International Journal of Innovation and Applied Studies
ISSN 2028-9324 Vol. 43 No. 3 Sep. 2024, pp. 800-808

http://www.ijias.issr-journals.org/

Contribution to highlighting the negative effects of climate variability in the Tillabéri region (Niger)

Daouda Boukary[1], Hassimiou Halidou Djabri[2], Karimou Harouna Boureima[2], and Alzouma Mayaki Zoubeirou[3]

[1]Directorate General for the Environment, Post Box 578 Niamey, Niger

[2]Boubakar Bâ University of Tillabéri, Faculty of Agricultural Sciences, Agroecology Laboratory, Post Box: 175, Tillabéri, Niger

[3]Abdou Moumouni University of Niamey, Faculty of Science and Technology, Biology Department, Garba Mounkaila Laboratory, Post Box: 10662 Niamey, Niger

ABSTRACT: Rainfall variability in the Tillabéri region is the result of significant vulnerability, which has been observed for decades. The aim of this study is to highlight the adverse socioeconomic and environmental effects of these rainfall deficits. The methodological approach used in this study included assessing farmers' perceptions of climate change indicators through field investigations, analysing variations in temperature, relative humidity and rainfall indices in the area to better characterise the climate. The results show a low level of education among the farmers surveyed and a good perception of the effects of climate change. Rainfed and irrigated agriculture are the main economic activities in the region (99.3%), with livestock rearing and market gardening as secondary activities for 31.3% and 18.7% of respondents respectively. Access to inputs (50.8%) and agricultural credit (10.3%) are major assets for producers in the area, in addition to their experience of new agricultural technologies (62%). The most significant inter-annual peaks in rainfall indices were observed on the following dates: 09/25/1988, 03/01/199, 05/18/2004, 08/05/2009 and 01/10/2020. However, inter-annual variations are also observed (09/25/1988 and 01/10/2020). The indicators of environmental change as perceived by farmers are bare soil (77.3%), gravelly soil (9.7%), erosion gullies (7%), silting up of fields (8.7%) and proliferation of Striga sp. (7%). The reduction in herbaceous plants (30.7%) and the drying out and mortality of woody plants (20.3%) are visible signs of land degradation on natural vegetation. The main causes of these changes are reduced rainfall (82%), the action of strong winds (37.3%), water erosion (34%) and intensive deforestation (24.3%). To these must be added harmful agricultural practices such as the absence or reduction of fallow periods, bush fires, low inputs of organic and mineral fertilisers, low use of CES/DRS techniques, etc. The natural vegetation cover (woody and herbaceous) that used to protect the soil has declined sharply, leaving it vulnerable to erosion.

KEYWORDS: rainfall index, climate change, vulnerability, negative effects, Tillaberi.

1 INTRODUCTION

The issues of climate change and variability have for some time been at the center of the concerns of scientists and policy-makers around the world in general and in Niger in particular (Kouassi et al., 2010). As the water cycle is one of the major components of climate, the implications of these changes for rainfall patterns are significant (Kouassi et al., 2010). Rainfall is the most important factor in climate, both for people and for ecosystems, in that it is easy to measure. Several studies and analyses have highlighted the effects of climate change on rainfall, relative humidity and evapotranspiration. As a result, characterising the impact of climate variability on seasonal rainfall patterns is becoming essential in order to propose appropriate solutions and mitigation mechanisms.

The variability of climatic conditions in the Tillabéri region no longer needs to be demonstrated (TIEPOLO, 2016). Indeed, these rainfall anomalies, which have been observed for almost a decade, have had an exceptional impact on the northern and western regions of the country. But in reality, the whole country is highly vulnerable to rainfall deficits (LAWAN et al., 2014).

Climate variability as a phenomenon has long been studied and characterised. The most important question, both for the study area and for the other regions of Niger, is the search for explanatory factors (Tarchiani Et Tiepolo, 2016). Most climate studies have been limited to the analysis of annual or monthly rainfall data. As a result, rain-related variables such as the frequency of rainy days and the length of the rainy seasons have generally received very little attention. This could be justified by the difficulty of acquiring reliable daily measurement data with few gaps. To compensate for these shortcomings, climatic parameters such as air temperature, relative air humidity and the frequency of rainy days need to be analysed and their impact on the variability of rainfall patterns studied.

The aim of this study is therefore to investigate the influence of climatic events on seasonal rainfall patterns in the localities of Tillabéri, Kourthèye, Say, Tamou, Téra and Diagourou. The geographical area formed by these localities is a transition zone between different climates.

