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Impact of Climate Change on Farms in the Commune of Savalou (Benin, West Africa)

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***Abstract*— *Climate change affects the development of agriculture in the Commune of Savalou. This research studies the impacts of climate change on farms in the Commune of Savalou. The methodological approach used consisted firstly of data collection, then their processing and finally the analysis of the results. The data processing was carried out using Khronostat, SPSS and ArcView software. The results show a climatic divergence in terms of monthly average rainfall totals. The decrease in rainfall intensity associated with the reduction in the number of rainy days is a factor in the decrease in rainfall amounts in the Commune of Savalou. Only the month of August recorded a 23% increase in monthly rainfall amounts during the 1980-2021 sub-series. In addition, non-compliance with social norms (40% of those interviewed), divine will (27%), deforestation (19%) and wildfires (14%) are the causes of climate change. These climate changes are characterized by the decline, late arrival and early end of rainfall, the rise in temperature and the high frequency of dry years. This recorded rainfall dynamic has consequences on farms. Climate change causes the reduction of sown areas ranging from 2 ha to 0.5 ha during the agricultural season. The loss of corn is 317.29 kg. Peanuts recorded a loss of less than 100 kg per farm and by the total sown area.*

I. INTRODUCTION

For several years, countries around the world have been concerned about the issue of climate change and its impacts. In terms of impacts, the countries that will suffer the most are the poorest. Indeed, these countries are already in a state of fragility that climate change will contribute to aggravating (SP Dovonou-Vinagbé, 2017, p. 4). Half of the world's population lives in rural areas and 75% of this population (2.5 billion) makes a living from agriculture. In countries with weak economies, agriculture employs more than 80% of the working population and contributes nearly 29.7% to GDP (World Bank, 2016, p. 21). However, agriculture is directly and indirectly affected by climate change, much more negatively in developing countries (RB Yaro, 2019, p. 12). African countries are experiencing the effects of climate change: floods, heavy rains, strong winds, drought, excessive heat, with observed impacts, biodiversity loss in the form of disappearance of animal and plant species, disruption of socioeconomic activities, in the form of temporary closure of health centers, schools or businesses following floods, or in the form of disruption of agricultural calendars due to increasingly late or early start of rainy seasons (YJP Degue Kakpo, 2016, p. 8). Africa is more vulnerable to climate variability and change, particularly because of some of its physical and socio-economic characteristics that predispose it to be disproportionately affected by the negative effects of climate variations (IPCC, 2007, p. 12). The major component of recent floods in Africa is believed to be the aggravation of vulnerability (EW Vissin, 2007, p. 32).

Benin experiences strong climatic variability characterized by a fluctuation in the period and duration of rainfall, a variation in annual rainfall, an increasingly hot climate, drought, soil degradation, unexpected floods, strong winds and the proliferation of diseases and pests (I. Yabi and F. Afouda, 2011, p. 3). Indeed, the agricultural production sector is characterized by the predominance of small farms and its vulnerability to climate variability and extreme climate events (C. Dodo, 2021, p.57). The increase in extreme climate events such as floods and droughts has remarkable consequences on family farming and results in the destruction of crops, disruption of crop cycles, disruption of the classic agricultural calendar and lower yields (NB Saré, 2019, p. 51). In the Commune of Savalou, farms are subject to various forms of vulnerability which can be political, technological, socio-economic and environmental. The objective of this research is to analyze the impacts of climate change on farms in the Commune of Savalou.

II. DATA AND METHODS

Several types of data were used in this research. These include climatic, soil, economic andpeople's perceptions of constraints to the development of agricultural holdings.Qualitative data obtained during socio-anthropological investigations made it possible to understand the population's perceptions of the impact of climate change in the Commune of Savalou.Several types of data were used in this research. These are:socio-anthropological and climatological data to analyze climate change indicators.

The sample size (N1) is determined by the probabilistic method using the Schwartz formula (1995): N1= or T (critical reduced deviation) is a coefficient depending on the confidence threshold, E the margin of error in percentage, P (in percentage) the proportion of agricultural households in the Commune of Savalou.$\frac{T^2 \times P(1-P)}{E^2}$ In this study, the confidence threshold used is 95%, allowing a large number of agricultural households to be reached. Thus, T is equal to 1.96 and the margin of error is equal to 5%. P is obtained after the ratio of the total number of agricultural households living in the Commune of Savalou, i.e. (18,792 agricultural households) by the total number of people in the Commune of Savalou, i.e. 144,814 people (INSAE, 2013, p. 12). Thus, the proportion P of agricultural households surveyed is equal to 13%. By replacing these values in the formula, a value of 173 agricultural households is obtained for N1 (sample size).

