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Impacts of Climate Disturbances on Crop Productivity in Santchou, Western Cameroon

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Abstract

The problem of agricultural production in the face of climate fluctuations in the Municipality of Santchou over the last few decades, is acutely posed. This work focuses on the impacts of climate disturbances on agriculture in the Municipality of Santchou in western Cameroon. A total of 309 randomly sampled households were surveyed using a questionnaire and 17 community leaders were interviewed. Crop growth and agricultural systems were observed and described directly on the field. Crop yields data for year 1971 to 2016 were obtained from the Santchou District Delegation of Agriculture and Rural Development (DAADR). The results indicate that increased rainfall combined with a drastic decrease in the number of rainy days caused flooding, leading to tubers rot and early harvests. There is also a proliferation of pests and parasites such as fall armyworms and *Striga hermonthica*, especially on maize, leading to a drop in yields of about 25% to 30% and a significant increase in the prices of products on the local market. The price per kilogram of maize, cassava, new cocoyam and sweet potato increasd respectively from 95.67 francs, 64.17 francs, 82.83 francs and 83.50 francs in 2000 to 437.5 francs, 95.83 francs, 187.17 francs and 117.67 francs in 2010. In this context, it appears imperative to develop more appropriate adaptation strategies in order to reduce famers' vulnerability to climate change.

Subject Areas

Agricultural Science

Keywords

Climate Disturbances, Decline in Yields, Food Crops, Rural Population, Vulnerability

1. Introduction

Climate change is a global issue, but each country has its vulnerability rating [1]. Agriculture is a vital economic sector in sub-Saharan African nations, and increasing and diversifying it continues to be a major goal [2]. Over 950 million people, or roughly 13% of the world's population, live in Sub-Saharan Africa. By 2050, it is anticipated that this population will have grown to over 22%, or 2.1 billion people [3]. For many years, undernourishment and malnutrition have been problems [4]. The proportion of undernourished people is still largest in developing nations, notwithstanding a decline from 33% in 1990-1992 to 23% in 2014-2016 [5].

Cameroon and other African countries are most vulnerable due to their high dependence on agricultural income [6]. The impact of climatic disturbances on agriculture varies according to the type of cover and climatic conditions associated with the growing conditions of cultivated plants [7]. But the general trend is clear: while temperate regions can expect positive and sometimes negative effects on yield, climatic variations will almost always have negative effects in tropical areas [8].

The economy of Cameroon is heavily dependent on agriculture [9]. It accounts for more than 40% of the nation's overall exports and 30% of its GDP [10]. With 62% of the working population employed, the agriculture sector is the largest employer, according to the Minister of Agriculture and Rural Development. However, the country's five agro-ecological zones, the Sudano-Sahelian zone, high Guinean Savannas, high plateaus of the West, monomodal rainfall tropical rainforest, and bimodal rainfall tropical rainforest have different pedoclimatic conditions from north to south, which leads to a rich and varied agricultural potential [9]. This is clearly evident from the large number of studies devoted over the past two decades to predict the impact of global warming on agriculture on a global scale ([11]-[14]). Cameroon is no exception, the country already faces an abnormal recurrence of extreme weather phenomena such as strong winds, high temperatures or heavy rain that endanger human communities, the ecosystems and services they provide. Several authors, including [15] and [16], have shown the strong correlation between crop yield and rainfall during the main agricultural season in West Africa, particularly in Benin.

The agricultural implications of climate vulnerability have been extensively addressed in studies by [17] and [16]. The synthesis of their analysis highlights the high variability of rainfall and the different seasonal contrasts characterizing the climate that determine the evolution of agricultural yields.

Such a climate-dependent context of agriculture will be aggravated by climate change in several agricultural basins of tropical Africa like that of Santchou in western Cameroon. This compromising situation highlights the issue of agricultural vulnerability and food insecurity, which is a difficult problem in the peasant world, increasingly recurrent. The objective of the present study is to assess the impact of climate disturbances on agricultural production in the Municipality of Satchou.