2 MATERIALS AND METHODS

2.1 STUDY AREA

The study area is located in the extreme west of Niger, between latitudes 11°50 and 15°45 north and longitudes 0°10 and 4°20 east. It covers an area of 97,251 km^{2}, or approximately 7.7% of the national territory. On 17 December 2012, it had an estimated population of 2,722,482, 49.5% of whom were men and 50.5% women, making up 15.9% of Niger's population. The population is expected to grow by 3.2% between 2019 and 2021. The Tillabéri region is characterised from north to south by four major climatic zones: the Saharo-Sahelian zone, the Sahelian zone, the Sahelo-Sudanian zone and the Sudanian zone. Figure 1 below illustrates the agro-ecological zoning of the study area.

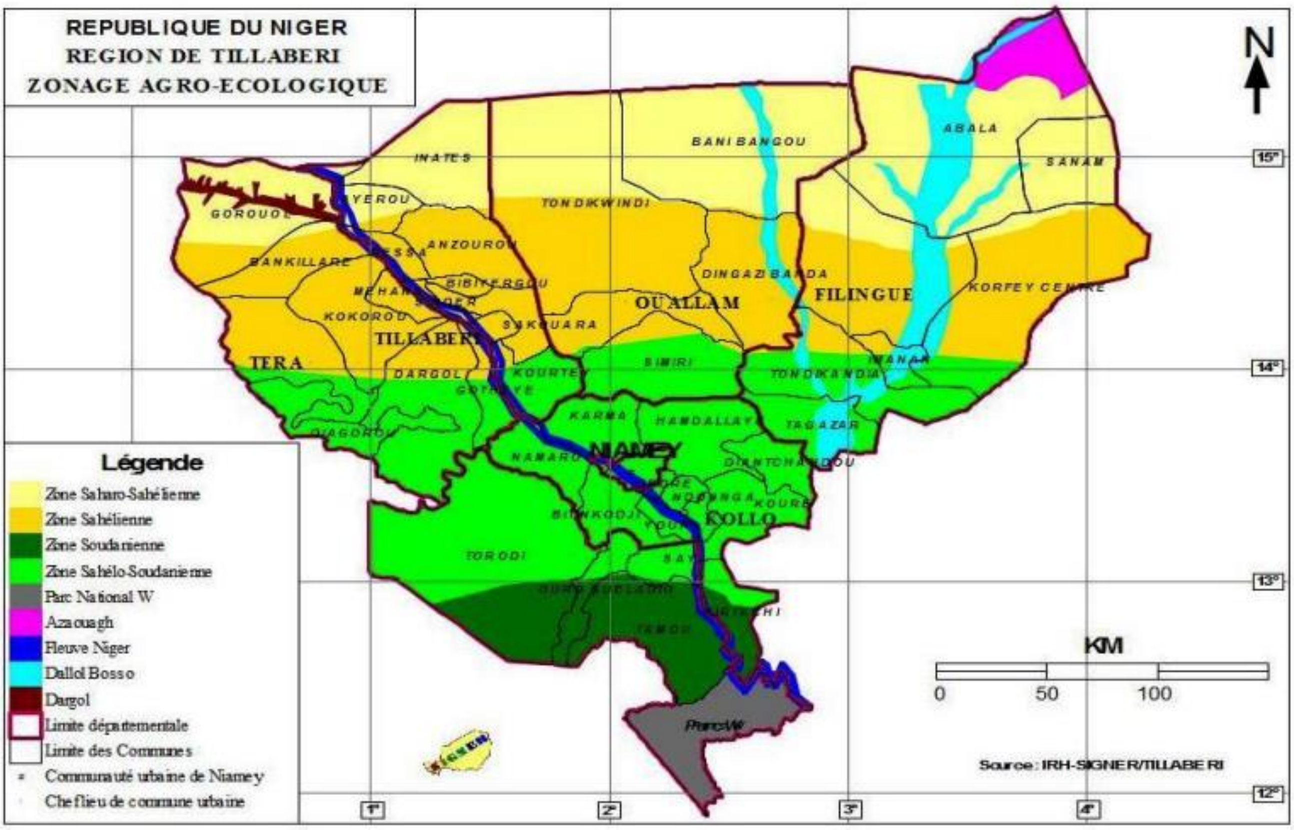

Fig. 1. Agro-ecological zoning map of the Tillabéri region

2.2 METHODS

2.2.1 SAMPLING AND FIELD INVESTIGATION

The survey was carried out in Tillabéry, Kourthèye, Say, Tamou Téra and Diagourou. These sites were chosen on the basis of rainfall variability, vulnerability to climate change and cropping practices. In each locality, 10 farming households were selected at random from a list of people meeting the following criteria: The target households were mainly farmers, market gardeners and agro-pastoralists. These households were selected with the help of the technical services. The head of household must be at least 45 years old. This age criterion is explained by the fact that climate change is very slow and it is adults who can have experienced it. The head of household must also have lived in the locality for at least 15 years. It is also assumed that, at the age of 15, an individual is capable of memorising certain key facts about climate change and changes in the natural environment over the past 30 years and of revealing them. The data was collected over a period of six (6) days. The work was carried out in two sequences, the first of which took the form of a focus group that enabled us to interview 60 farmers (men and women) using an interview guide. These groups ranged from 6 to 10 people in each of the localities; then thirty (30) other selected people answered an individual questionnaire containing closed and open questions, and finally twenty (20) other people were questioned about their perception of climate change indicators and environmental and agricultural impact indicators. Climate change indicators are meteorological parameters whose evolution over time reflects climate change. It should be noted that the questions asked of the farmers about their perception of climate change are consistent with the indices of the Expert Team on Climate Change Detection Monitoring and Indices (ETCCDMI) (Zhang and Yang, 2004).