The creation of graphs, maps and the calculation of certain statistical values with parametric tests are respectively done using software such as: KronoStat 10.1, Excel 2010; ArcView 3.2.There are several methods for detecting breaks in time series (Pettitt test, Buishand statistic, Lee and Heghinian Bayesian procedure, Hubert segmentation). Pettitt tests detect a maximum of one break while Hubert segmentation can detect several if they exist in a time series of data. The application of these different tests is done using the KhronoStat 1.01 software. The stationarity break tests made it possible to have sub-periods and to calculate the rainfall and temperature variation rates. The Mann-Kendall Test, which is a non-parametric test, made it possible to measure the degree of significance of the trend and the stationarity breaks in the rainfall series. The Standardized Precipitation Index used for this research corresponds to the transformation of the precipitation time series into a standardized normal distribution with zero mean and unit standard deviation, also called z-distribution, normal distribution or Gaussian distribution. The standardized anomaly index is calculated using the formula: where Xi represents the annual average cumulative rainfall for year i; $\bar{X}$ and represent, respectively, the mean and standard deviation of the series considered. In this work, the negative indices were determined in relation to the Lamb rainfall index (. According to this index, a year is considered normal if its index is between -0.1 and +0.1. It is called wet if its index is greater than 0.1 and dry when its index is less than -0.1. The calculated trends were used to confirm the sequential trends (upward or downward) highlighted by the moving averages and breaks, to characterize wet or dry years. In addition, a drought occurs when the index is consecutively negative and its value reaches an intensity of -1 or less and ends when the index becomes positive. The creation of graphs, maps and the calculation of some statistical values with parametric tests are respectively done using software such as: Excel 2010, Khronostat and ArcView 3.2.IAS $= \frac{Xi-\bar{X}}{\sigma(X)} \sigma(X)$,

The Commune of Savalou is located between 7°31' and 8°15' north latitude and between 1°37' and 2°10' east longitude. It shares borders with the Communes of Dassa Zoumé and Glazoué to the east; Djidja to the south; Banté to the north; and the Republic of Togo to the west. Figure 1 shows the geographical and administrative location of the Commune of Savalou.

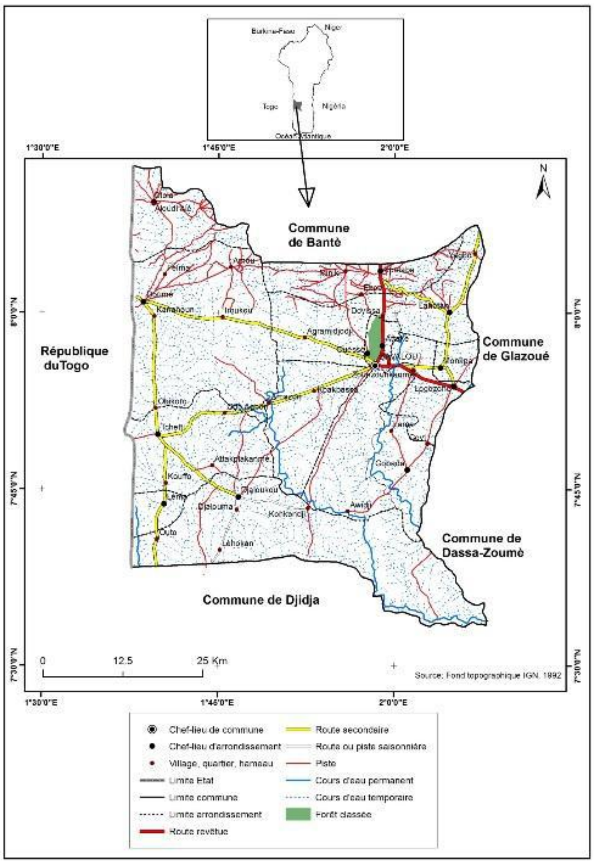


Fig.1: Geographical and administrative location of the Commune of Savalou

The Commune of Savalou extends over nearly 58 km from West to East and covers an area of 6,674 km2, or 2.37% of the national territory. The agricultural development of an environment is essentially based on a certain number of physical characteristics (SFNC Djessonou, 2016, p. 31). Thus, physical characteristics are part of the potential available to the Commune of Savalou.All of this work carried out has enabled the following results to be obtained.

III. RESULTS

3.1 Interannual dynamics of precipitation

This section covers interannual variability in precipitation and rainfall indices between 1951 and 2022.