2. Methodology

2.1. Study Area

Figure 1 shows the location of the study area, which is an integral part of the Mbo plain, located in western region of Cameroon and administratively belonging to the Menoua division. It is circumscribed between latitude 5˚05' and 5˚25'N and longitude 9˚50' and 10˚10'E, and its altitude is between 700 and 1500 meters. The climate is a guinean equatorial type which is characterized by a long rainy season of eight months (from March to October) and a short dry season (from October to March), Santchou being subject to rainfall between 17- and 300-mm. September being the wettest and January the least. Temperatures range from 21.1˚C to 23.9˚C with an average of 22.5˚C, meaning that temperatures are generally cool and below 25˚C. Santchou is an agricultural basin with high production of maize (*Zea mays*), cassava (*Manihot esculenta*), sweet potato (*Ipomoea batatas*) and new cocoyam (*Xanthosoma sagittifolium Schott*); more than 80 per cent of the active people are farmers. The vegetation is composed of the herbaceous layer, the shrub layer and the tree layer.

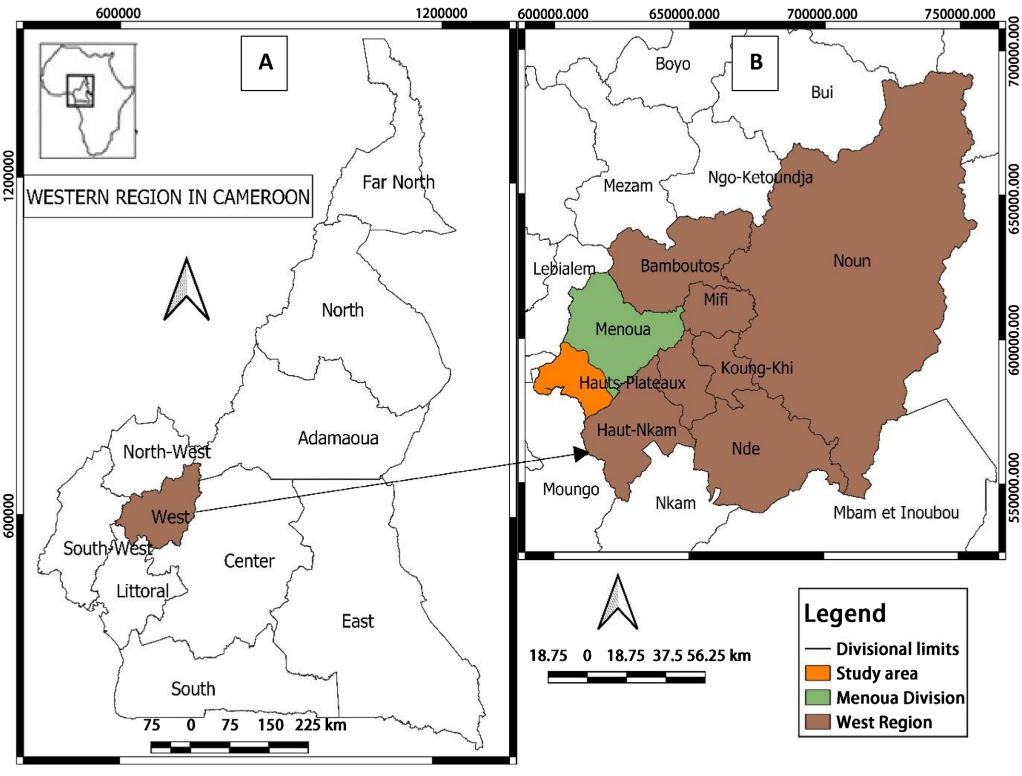

Figure 1. Location map of the study area: (A) = location of Cameroon in Africa and the Western Region in Cameroon; (B) = location of the study area in the Western Region.

2.2. Data Collection

Several types of data were used for this study, these are climatic data (rainfall and temperatures) collected at the Santchou District Delegation of Agriculture and Rural Development, supplemented with those from the archives of the former SODERIM (Société de Développement de la Riziculture de la Menoua) on the period 1971-2016.

Statistics on the evolution of prices for maize, cassava, sweet potato and new cocoyam for the period from 2000-2010 were collected from the website of the Ministry of Agriculture and Rural Development of Cameroon.

