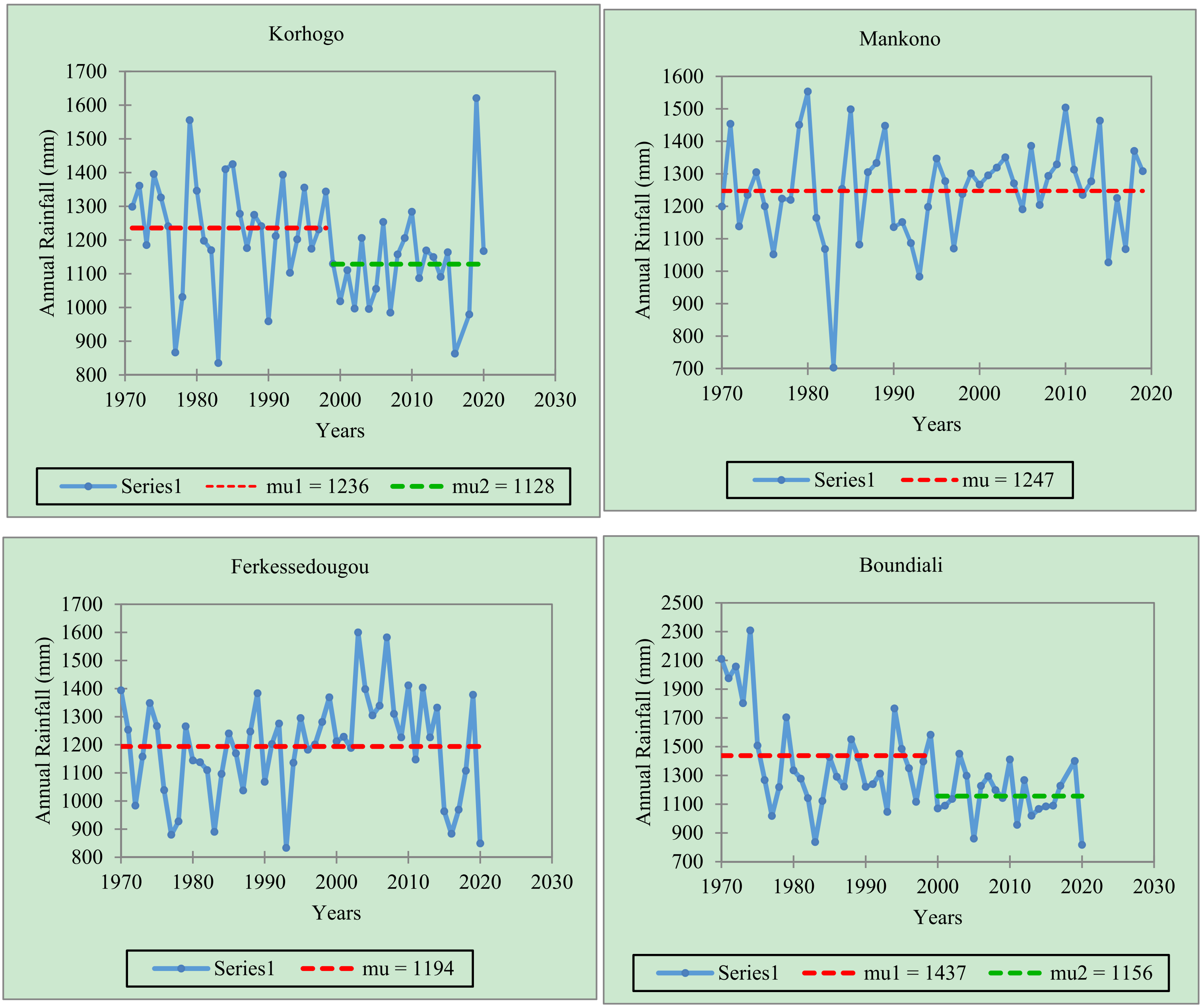

Figure 4. Rainfall fluctuations from the Pettitt breakage test for (a) Korhogo, (b) Boundiali, (c) Ferkessédougou and (d) Mankono departments in the study area