2.2.2 STUDY OF CLIMATE VARIABILITY

2.2.2.1 ANALYSIS OF AIR TEMPERATURE AND RELATIVE HUMIDITY

Air temperature and relative humidity in the study area were analysed using descriptive statistics (mean values) and graphical representations. This analysis was carried out using DSSAT. DASST is a software package that enables crop simulation, assessment of the impact of climate variability and climate change, gene-based modelling and breeding selection, water use, greenhouse gas emissions and long-term sustainability through soil organic carbon and nitrogen balances.

2.2.2.2 ASSESSMENT OF THE RAINFALL INDEX

The study of variability in the length of the rainy season is based on the method developed by Ozer and Erpicum (1995). To assess changes in rainfall over the years, the rainfall index method was applied. This method has the advantage of highlighting periods of surplus and deficit. For each of the rainfall stations selected, an interannual rainfall index was determined. It is defined as a reduced centred variable expressed by equation 1 (Servat et al., 1998). The dynamics of seasonal rainfall patterns in the study area were analysed by comparing the rainfall normals for the periods 1984-2021 with those for the 1961-1984 period (reference). A normalised principal component analysis (NCCA) was used to analyse the impact of climatic factors on seasonal rainfall patterns.

2.3 DATA ANALYSIS AND PROCESSING

The climatic data collected were observed and processed using DSSAT version 4.8, STATA 13.0 and Excel spreadsheet software. The climatic parameters recorded in Tillabéri, Kourthèye, Say, Tamou, Téra and Diagourou cover the period 1984-2020. Descriptive statistics such as the mean and frequencies of the variables studied were calculated using STATA 13.0 software. Past data (over 30 years) relating to meteorological parameters was compared with that of the last 15 years in order to highlight climate change. This comparison was also used to find out whether growers had noticed an increase or decrease in rainfall in their area in recent years. The factors influencing local perceptions of the disruption of the rainy season were analysed using binary logistic regression. The disruption of the season is reflected in the decrease, irregularity, late start and early cessation of the rains. Four regressions were run on these perception variables. The model parameters were estimated using the maximum likelihood method (Nkamleu and Kielland, 2006; Adesina *et al.*, 2000). The equation for the binary model is as follows: $Yi = xi\ \beta + \varepsilon i$ (1) Where:

- Yi is the latent variable which takes the value 1 if the producer perceives the disruption of the rainy season and 0 if he does not;
- Xi designates the explanatory variables indicating the factors that influence farmers' perception of this seasonal disruption and,

- εi is the standard error. The explanatory variables for these regressions are the socio-economic characteristics of the households: the sex of the head of household (Sex), his or her age (Age), level of education (Education), membership of a farmers' organization (FO), household size (Size) and agroforestry activity. The table below shows the explanatory variables. Binary logistic regression has also been used to determine the determining factors in the choice of climate change adaptation strategies (Sale et al., 2014; Loko et al., 2013). In equation (1), Yi represents a dichotomous dependent variable that takes the value 1 if the agricultural producer adopts a climate change adaptation strategy and the value 0 if he does not, and xi is the set of explanatory variables. These variables are the adaptation practices. Four practices were modelled. These were zaï, stone barriers, manure pits and irrigation. The explanatory variables are the perception variables (decrease in rainfall, irregularity, late onset and early cessation of rains).

3 Results

3.1 Socio-Economic Characteristics Of Households

The survey population was made up of 76% men and 24% women. The average age of the heads of household was 55. The average household size was 13 people. More than half (57.6%) of the heads of household are illiterate. Rain-fed and irrigated agriculture are the main economic activities in the region (99.3%). Livestock rearing and market gardening are secondary activities, practiced by 31.3% and 18.7% of the population respectively. The majority of producers (68.7%) are engaged in subsistence farming, while 30.3% are also engaged in cash crops. Half of all households are members of a farmers' organization (FO). Nearly two-thirds of farmers (62%) have already received training in agricultural technologies. The average level of agricultural equipment owned by households is 75% for ploughs, 71.7% for carts, 65.3% for picks and 42.3% for shovels. Breeders of small ruminants account for 51.7% of the population. Breeders of large ruminants with more than 12 head of cattle account for 12% of producers. Almost half of farmers (50.8%) have access to agricultural inputs (improved varieties, mineral fertilizers, etc.) subsidized annually by the State. A small number of farmers (10.3%) have access to agricultural credit. This poor access limits the scope for substantial investment in more intensive farming in the study area.