The fieldwork provided mainly qualitative information. In total, 309 agricultural households (located in 11 villages grouped into 5 agricultural posts in the study area (See Table 1) were surveyed in the locality, based on random sampling. Individual interviews with farmers were coupled with interviews with 17 resource persons from the study area (the District Delegate for Agriculture and Rural Development, the 5 heads of agricultural posts, the heads of the 11 villages). Direct observations in the fields supplemented the information collected from surveys and interviews. The main information collected concerned the impact of climatic disturbances on the production of the main food crops in the study area, such as maize (*Zea mays*), cassava (*Manihot esculenta*), sweet potato (*Ipomoea batatas*) and new cocoyam (*Xanthosoma sagittifolium Schott*). All the data collected were analyzed using the xlstat 2014 statistical software.

Table 1. Distribution of respondents by agricultural post and by village.

Agricultural posts	Villages	Desired household size for the survey per village	Household size surveyed per village	Percentage of households surveyed per village (%)
Ngwatta	Ngwatta	45	38	84.44
	Fongwang	40	31	77.50
	Tawoum	35	29	82.86
	Fombap	40	35	87.50
	Fongotaffo	35	30	85.71
	Bamia	35	27	77.14
Balé	Balé	20	17	85.00
Fiala	Fiala	34	28	82.35
Fondonera	Fondonera	34	23	67.65
	Nzong	34	22	64.70
Singaim	Singaim	35	29	82.86
Total		**387**	**309**	**79.84**

To determine the size of agricultural households to be surveyed in each preselected village, a multi-step process was followed. Initially, the amounts of agricultural households per village were collected from the heads of agricultural posts. The following Schwartz formula was used to determine the number of agricultural households to be surveyed throughout the Municipality.

$$n = t^2 * p * (1 - p) / m^2$$

With: n = size of household to be surveyed; t = confidence level which is 1.96 at 95 per cent; p = proportion of the population with the characteristic (82.54 per cent); and m = the margin of error which is generally 5 per cent.

This resulted in a total of 226 households out of 3868 or about 6 per cent; but to maximize the diversification of information and limit the redundancy of responses, which is often possible in the case of significant homogeneity of different households, this percentage has been revised upwards (10 per cent) (See **Table 1**).

Due to the absence of some heads of households, unavailability and sometimes very dubious (inconsistent) responses, the desired number of households was only partially achieved, which means 64 to 87 per cent in the best case per village.

3. Results

3.1. Climate Disturbances Noted in Santchou

For this study, only the annual change of temperature and precipitation were considered.

3.1.1. Interannual Variation in the Average Temperatures

The rise in temperature is the first persuasive factor of climate change in the study area. The increase in recorded temperatures from 1971 to 2016 marked the collective memory of local populations. Daily temperature data was collected and then aggregated to annual data.

The data show that the average annual temperature in the study area from 1971 to 2016 ranged from a minimum of 21.65˚C (1981) to a maximum of 24˚C (1973). The difference between the minimum and the maximum is 2.35˚C. This temperature difference reflects the variability of temperatures between years. The overall average temperature is 22.56˚C with a standard deviation of ±0.51. The trend line is shown in **Figure 2(A)**.

The Pettitt test applied to this time series (1971-2016), detects a rupture at p = 0.0056 in 1991, thus a significant rupture [18]. The mean of this temperature before rupture in this test is 22.31˚C and that after is 22.78˚C, therefore a difference of 0.47˚C; thus, an increase in the annual average temperature of 0.017˚C. This break is confirmed by the Buishand test with a post-point probability of p = 0.0039 in the same year, thus a significant increase (**Figure 2(B)**).

Figure 2 shows that between 1986 and 1998, 2009 and 2016, average temperatures increased significantly (from 21.84 to 23.29˚C between 1986 and 1998 and from 22.15 to 22.94 between 2007 and 2016). Between 1998 and 2007, average temperatures decreased with slight fluctuations. The trend line generally shows an increase in average temperatures over the last four decades, confirming the elderly' responses: "It is getting warmer and warmer, with more sunny days". For older producers (over 45 years), it had been warm for three decades, even in the rainy season with a little sunshine, it is always warm. With the persistence of increasingly higher temperatures recorded, it is no longer only crops that suffer, the growth of domestic animals (goats, pigs and poultry in particular) is also hindered.