3.1.1 Interannual variability of rainfall heights

Climate change leads to long-term changes in precipitation patterns and weather regimes. Figure 2 shows theinterannual variability of precipitation from 1951 to 2021.

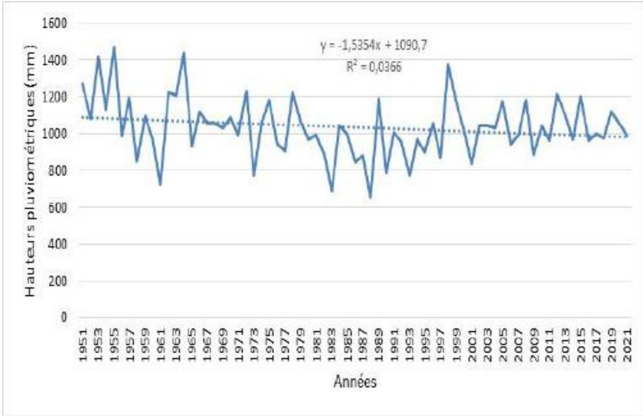


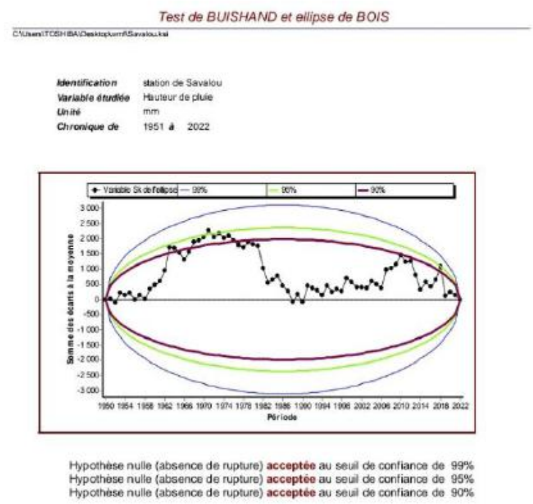
Fig.2:Interannual variability of precipitation from 1951 to 2021

Source :*Data processing, 2023*

Examining Figure 2 shows thatrainfall heights between 1951 and 2021 in the research area are 1021.67 mm per year.The year 1983 recorded the lowest rainfall (687.3 mm) and the year 1964 recorded the highest rainfall (1436.2 mm) over the period 1951 to 2021.To test the significance of the annual rainfall trend from 1951 to 2021, the Mann Kendall test was used at a 5% threshold. Thus,the downward trend in annual rainfall heights is not significant at the 5% threshold.The decrease in rainfall intensity associated with the reduction in the number of rainy days is a factor in the decrease in rainfall heights in the Commune of Savalou.

3.1.2 Analysis of the break in stationarity

To better analyze climate changes in the research area, a stationarity test was performed (Figure 3).



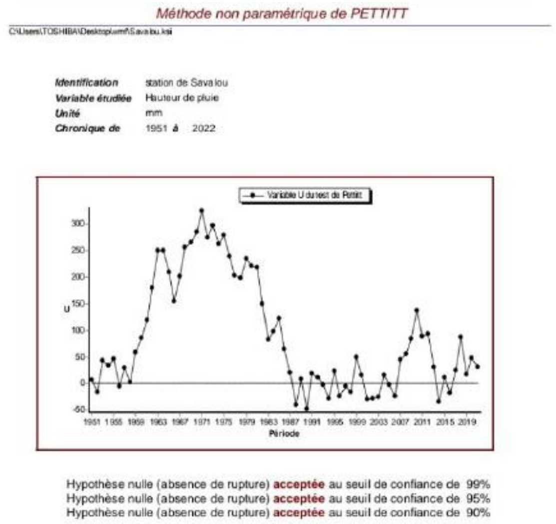


Fig.3:Results of the Pettitt and Buishand tests applied to the annual rainfall series from 1951 to 2022

***Source :**Data processing, 2023*

Figure 3 shows a break in stationarity between 1970 and 1980 in the rainfall series according to the Pettitt test. The null hypothesis, no break, was rejected at the 99% confidence level. Hubert's segmentation test indicates the beginning and end of the defined sub-series (Table I).

PaintingI: Hubert's segmentation test result

Defined sub-series		Average (mm)	Standard deviation (mm)
Beginning	END		
1951	1980	1108.26	181.94
1981	2022	1003.24	123.71

Scheffé test significance level: 1%

The test indicates a break in stationarity in 1980. This is justified by the difference between the means of these two (2) defined sub-series; which is in line with the results obtained by Moutier (2013) which show that the beginning of the 1970s to the end of the 1990s are marked by a decrease in rainfall heights in West Africa. From this test, two sub-series emerge: the sub-periods 1951-1980 and 1981-2022.