3.2 Variation Of Temperatures (Max & Min) In The Area By Year

The figure below illustrates the inter-annual variation in temperatures in the study area.

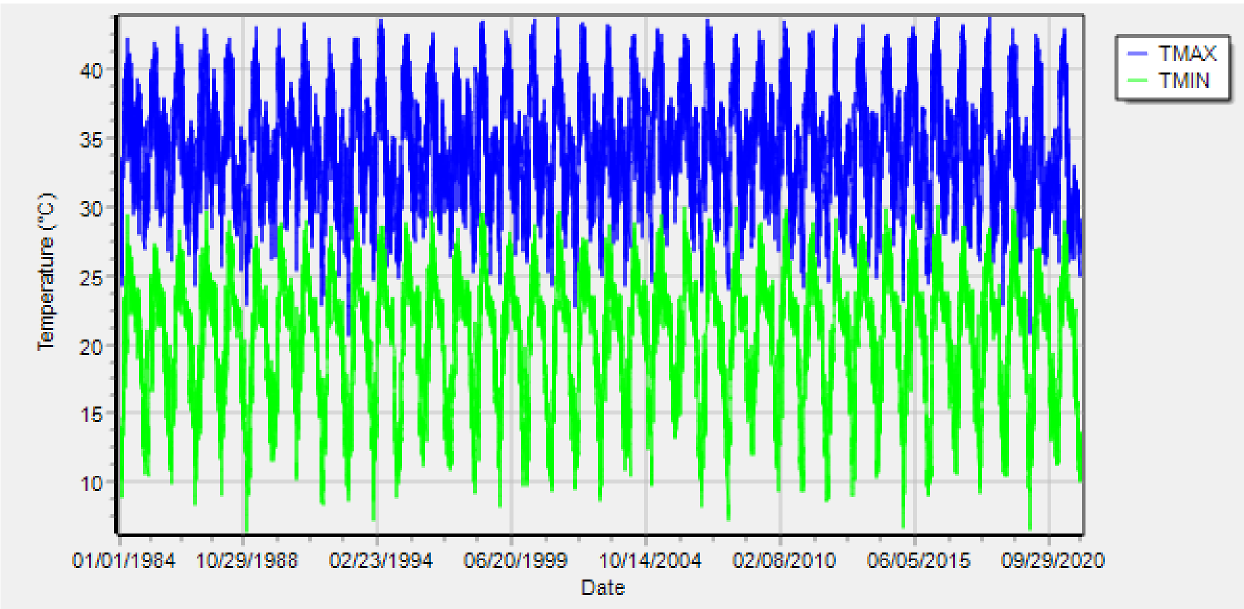

Fig. 2. Variation in minimum and maximum temperatures from 1984 to 2020 in the study area (DSSAT version 4.8)

The table below illustrates the climate parameters and indicators of climate variability.

Table 1. List of climate parameters and indicators linked to climate variability and change

Climatic parameters	Climate change indicators
Temperatures	Hot days, hot nights, cold days, cold nights, length of cold period
Rainfall	Decrease in rainfall, intensity, irregularity, late onset, early cessation, frequency and duration of dry spells
Winds	Violence and frequency
Swirls	Violence and frequency
Mists of dust	Frequency and persistence

These data are fairly homogeneous, of good quality and representative of the study area. The availability of data for all the climatic parameters is linked to the availability of these data at the national meteorological service. The data used were used to study climate variability in time and space and its impact on seasonal weather patterns.

3.3 Rainfall Indices

The figure below shows how the rainfall index varies from year to year in the study area.