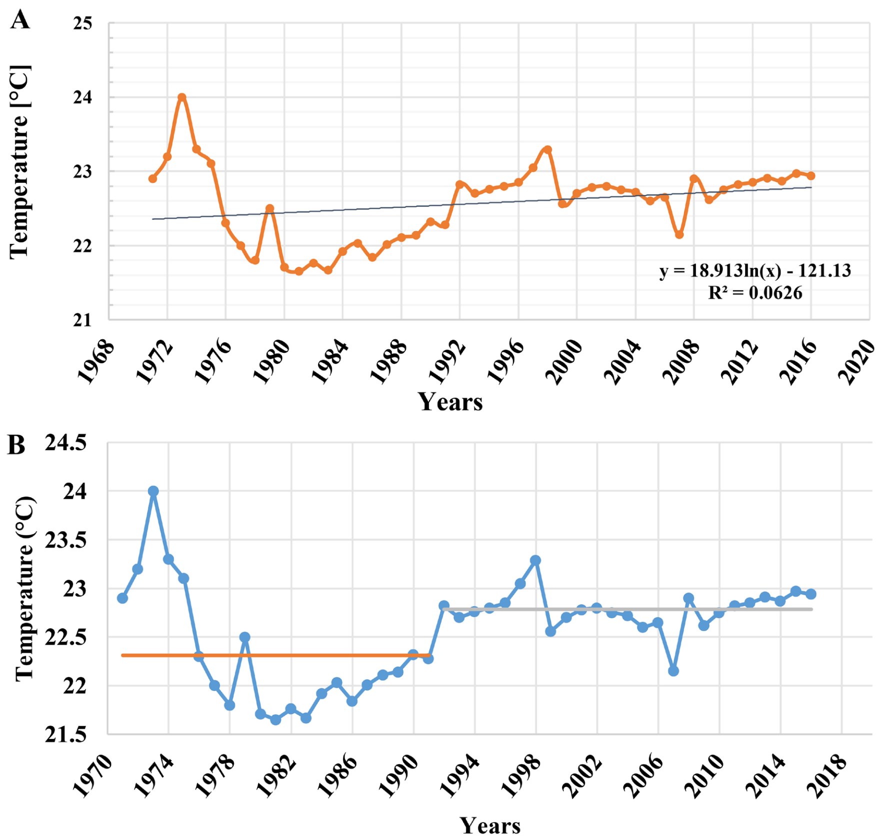

Figure 2. Annual change in temperatures (A) and ruptures (B) in Santchou from 1971 to 2016.

3.1.2. Interannual Variation in Precipitation

Figure 3(A) shows significant inter-annual variability in rainfall over the past four decades, with the lowest annual average recorded in 1980 (1318.80 mm) and the highest annual average recorded in 2015 (3121.3 mm), with a difference of 1802.5 mm, a mean of 1708.9 mm with a standard deviation of ±289.8811 mm. This variability agrees with the testimony of the chief of the Fombap village according to whom: "we no longer understand anything about the rains these days, one year it may rain a lot, but the following year, it only rains a little. This is a phenomenon that was not known about thirty years ago".

To determine the years of rainfall ruptures, the application of the Pettitt test (1979) to the 1971-2016 series detects an initial rupture ($p = 0.0042$), which means that the series is not homogeneous at an interval of 99% confidence around the p-value: (0.0025; 0.0059) (Figure 3(B)). Buishand's test (1982) confirms this inhomogeneity ($p = 0.0074$) in the precipitation totals at a 99% confidence interval around the p-value: (0.0052; 0.0096).