3.1.3 Inter-monthly variation in rainfall heights

The research area belongs to the domain of the Sudanian type tropical climate (S. Adam and M. Boko, 1993). Figure 4 presents the rainfall regime of the two sub-periods 1951-1980 and 1981-2021 in the Commune of Savalou.

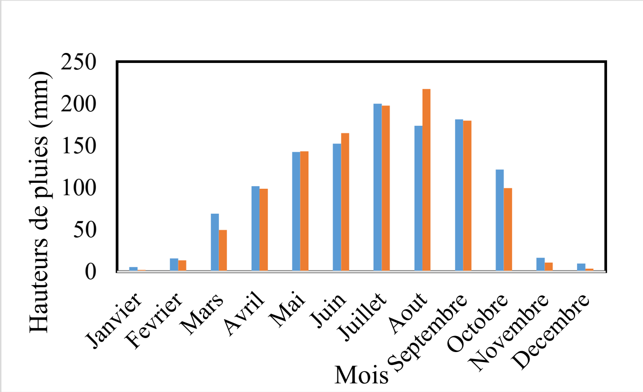


Fig.4:Rainfall regime of the two sub-periods 1951-1980 and 1981-2021 in the Commune of Savalou

***Source :**Data processing, 2023*

Examination of Figure 4 shows that the Commune of Savalou is characterized by: a dry season running from mid-October to mid-April, a total of six (6) months, and a rainy season which also lasts a little over six (6) months, extending from mid-April to mid-October. A climatic contrast is observed in terms of average monthly rainfall totals at the different stations. Indeed, the sub-period 1981-2021 is less humid compared to the sub-period 1951-1980. The peak is observed in the months of July (199 mm) and August (181 mm) for the sub-period 1951-1980 and respectively July (197 mm) and August (217 mm) for the sub-period 1981-2022. The month of July, which recorded the peak in the 1951-1980 sub-period, gave way to August in the 1981-2022 sub-period. Rainfall begins completely at the end of April today compared to the 1951-1980 sub-period. Similarly, October has become less rainy in the Commune of Savalou. Overall, the period from May to September is the wettest of the year in the research area. Table II shows the difference between 1910-2021 and 1951-1980.

PaintingII: Gapmonthly average rainfall between 1981-2021 and 1951-1980

	Jan	Feb	March	April	May	June	Jul.	Ao	Seven.	Oct.	Nov.	Dec.
Δ (mm)	-4	-9	- 22.9	-42.8	-13.6	- 31.7	- 15.6	24	- 81	-56.9	- 12	- 4

***Data source:**Weather-Benin, 2023*

Examination of the data in Table II shows that the rainy months experienced a very remarkable decrease in their rainfall height between 1951-1980 and 1981-2022. The observed deficits indicate that the period 1951-1980 is wetter than that from 1980 to 2021. Only the month of August recorded a 23% increase in monthly rainfall heights during the 1980-2021 sub-series. These valuesare significant at the 5% thresholdwith the Wilcoxon test which remains identical to that of Mann-Whitney (1947) according to Bertrand and Maumy (2011). Indeed, the results of the Wilcoxon signed test indicate a value of 0.012 for thep-value (two-tailed); a significant value at the 5% threshold.

3.1.4 Rainfall index

The rainfall indices calculated over the periods 1951-1981 and 1981-2021 made it possible to identify the years of extreme rainfall in the Commune of Savalou (figure 5).