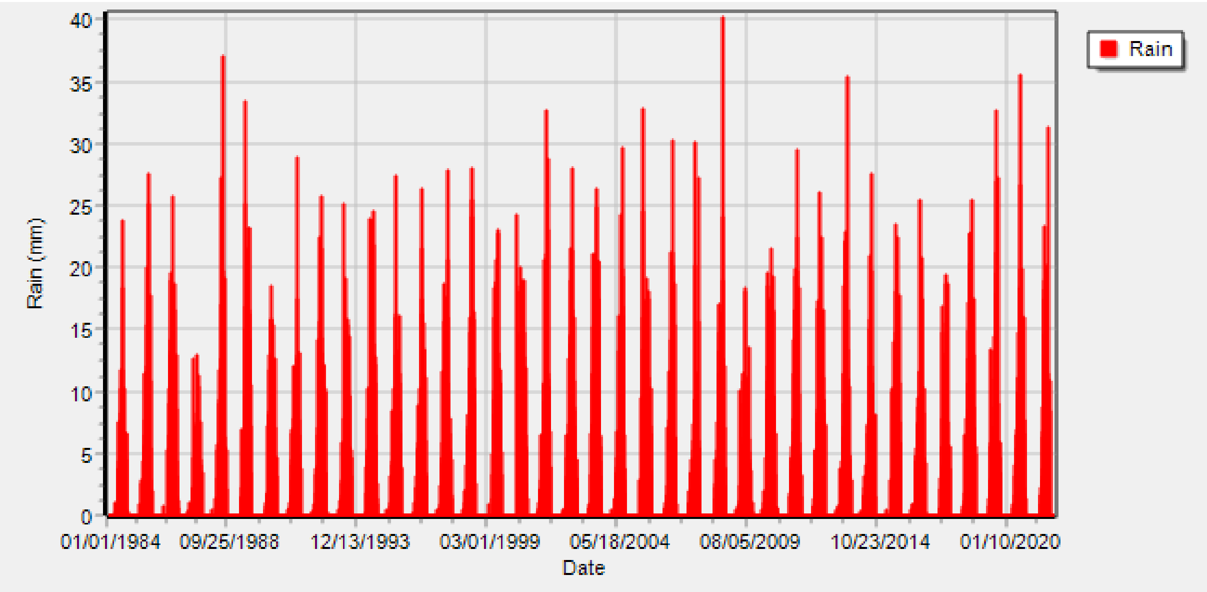

Fig. 3. Variation in rainfall indices for the study area over the period 1984-2020 (DSSAT version 4.8)

The figure shows inter- and intra-annual variation in rainfall indices in the study area. This reflects a spatio-temporal distribution of rainfall according to geographical area. The highest inter-annual peaks are observed on the following dates: 09/25/1988, 03/01/199, 05/18/2004, 08/05/2009 and 01/10/2020. However, inter-annual variations are also observed (09/25/1988 and 01/10/2020).

3.4 Perception Of Climate Change Factors

The figure below presente the perception of climate change factors by farmers.

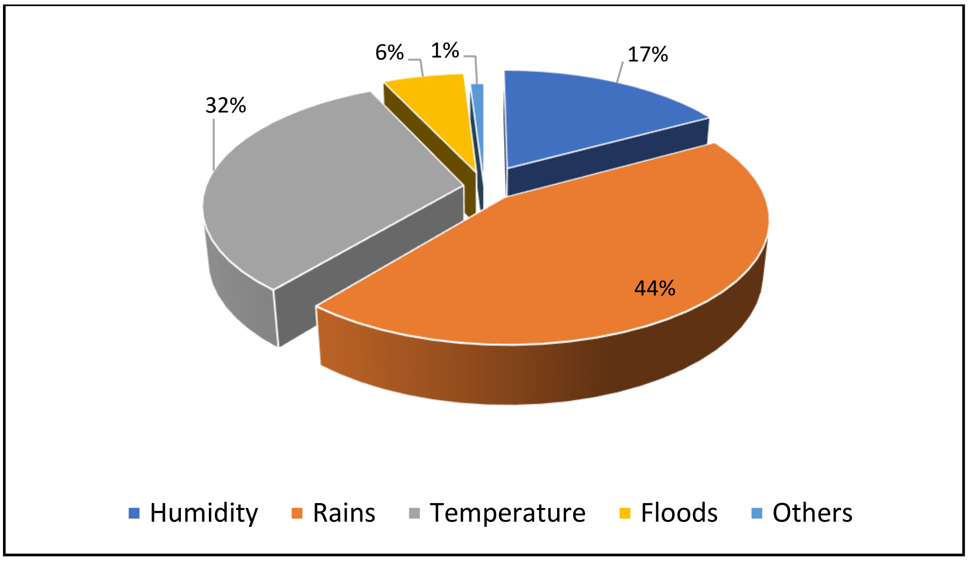

Fig. 4. Distribution (%) of surveys according to their perception of the most decisive elements of the climate change

Analysis of the diagram shows that for parameters such as rainfall, temperature, humidity, flooding and others (drying up of the river), which are indicators for measuring climate change at local level. Rainfall variation is the element with the highest rate of perception of climate change, with a percentage of 44%, followed by temperature with 32%, then humidity with 17%, and then flooding with 6%.

3.5 Endogenous Perception Of Climate Change Indicators

3.5.1 Paysan Perception Of Rainfall Variations

Local people remember abundant and regular rainfall in the past, and longer rainy seasons. In the past, when we saw cloudy skies in the morning, we were sure it was going to rain during the day". This result reflects the regularity of the rainfall. The rain used to be light and could last for several hours during the day. At present, local people are noticing a change in the rainy season. Indeed, 76.7% of the people questioned noted a 50.7% drop in annual rainfall and felt that the rains were irregular (Figure 6).