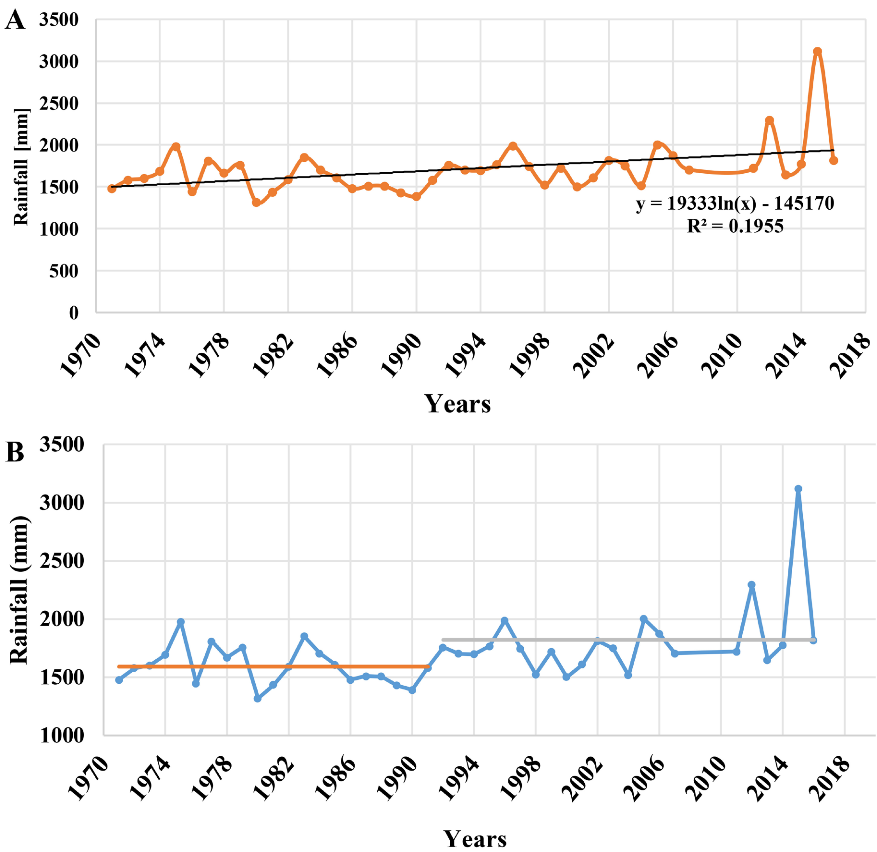

Figure 3. Evolution of annual rainfall (A) and ruptures (B) from 1971 to 2016 in the Municipality of Santchou.

Given the linear trend, annual precipitation is increasing (**Figure 3(A)**). To see if this trend of increasing precipitation is significant, the Mann-Kendall and Buishand trend tests were applied to all data series. This method has already been applied in a similar study by [19] in West Africa, to detect a significant trend change in the rainfall time series. In this study, the trend of the annual average total rainfall is significant with the Buishand test at a significance level of at least 95 per cent. A conclusion can therefore be drawn on an upward rainfall trend over time.

3.2. Consequence of Climate Disturbance on Cropping Systems and Yields

The consequences of climate disturbances on different crops are manifested according to the climate factor considered. Since these events differ significantly between seasons in the study area, the consequences are more severe during rainy seasons. The effects of rain delays/rupture, excessive rains and high temperatures, characteristic of climate change in the study area and their consequences are given for the main crops which are maize (*Zea mays*), cassava (*Manihot esculenta*), sweet potato (*Ipomoea batatas*) and new cocoyam (*Xanthosoma sagittifolium*).

The food needs of the Cameroonian population have evolved constantly with a growing demography, and yet production is facing enormous problems due to climatic disturbances. Indeed, with heavy rains and given the morphology of the study area (plain), agricultural activities are slowed down. According to the 20215 reports of the Santchou district delegation of agriculture and rural development, flooding causes early harvests of crops grown in the lowlands, such as cassava, corn, sweet potato, new cocoyam, okra, pepper. The roots of the plants rot when they are swallowed up by water. Figure 4 shows the evolution of yields (in kg/ha) over the past 30 years, as reported by more than 74 per cent of the farmers surveyed (Note that the decrease in agricultural yields could be directly linked to factors such as pest infestation, poor agricultural practices, less and less fertile soils, the proliferation of parasitic plants etc...).