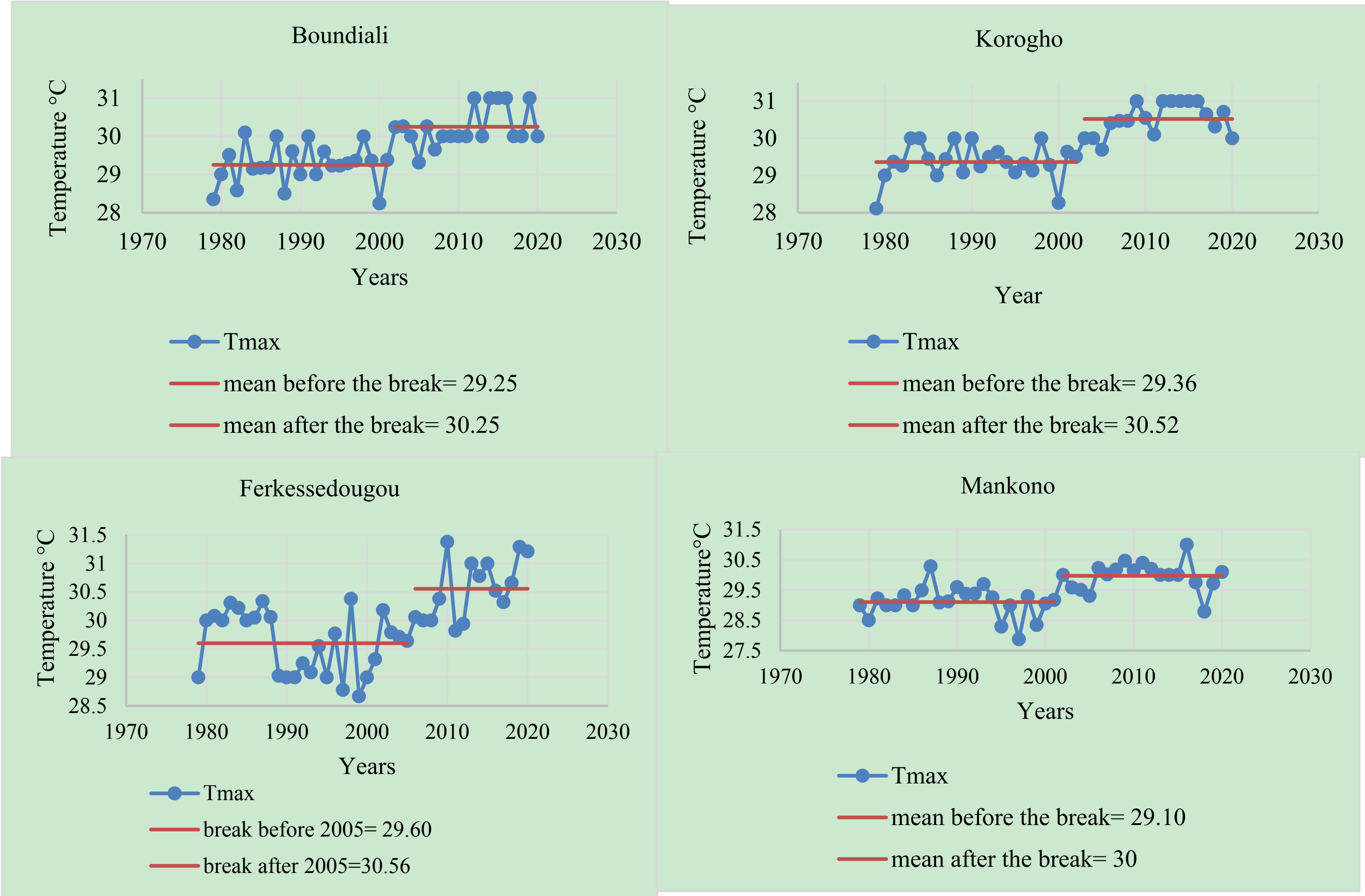

Figure 5. Temperature evolution from the Pettitt breakage test for (a) Korhogo, (b) Boundiali, (c) Ferkessédougou and (d) Mankono departments in the study area

4. Discussion

4.1 Socio-Economic and Demographic Characteristics in the Study Areas

The survey showed that the majority of cotton farmers in the study area were in the age groups above 20 years. Furthermore, most of them had between 10 and 60 years of farming experience. Therefore, they should be able to give credible information on climate change and its impacts in the studied area. However, their level of education was very low in all four departments of the study area. The level of education influences farmers' ability to appreciate climate patterns and adaptations. Cotton farmers with primary and secondary education have better perception of climate change, probably due to their regular contact with the outside world and their better access to information sources such as the mass media (Kabore et al., 2020; Assoumana et al., 2016). Thus, farmers' level of education increases the likelihood of adaptation for temperature and rainfall seasons. Educated farmers are more aware of accessing, understanding, accepting and adapting to climate change information and improved technologies, which leads to higher productivity. The level of education of the farmer has been found to have a significant relationship with intensive knowledge of climate change (Jha & Gupta, 2021). There is therefore a need to empower farmers with educational skills and knowledge.