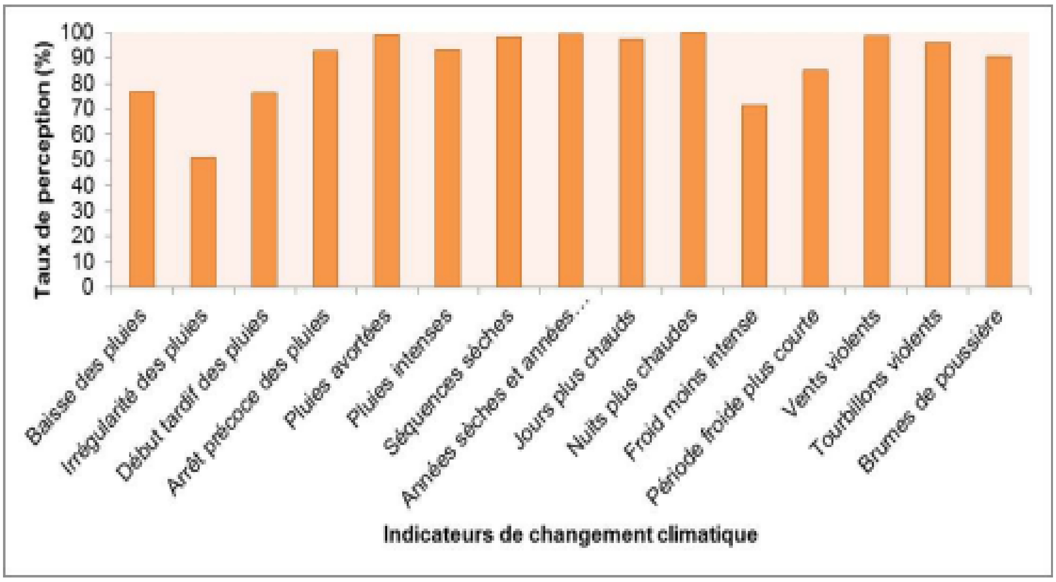

Fig. 5. Climate change perception indicators in Tillaberi, Kourthèye, Say, Tamou Téra and Diagourou

The high incidence (99% of responses) of aborted rains reflects this irregularity. Some people even mentioned this variability in rainfall from one village to another. The rainy seasons start late and end earlier, according to 76.3% and 92.7% of the population respectively. This early cessation sometimes occurs around the crop flowering-maturing period. According to the local people, "There is often a shortage of two or three rains spread out over time to enable rain-fed crops to complete their cycle". The current rains are heavier and only last for a few moments during the day. Dry spells are more frequent and last longer. The ones most observed by people are those lasting [10-13] and [15-18] days, because of their negative impact on rain-fed crops. Rainy and dry years have alternated over the last 15 years. This alternation is perceived through its positive or negative impacts on crop yields. In the localities of Tillaberi, Kourthèye, Say, Tamou Téra and Diagourou, people do not perceive an increase in rainfall in recent years in their area, but rather the occurrence of extreme rainfall.

3.5.2 Paysan Perception Of Extreme Temperatures

People are recognising that the days and nights are getting hotter. These results reflect an increase in daily maximum and minimum temperatures observed throughout the year. Local perceptions indicate that the traditional cold season of the past (December to February) is becoming warmer (71.3% of responses) and shorter (85% of responses). People perceive the rise in temperatures through its impact on their activities. The high temperatures in March, April and May have an impact on field preparation (spreading organic fertilizer, collecting rubble to build stone barriers, making zaï holes, etc.). The early drying up of water reservoirs is partly linked to higher temperatures, which cause evaporation.

3.5.3 Public Perception Of Winds, Whirlwinds And Dust Mists

The appearance of high winds is a new phenomenon for local people. According to 98.7% of those surveyed, the winds have become more violent and more frequent. They appear in the form of tornadoes during the rainy season, causing major damage to homes and crops. The increasing violence of the whirlwinds is reported by a large majority of the population (95.7%). In addition, almost all the population (90.7%) report that dust mists are more frequent as the rainy season approaches and can persist for several days. These mists affect the fruiting of woody plants such as *Vitellaria paradoxa, Lannea microcarpa, Parkia biglobosa,* etc.

3.5.4 Paysan Perception Of Environmental Changes

Figure 7 below illustrates farmers' perceptions of environmental changes as a result of climate change.