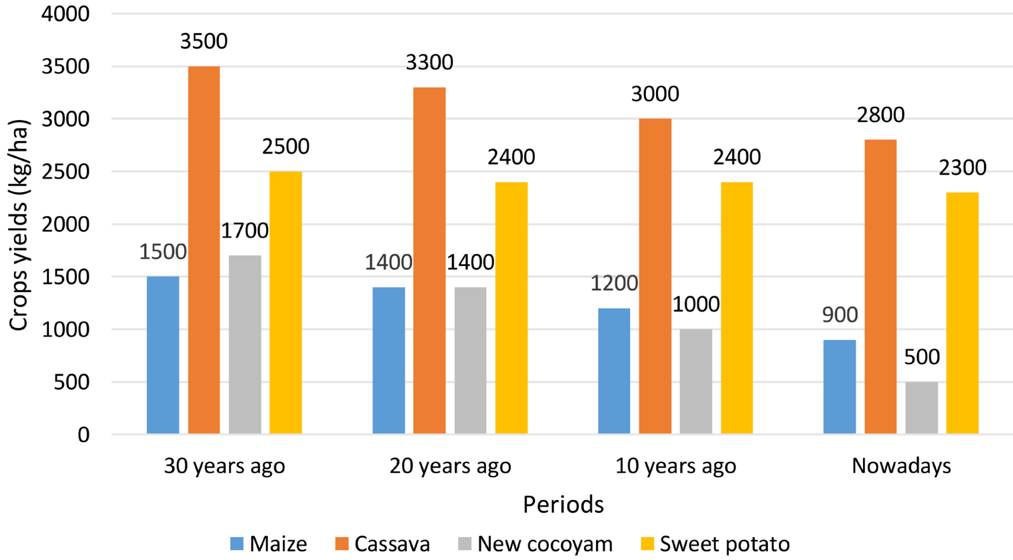

Figure 4. Evolution of yields (in kg/ha) and on the same plots of these crops from around thirty years to the present day.

From Figure 4, it appears that the new cocoyam is the crop with greatest yields loss, as it can withstand less adverse environmental conditions. In sweet potatoes, the decrease is not significant (sweet potato seems to be more resistant to weather disturbances than corn, which is why yields are almost stable).

3.2.1. Consequences on Maize Cultivation

Maize is grown on the two crop cycles practiced by farmers in the Commune of Santchou in western Cameroon. It is grown for both self-consumption and sale. But with the current climate disturbances, maize cultivation is being severely affected, resulting in crop losses and significant yield reductions.

In fact, maize is a water-intensive crop that is particularly sensitive to drought during emergence, but especially during flowering which is the most critical period of its cycle, and temperatures must be high and regular.

However, excess water is detrimental to growth as it causes suffocation or even root rot. It appears that maize is a crop that does not tolerate rain delays/breaks and excessive rainfall. Delays/breaks of rain at the start of the rainy season mean that sowing and re-sowing operations are spread over unusual periods. These operations continue until the end of May for some farmers instead of being carried out in mid-April as before. The disturbance results in exposure of maize throughout its cycle during the rainy season to frequent periods of water and thermal stress. During the off-season harvest, the situation is more disastrous, given its short duration, so that prolonged sowing and re-sowing operations project the closure of the crop cycle outside the rainy period.

In addition, all producers interviewed complained about the proliferation of caterpillars and stem borers, which are increasingly recurrent (Figure 5(B) and Figure 5(C)), as well as *Striga hermonthica* (Figure 5(A)). Losses can reach 40% during the rainy season and 50% in the off-season. The Chief of the Fombap village farmer, on the other hand, testifies the effects of the climatic disturbances by saying: "For a while, with the excess of rainfall over a short period of time, even the doses of fertilizers and pesticides that we put on the crops no longer have any effect. With the arrival of heavy rains several weeks late, we rarely bring home undamaged corn cobs. Nowadays, if I harvest 60 bags of maize, it is because God is great, whereas I often harvested up to 100 bags".