4.2 Cotton Farmers' Perception of Changes in Rainfall Patterns and Correspondence with Climate Records

Climatic data spanning the past 50 years were analysed to compare with farmers' perceptions of changes in rainfall patterns in the four departments of the cotton basin area. Regarding the duration of the rainy season as well as the amount of rain, we observed a shorter duration of the rainy season (99.4%), a decrease in the number of rainy days (98.9%), and a decrease in rainfall (98.6%). The rainy seasons had a late start and an early start according to 91.3% and 7.9% of cotton producers respectively. The analysis of long-term rainfall data showed a large variation from season to season in the amount and distribution of rainfall at some locations in the study area. This situation negatively affects cotton seed yields. Although farmers do not have a quantitative measure of the amount of rainfall received in different seasons, they had a good knowledge of the general climatic conditions, especially with regard to variables that have a significant impact on crop performance (Rao et al., 2011). In Korhogo and Boundiali departments, the perceptions of the cotton farmers were confirmed by the climatic data. There was a concordance between cotton farmers' perceptions and the perceived break in the rainfall sequence in Korhogo and Boundiali marking a decrease in the amount of rainfall. Although there was no break in the sequence in the other two departments (Ferkessedougou and Mankono), cotton growers perceived a decrease in the amount of rainfall there. A large fraction of cotton farmers perceived decreases in annual rainfall despite instrumental records indicating no significant trends for the Ferkessedougou and Mankono departments. This perception might be linked to the greater decrease in rainfall associated with a decrease in seed cotton yield. Furthermore, the large number of illiterate cotton farmers and the high spatio-temporal variability of rainfall patterns could limit their ability to remember events over the years (Assoumana et al., 2016).

Several studies on farmers' perceptions of climate change repeatedly showed a clear concordance between observations of climate data and farmers' perceptions of a shorter rainy season (e.g. Atiah et al., 2021; Nguyen et al. 2016; Rao et al., 2011). However Study in Ghana by Guodaar et al.,(2021) showed that farmers' perceptions of climate change in northern Ghana deviated from weather records. A possible explanation for the discrepancies between farmers' perceptions and weather observations could be their inability to understand climate change and their inability to differentiate between climate variability and change (Darabant et al., 2020). With regards to long-term climate change, farmers' observations in our study that rainfall patterns were changing corroborated well with perceptions reported in other parts of the African continent such as Burkina Faso and Ghana where the respective studies by Kabore et al., (2020), and Fossou et al., (2014) showed good farmer perceptions of the climate change phenomenon.

4.3 Cotton Farmers' Perception of Changes in Temperature and Wind, and Correspondence with Climate Records

The temperature trends exhibited apparent break in the four departments of the study area with an average temperature of 30°C. There was a significant increase in temperature (0.7 °C per decade) over the 50-year period. This upward trend in temperature was confirmed by studies by the National Meteorological Directorate, which indicate that Côte d'Ivoire as a whole has warmed by an average of 0.5°C since the 1980s (Kouassi et al., 2020). In addition, this upward trend in temperature was also confirmed by the ECOWAS-SWAC/OECD report (2008) which indicates that temperatures in West Africa have been increasing by between 0.2°C and 0.8°C per decade since the late 1970s. This temperature increase was in line with the perceptions of respondents who perceived rising temperatures through its impact on their production activities (93.8%). Almost all cotton producers surveyed reported a strong presence of heat in recent decades in the study area. These results were in agreement with studies conducted by Mkonda et al., (2018) in Tanzania. The authors compared farmers' perceptions with the results of temporal trends in weather data mainly temperature. The perceptions of the farmers in all studied areas of Tanzania agreed with the measured weather data manifested as rising temperatures. The majority of farmers correctly perceived the increase in temperature in their locality. They also noted that the increase in temperature has had negative impacts on agricultural production in all areas of Tanzania. Furthermore, other studies (Amadou et al., 2015; Fosu-Mensah et al., 2010; Kouassi et al., 2010) had reported increases in temperature over the years. The temperature remains the only climate parameter which the climate trend was clearly in agreement with the perceptions of farmers in the four department of the study area. Additionally, the presence of strong winds was a recent phenomenon in recent years for the cotton producers. According to 95.5% of those surveyed, the winds have become more violent and more frequent. The winds were increasingly violent and had become an important factor in the destruction of cotton plants. The communities around Lake Tana, Ethiopia lamented a rise in wind occurrence and speed (Darabant et al., 2020). According to Kosmowski et al., (2016), these high winds caused a lot of damage to crops in Niger. Based on these trends, it can be concluded that the perceptions of climate change by cotton farmers in the cotton basin were in line with climate trends.