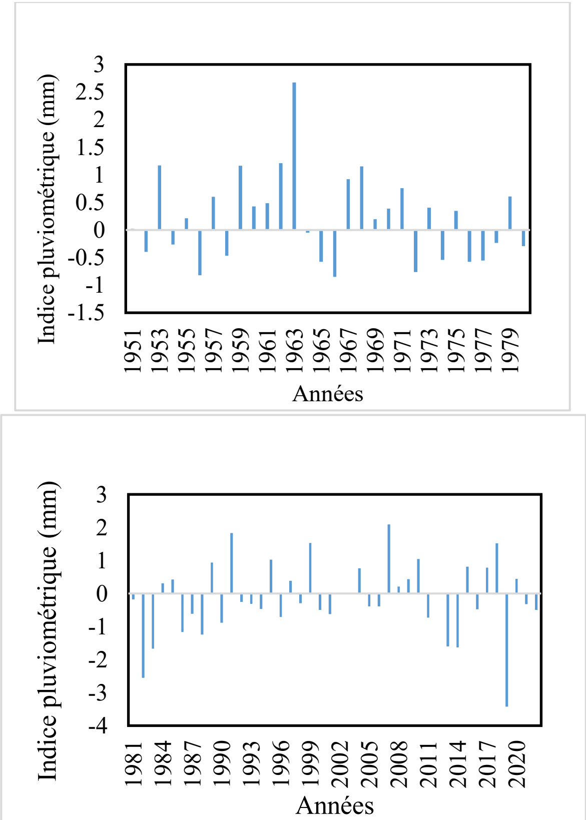


Fig.5:Rainfall indices between the period 1951 and 1980 and the period 1981 and 2021

Source :*Data processing, 2023*

The analysis of Figure 5 shows that the indices are between -2.52 and 2.58 over the study period (1951-2021). Deficit years are more observed during this phase, which indicates that the rainfall recession started in the 1970s. The second phase began with the rainfall height signal in 1981. Over the period 1981-2021, the indices are between -1.15 and 2.04. The second phase is marked by an irregular evolution of positive and negative anomalies. Over the years in the series, 53% of the years are dry and 47% of the years are wet. From 1981 to 1997, it is characterized by a high frequency of negative rainfall indices, and positive ones from 1998 to 2021. Overall, the frequency of deficit years is high between 1981 and 1998. In the same context of high occurrence of deficit years, there are more recent very rainy years between 1999 and 2010. This alternation of deficit and rainy years has repercussions on agricultural activities.Rainfall levels fell over the period 1981-2021 compared to the period 1951-1981 (-10.20%). This recorded rainfall dynamic has consequences on agricultural activities because rainfall is one of the important factors in agricultural production in the Commune of Savalou. In addition to these rainfall disturbances, there is the disruption of thermal parameters.

3.2 Thermometric indicators of climate change in the Commune of Savalou

Minimum and maximum temperatures increased between 1951 and 2021. Figure 6 shows the interannual evolution of maximum and minimum temperatures in the Commune of Savalou between 1951-2021.

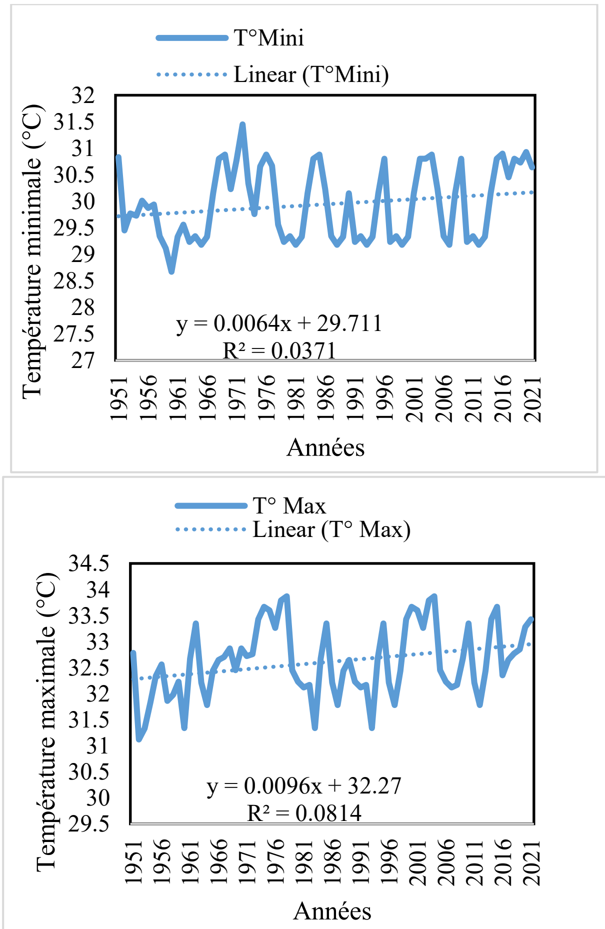


Fig.6:Interannual temperature changes in the research area between 1951 and 2021

Data source: Weather-Benin, July 2023

The analysis of Figure 6 shows that the minimum and maximum temperatures have increased during the period 1951-2021. The non-parametric test of Mann and Whitney (1947) is applied to these averages in order to see if the observed difference is significant or not (Table III).