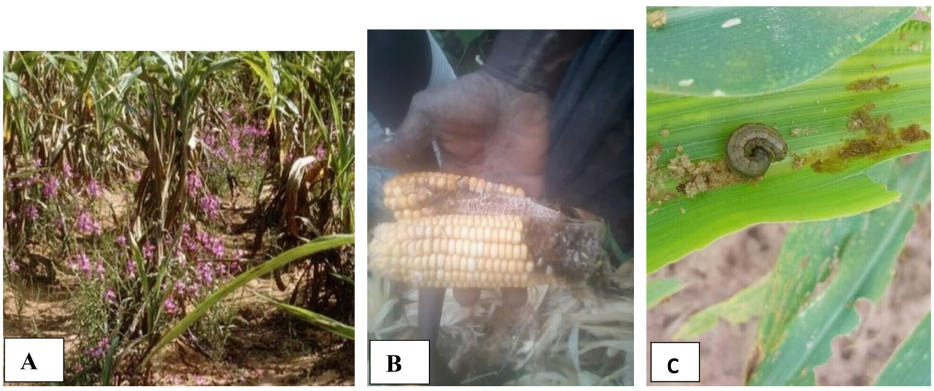

Figure 5. Consequences of climatic disturbances on maize ((A) = Proliferation of *Striga hermonthica* in maize plantation, (B) = Corn cob attacked by diseases, (C) = Corn leaf gnawed by the fall armyworm).

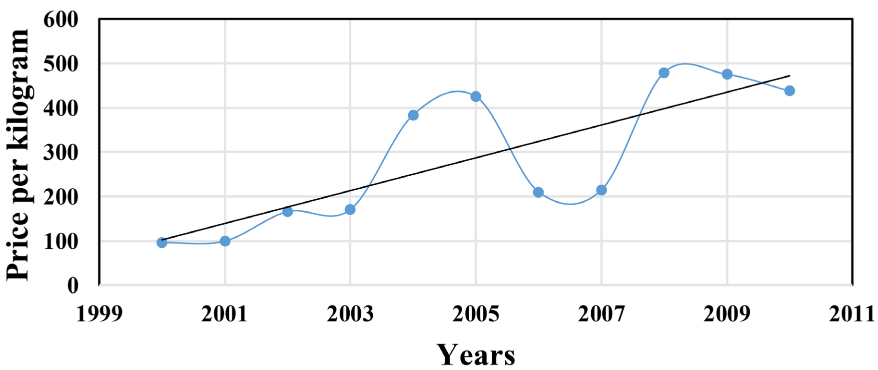

Figure 6. Annual evolution of the price (in FCFA/kg) of maize in the market of Western Cameroon during 2000 to 2010.

The indirect consequence is the increase in the price on the market. Figure 6 shows the evolution of the price (FCFA/kg) of maize on the west Cameroonian market from 2000 to 2010. The trend is towards a sharp rise in the price from 95.67 francs in 2000 to 437.5 francs in 2010, with a spread of 341.83 francs, an average of 286.82 francs for a standard deviation of ±153.17 francs.

3.2.2. Consequences on the Cultivation of Tubers (Cassava, New Cocoyam and Sweet Potato)

According to the comments from 93 per cent of producers, crop infestation is higher today than it was in the past (20 years ago). Indeed, with climatic disturbances, we notice in these tubers a lot of leaves. According to the report of the Santchou District Delegate of Agriculture, flooding (Figure 7(A) and Figure 7(B)) causes early harvests of crops grown in the lowlands such as cassava, corn, sweet potato, new cocoyam, okra, pepper… The roots of the plants rot. As a result, yields drop sharply. Some crops like the Ibo cocoyam have completely disappeared. In the case of prolonged droughts, crops will be subject to water stress.

Figure 7. Consequences of climatic disturbances on crops ((A) Sweet potato plantation submerged by water; (B) Cassava plantation submerged by water, dying leaves are observable; (C) New cocoyam plants attacked by leaf rot after flooding).

With lower yields combined with strong demand due to population growth, prices will explode in the market. Figures 8(A)-(C) respectively show price trends (FCFA/kg) of sweet potato, cassava and new cocoyam on the West Cameroonian market from 2000 to 2010. Based on the analysis, it appears that the price has increased regardless of crops.

The sweet potato rose from 83.50 francs in 2000 to 117.67 francs in 2010, with a difference of 34.17 francs; for an average of 104.06 francs and a standard deviation of ±27.85 francs (Figure 8(A)).

Cassava rose from 64.17 francs in 2000 to 160 francs in 2010, with a difference of 95.83 francs, an average of 91.58 francs and a standard deviation of ±32.01 francs (Figure 8(B)).

The new cocoyam rose from 82.83 francs in 2000 to 270 francs in 2010, a difference of 187.17 francs, with an average of 189.48 francs and a standard deviation of ±84.63 francs (Figure 8(C)).

Of all these tubers, the macabo is the one whose price has increased the most, confirming that this tuber was struck by a disease called "new cocoyam disease".