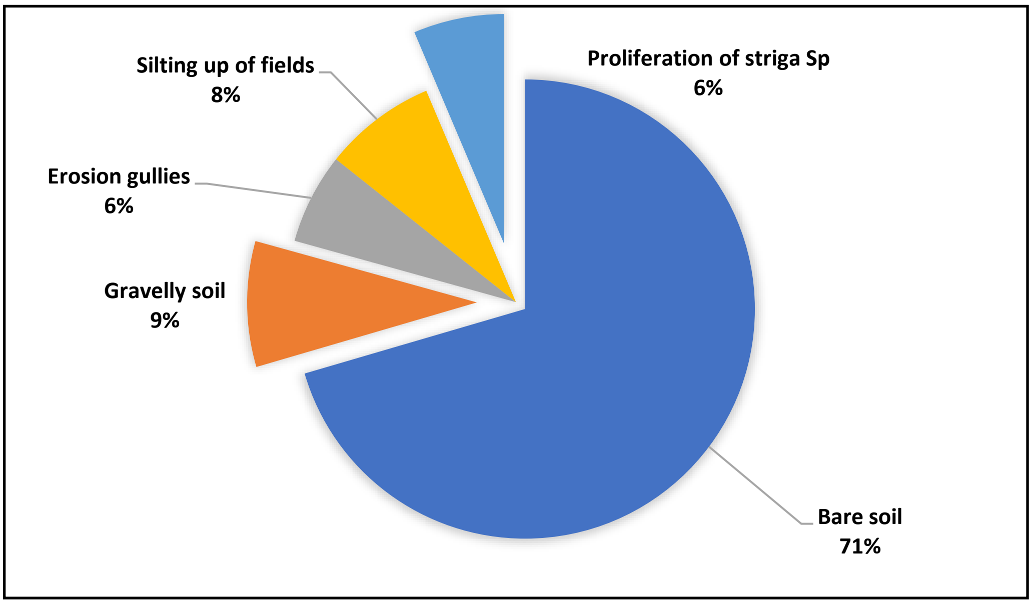

Fig. 6. Perception des indicateurs sur la modification environnementale

Farmers identified five indicators of environmental change, Bare soil (77.3%), gravelly soil (9.7%), erosion gullies (7%), silting up of fields (8.7%) and the proliferation of Striga sp. (7%) in sorghum, millet and cowpea fields are all indicators of degradation of agricultural land.

Table 3 provides information on the reduction in herbaceous plants (30.7%) and the drying out and mortality of woody plants (20.3%), which are visible signs of land degradation in natural vegetation. Low agricultural yields (40.7%) are an indicator of soil degradation. The main causes of these changes are reduced rainfall (82%), the action of strong winds (37.3%), water erosion (34%) and intensive deforestation (24.3%). To these must be added harmful agricultural practices such as the absence or reduction of the fallow period, bush fires, low inputs of organic and mineral fertilisers, low use of CES/DRS techniques, etc. The cover of natural vegetation (woody and herbaceous) that used to protect the soil has declined sharply, leaving the soil vulnerable to erosion.

Table 2. Parameters and indicators of environmental change

Parameters	Indicators of environmental changes
Soil	• Appearance and spread of bare ground ; • Appearance and spread of gravelly soils; • Silting of cultivated plots; • Appearance and extension of erosion gullies..
Ecological	Appearance and proliferation of invasive terrestrial and aquatic plants and death of trees.
Agronomic	Low agricultural yields

4 DISCUSSION

The first important observation to emerge from this study concerns the structure of the respondents. There is a slight numerical superiority of men over women. According to Jacques et al (2007), one of the important aspects of African agriculture is the family nature of farms, the family being the unifying factor and therefore the bearer of the project and objectives. The populations of Tillabéry, Kourthèye, Say, Tamou Téra and Diagourou perceive the negative effects of climatic variations to be due to the decrease and irregularity of rainfall, the late start of the rainy season and the early cessation of the rains. The period 1984-2020 is characterised by alternating dry and wet years, reflecting greater inter-annual variability in rainfall in Tillabery Kourthèye and Diagourou. December, January, August and September will become warmer, and November and March will also see slight increases in temperature (Ministère de l'Environnement et du Cadre de vie, 2007).

Extreme climatic phenomena are veritable catalysts for the degradation of the biophysical environment. In the study area, this degradation is reflected in the spread of bare soil, glacis commonly known as "Gangani", erosion gullies, the disappearance of grass cover, the silting up of fields, the proliferation of invasive plants, the mortality of ligneous plants and the drop in agricultural yields. Most of these signs are indicators of the negative effects of climatic variations.

The majority of farmers surveyed noted a drop in crop yields. The sudden cessation of rain prevents crops from completing their vegetative cycle. Similarly, the dry spells that occur during the seed set phase have a significant impact on yields. In addition, the soils in the study area are low in organic matter, phosphorus and nitrogen (Da et al., 2008), which has a major impact on cereal yields. In addition, heavy pressure from invasive plants is a major agricultural constraint. To adapt to the recent negative effects of climate change, farmers have implemented a number of strategies and practices. The most important of these are the adoption of CES/DRS techniques, ANR, small-scale irrigation, manure pits and varietal adaptation. Recurrent droughts and deforestation have led to a reduction in vegetation cover, exposing soils to wind and water erosion. This has led to a decline in soil fertility, reducing crop yields and affecting farmers' incomes. Farmers have responded by adopting techniques such as stone cordons and zaï. Various practices have been implemented by farmers in response to climatic constraints in the study area.