PaintingIII: Mann-Whitney test result for comparison of means

	Tmin	Tmax
U	2,000	4,000
Hope	2,000	2,000
Variance (U)	1,333	1,667
p-value (two-tailed)	< 0.0001	0.167
α (alpha)	0.05	0.05
The p-value is calculated using an exact method		

Examination of the data in Table III shows that the increase in minimum temperatures is significant at the 5% threshold. The p-value calculated for maximum temperatures is greater than 0.05. This increase in maximum temperature is not significant. However, recent decades have seen an increase in minimum and maximum temperatures compared to their upward trend. Indeed, minimum and maximum temperatures have experienced a gradual evolution from 1951 to 2021. The growth is more pronounced at the minimum temperatures level with a growth rate of 0.5. The stationarity break tests were applied to this series of minimum and maximum temperatures. Indeed, breaks were detected using Pettitt's (1979) non-stationarity test or regime change. This demonstrates the clear trend towards warming of the climate with potential impacts on the crops grown. This warming affects all seasons of the year.The rise in temperatures due to strong solar radiation, which is deplored by local populations, results in increasingly oppressive heat in homes and also affects agricultural activities.. The IPCC (2007, p.32) predicts theincreasing number of episodes of extreme heat and heavy precipitation on a global scale. He believes there will be an increaseprecipitation increases by 1 to 2% for each degree of temperature increase. In the Commune of Savalou, the highest temperatureswill increase as much as the frequency and intensity of extreme weather events.

3.3 Endogenous perceptions of climate change manifestations

Populations have been perceiving the effects of climate change in recent years. Over the past thirty years, farmers have noted a widespread disruption of the established order, sometimes with the disappearance of some of them (Figure 7).

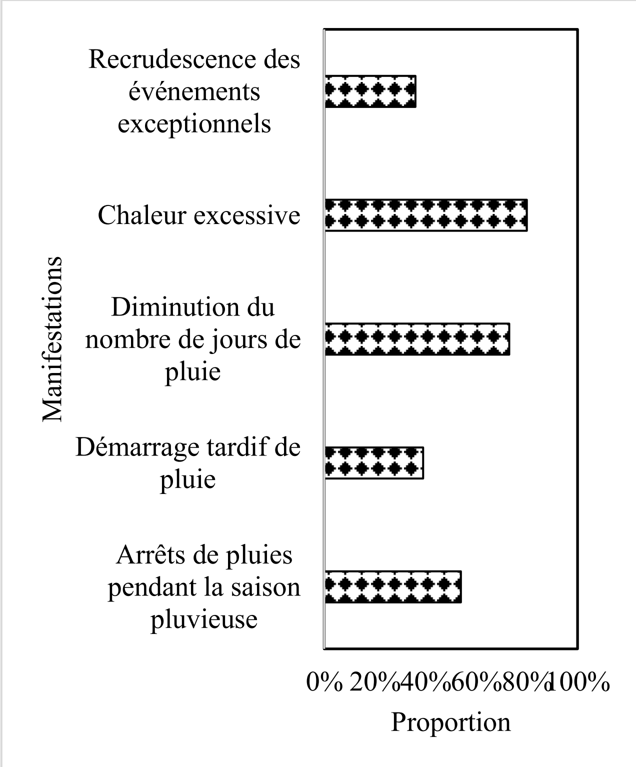


Fig.7:Climate change demonstration in the Commune of Savalou

***Source :**Processing of Météo-Benin data, 2023*

Analysis of Figure 7 shows thatFarmers have noticed a change in key climate parameters and also in the variables determining the agricultural season. The decline in annual rainfall totals, the spatio-temporal distribution, the shift in sowing dates which has led to the modification of the crop calendar, the late start and early end as well as the shortening of the length of the rainy season are the various socio-anthropological elements perceived by the populations as indicators of climate change in their living environment. Also, the occurrence of certain extreme climatic events such as droughts (in all its forms), years of excess rainfall, increased heat and strong winds constitute indications of a global change in the climate.In addition, strong winds are recurrent and are observed at the beginning of each rainy season.

3.4 Impacts of climate change on the structure and operation of farms in the Commune of Savalou

This section addresses the impacts of floods and droughts on the operation of farms.

3.4.1 Impacts of flooding on the structure and operation of farms

In the Commune of Savalou, climate change is shortening farming seasons. Figure 8 shows the effects of flooding on farms in the Commune of Savalou.