4.4 Cotton Farmers' Adaptation Strategies to Perceived Climate Change Effects

In order to adapt to the negative effects of climate change, cotton farmers had put in place adaptation strategies. The most important of these were, using new, more adapted short-cycle cotton varieties, using organic fertilisers to restore fertility to overexploited soils, shifting sowing dates and the timing of cultivation activities. Indeed, faced with the scarcity and uncertainty of rainfall, cotton farmers sowed their cotton seeds in the second decade to ensure that the cotton plant flowers at the right time of the rains.

Cotton farmers who have developed coping strategies have adopted ploughing before sowing to better exploit the first rains in the hope that they will last. Some producers make sacrifices to implore rain from protective spirits.

This finding was in line with the work of Boko et al, (2016) that people make offerings to their ancestors to implore the coming of rain.

Crop diversification was also an important coping strategy among cotton farmers according to their farming experience. Indeed, according to the farmers, mixing cotton with maize or groundnuts allowed them to harvest maize and groundnuts when the growing season was too short for cotton to develop successfully. Agronomic research has shown that mixing cotton with groundnuts increases soil fertility, as legumes (groundnuts) are particularly important because of their ability to fix atmospheric nitrogen, which helps to improve soil fertility (Yuvaraj et al., 2020). Diversification of crop types is an emerging agronomic practice as a coping strategy attributed to the risk of averse behaviour of farmers in northwestern Ethiopia (Asrat & Simane, 2018). The reasons for these coping strategies are the decrease in rainfall and the scarcity of arable land.Therefore, this approach appeared to be more of a traditional strategy to reduce the risk of cotton crop failure in the study area than a specific response to climate change.

However, to compensate for drought adaptation, farmers were shifting from long-cycle cultivars (late cotton) to short-cycle cultivars (early cotton). According to Kouressy et al., (2008) and Djohy et al., (2015), it was evident that the decrease in rainfall had led famers to adopt shorter cycle varieties than traditional cultivars. Agricultural inputs such as organic and mineral fertilisers were used to boost crop production and thus reduce the negative impact of climate change on cotton production. This was in line with the finding of Sanou et al, (2018) who reported the importance of organic amendment in maintaining agronomic soil quality. Education was positively associated with the cotton farmer's adaptation decision. As such, cotton farmers with a good level of education were able to develop better adaptation strategies. This was in line with the findings of Asrat & Simane (2018) who reported that education improved farmers' ability to reason about induced technologies to adopt strategies to cope with climate change.

5. Conclusion and Recommendation

This study provided an overview of perceptions and adaptations of local cotton farmers to climate change events in the cotton basin area of Côte d'Ivoire. The results showed that cotton farmers in the cotton basin perceived changes in rainfall patterns, temperature and wind speed. The climate, especially rainfall, due to its irregularity and the downward trend in the amount of rainfall received, was a major limiting factor for cotton productivity. The perceptions of cotton farmers did not fully correspond to the past weather records in two departments of the study area. Although farmers were fully aware of climate change, few of them seemed to be taking measures to adapt their farming activities in order to cope with the consequent negative effects on their livelihoods. However, farmers' perceptions should not be the only criteria for identifying the gaps and needs of cotton farmers, but rather criteria for exposing them to objective facts that would enable them to take more concrete adaptation measures. Given the importance of climate change in the cotton basin and its direct implications for cotton production, there is an urgent need to make technological innovations that are oriented towards climate change adaptation measures available to cotton farmers. It would also be necessary to:

- Involve government policies to ensure that producers have easy access to credit in order to increase their capacity and flexibility to change production strategies according to expected climatic conditions;

- Support producers in the development of mechanised agriculture which favours the use of mounted implemented such as ploughs tractors to enable them to follow the new short crop establishment times.

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