5 CONCLUSION

People in the study area perceive climate change in terms of reduced rainfall, higher temperatures, flooding and the early drying up of water sources. These climatic hazards have a negative impact on the biophysical environment, with repercussions for agricultural production. This study has shown that the socio-economic characteristics of households influence their perceptions of climate change and the adoption of adaptation practices. The main adaptation strategies are the adoption of CES/DRS techniques, irrigation, ownership of manure pits and varietal adaptation. The adoption of an adaptation strategy by a farmer depends on his perception of climate change and its causes, its negative impacts on the biophysical environment and the means at his disposal to provide solutions. The adaptation and resilience capacities of farmers in Tillabéry, Kourthèye, Say, Tamou, Téra and Diagourou need to be strengthened through training in adaptation to climate change within farmers' groups. This helps to improve their perception of the phenomenon and helps them to better develop their adaptation strategies. Climate information is necessary to enable them to increase their agricultural production with a view to achieving food security. Providing them with agricultural equipment would strengthen their capacity to rehabilitate degraded land. In terms of future prospects, it is vital to innovate current agricultural practices or to seek new adaptation practices for producers. Endogenous seasonal climate forecasting indicators should be further promoted, as they enable farmers to predict how the rainy season will unfold and provide them with better guidance in implementing their strategies and practices for adapting to climate change.

REFERENCES

[1] Amani Michel Kouassi, Koffi Fernand Kouamé, Yao Blaise Koffi, Kouakou Bernard Dje, Jean Emmanuel Paturel and Sekouba Oulare, «Analyse de la variabilité climatique et de ses influences sur les régimes pluviométriques saisonniers en Afrique de l'Ouest: cas du bassin versant du N'zi (Bandama) en Côte d'Ivoire», Cybergeo: European Journal of Geography [Online], Environnement, Nature, Paysage, document 513, online 07 December 2010, accessed 03 June 2024.
URL: http://journals.openedition.org/cybergeo/23388
DOI: https://doi.org/10.4000/cybergeo.23388.

[2] Maurizio TIEPOLO, Climate risk and adaptation in the Tillabéri Region, Niger. Building capacity for analysis and assessment, 2016.

[3] KATIELLOU GAPTIA LAWAN, MAURIZIO BACCI and MOUSSA MOUHAIMINI, Caractérisation climatique de la région de Tillabéri, Rapport d'activité du Projet Adaptation Au changement climatique, prévention des catastrophes et Développement agricole pour la sécurité Alimentaire, Niamey-Niger, 36P, 2014.

[4] Tarchani and Tiepolo, Climate risk and adaptation in the Tillabéri region of Niger Pour renforcer les capacités d'analyse et d'évaluation, Études africaines - Série Géographie, l'Harmattan Paris, 282P, 2016.

[5] Zhang, X. ET F. Yang, RClimDex 1.0, User Manual. Climate Research Branch Environment, Downsview, Ontario, Canada, 23p, Expert Team on Climate Change Detection, Monitoring and Indices (ETCCDMI)
[online] URL: http://cccma.seos.uvic.ca/ETCCDMI/RClimDex/rclimdex.r, 2004.

[6] E. Servat, Jean-Emmanuel Paturel, Brou Kouame, Michel Travaglio, Mahaman Ouedraogo, Jean-François Boyer, Identification, characterisation and consequences of hydrological variability in West and Central Africa. Wafer Resources Variability in Africa during Ihe XXth Century (Proceedings of the Abidjan'98 Conference held at Abidjan, Cote d'lvoire, November 1998). IAHS Pub! no. 252,1998.

[7] Ozer, P., and Erpicum, M, « Méthodologie pour une meilleure représentation spatio-temporelle des fluctuations pluviométriques observées au Niger depuis 1905 ». Sècheresse, 6 (1), 103-108, 1995.

[8] Sale, A., D.P. Folefack, G.O. Olwoyere, N. LenahWati, W.V. Lendzemo and A. Wakponou, Climate change and determinants of organic manure adoption in the semi-arid Kibweri region of Kenya, International Journal of Biological and Chemical Sciences 8, 2, pp. 680-694, 2014.

[9] Loko, Y.L., A. Dansi, A.P. Agre, N. Akpa, I. Dossou-Aminon, P. Assogba, M. Dansi, K. Akpagana and A. Sanni, Perceptions paysannes et impacts des changements climatiques sur la production et la diversité variétale de l'igname dans la zone aride du Nord-ouest du Bénin, International Journal of Biological and Chemical Sciences, 7, 2, pp. 672-695, 2013.

[10] Da, C.E.D., H. Yacouba and S. Yonkeu, Unités morpho-pédologiques et gestion de la fertilité.