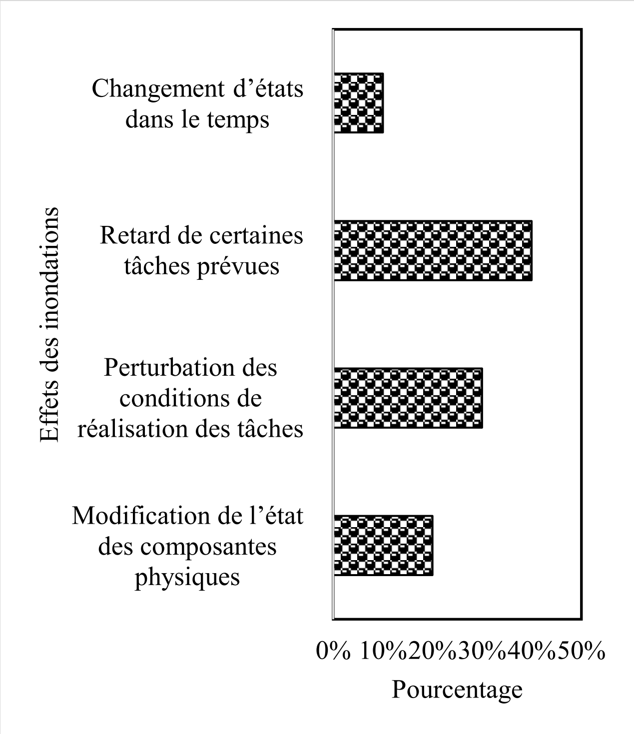


Fig.8:Effects of flooding on farms in the Commune of Savalou

***Source**: Field surveys, July 2023*

Analysis of Figure 8 shows that40% of farmers surveyed agree that floodingdelay the weeding and fertilization work planned in the technical itinerary and modify the conditions for carrying out tasks on plots that have been submerged. Similarly, 31% report thatfloodsdisrupt the conditions for carrying out tasks on non-flooded plots during and after submersion. In addition, 19% of the producers interviewed announced that theclimate risksmodify the state of the physical components of the earth (mineral, organic and gaseous) and 10% report that theclimate risksconstrain operators to a chronology of state changes over time. Thus, theclimate risksnegatively affect the structure and operation of agricultural holdings in the Commune of Savalou.

3.4.2 *Impacts of climate change on the financial performance of family farms in the Commune of Savalou*

The impacts of climate change also affect production activities and livelihoods. Indeed, the effects of climate change create financial insecurity. Farmers are no longer able to save. The cultivated area of these farmers becomes very small. In addition,climate changecause the reduction of sown areas ranging from 2 ha to 0.5 ha during the agricultural season. Farmers are unable to sow all the areas. This situation is detrimental to yields. The lean period is particularly feared by these farmers who are regularly affected byclimate changeThe financial situation of these farmers is becoming precarious. For 88% of the farmers interviewed, climate change increases expenses by 45%. This affects debt repayment.Farms are forced to make adjustments through the increase in the prices of agricultural products. Similarly, 75% of farms present a high financial risk.As a result, farms are much less productive and profitable than expected.

3.4.3 *Impacts of flooding on farmers in the Commune of Savalou*

In the Commune of Savalou, the life offarmersis affected by excessive rainfall causing flooding, which disrupts the social fabric. Workers in poor health are less able to work. This situation leads to a deterioration in productivity and income, perpetuates a downward spiral towards poor health and poverty, and jeopardizes food security and economic development for a larger part of the population (68% of those interviewed). There is also the proliferation of waterborne diseases and loss of human life.The impact on household human capital is significant. Climate risks have caused children to drop out of school over the past five (5) years for financial reasons (34% of farmers surveyed). Hundreds of hectares of crops, granaries, livestock and poultry have been destroyed by flood waters, jeopardizing food supplies and increasing the risk of disease (malaria and other waterborne diseases due to contaminated water).

3.4.4 *Impacts of droughts on socio-economic elements*

In the Commune of Savalou, the effects of droughts impact the economy.Indeed, droughts are a stressful phenomenon for farmers (78% of those interviewed). This phenomenon is one of the elements that seriously confuse agricultural forecasts both at the level of agricultural campaigns initiated by institutions (ATDA, DDAEP, etc.) and at the level of farmers. It has often manifested itself with other climatic factors (excessive heat, strong winds, etc.) likely to increase the severity of the phenomenon. According to 72% of those interviewed, when the effects of climate change persist, a loss of production could be recorded during the cassava and corn harvest as the soil will become hard. The direct consequences of drought are the deterioration of yield followed by the loss of crops. Table IV presents the average losses per sown area in the Commune of Savalou.

PaintingIV: Average losses per area sown for each crop

	Corn (ha)	Corn loss	Peanut (ha)	Peanut loss	Cowpea (ha)	Cowpea loss
Valid	143	143	143	143	143	143
Avg. 1	**1,612**	**198.03**	**1.18**	**84.5**	**0.98**	**104.19**
Avg. 2	-	**319.22**	**-**	**99.64**	**-**	**102.28**
Sum	580.3	114,920	391.5	33,080	321.0	33,445

*estimated in kg;

Average 1 = Total loss/total area ratio (Kg/ha);

Average 2 = Total loss ratio/number of farms (Kg/Farm)

Data source*: field surveys, July 2023*

A review of the data in Table IV shows that maize losses amounted to 317.29 kg. Peanuts recorded a loss of less than 100 kg per farm and per total sown area. Yield losses represent a deficiency for farmers in the Commune of Savalou. Thus, the level of vulnerability of maize to climate change is very high.

3.4.5 Impacts of droughts on agricultural populations

The occurrence of droughts in the research area affects populations. Figure 9 shows the impacts of droughts on farms in the Commune of Savalou.

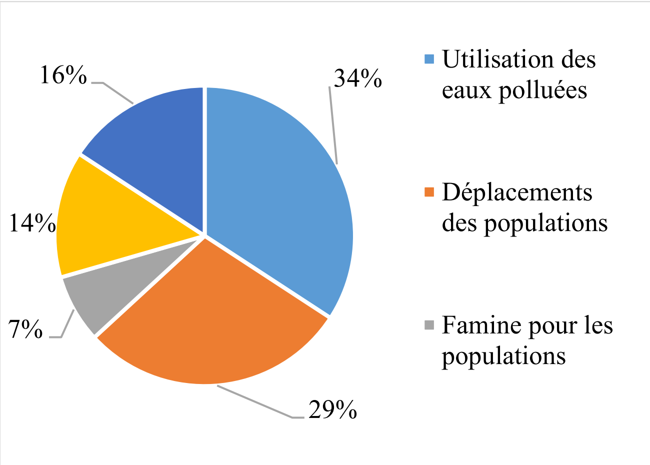


Fig.9:Impacts of droughts on agricultural populations in the Commune of Savalou

Data source:*Field surveys, 2023*

The analysis of Figure 9 shows that populations lack drinking water and are forced to use polluted water (34% of respondents) which is the source of many diseases such as cholera, chronic diarrhea and typhoid fever during droughts. For 29% of respondents, population displacement due to the effects of droughts leads to social breakdown, the disappearance of certain farming techniques and especially the proliferation of diseases such as cholera and meningitis.The stabilization of agricultural incomes is not enough to allow households to effectively meet household expenses. Indeed, this food situation does not allow households to adequately vary their diet. It is observedfamine for the population (14% of respondents), malnutrition (26%) for the most vulnerable groups (children, pregnant women and the elderly) and conflicts during periods of drought and high temperatures (69% of respondents).

3.5 Discussion

In the Commune of Savalou, rainfall levels decreased over the period 1981-2022 compared to the period 1951-1980 (-10.20%).The minimum and maximum temperatures have undergone a gradual evolution from 1951 to 2021. The recurrence of climatic events,in recent years, constitutes one of the main factors that affects both theproduction capacity of farmers in the research sector.In the research area, farmers perceive climate variability through the decline in annual rainfall totals, the spatial and temporal distribution, the shift in sowing dates which has led to the modification of the crop calendar, the late start and early end of their cultivation as well as the shortening of the length of the rainy season.Smallholder farmers (less than 1 ha) and medium-sized farmers (1 ha to 2 ha) are vulnerable because the areas they farm are relatively small, so that a loss of harvests or crops linked to poor weather conditions weakens their food security. This result is consistent with those ofMBD Ahouangan et al. (2013) and O. Koudamiloro (2017) who reported that theBenin is subject to increasingly marked rainfall variability resulting from climate change. In September 2010, the country experienced one of the most disastrous floods in its history, resulting in inestimable material damage and thousands of homeless people.

IV. CONCLUSION

At the end of this research, rainfall heights decreased over the period 1981-2022 compared to the period 1951-1980 (-10.20%) in the Commune of Savalou.The minimum and maximum temperatures have undergone a gradual evolution from 1951 to 2021. The recurrence of climatic events,in recent years, constitutes one of the main factors that affects both theproduction capacity of farmers in the research sector.In the research area, farmers perceive climate change through the decrease in annual rainfall totals, the spatial and temporal distribution, the shift in sowing dates which has led to the modification of the crop calendar, the late start and early end of their cultivation as well as the shortening of the length of the rainy season. The amount of cowpea losses varies depending on the type of crop. The effects of climate change are creating financial insecurity. Farmers are no longer able to save.

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