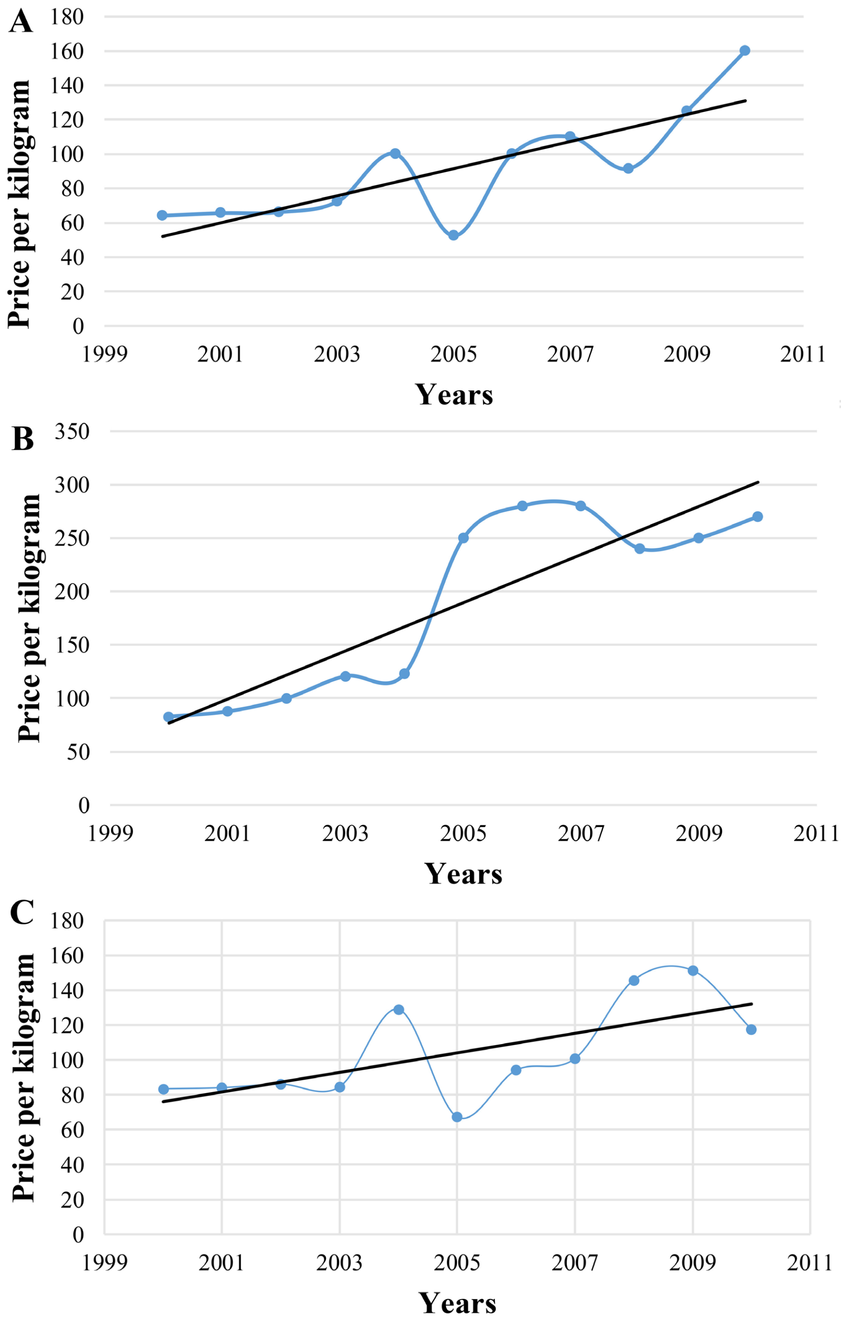

Figure 8. Annual evolution of prices (in FCFA/kg): (A) = of sweet potato; (B) = of new cocoyam; (C) = of casava.

4. Discussion

4.1. Climate Disturbances Noted in Santchou

The impacts of climate change are already severely affecting the environment, natural resources and the people who depend on them, including the poorest and most vulnerable communities ([1] [20]), because of their limited adaptive capacities and high dependence on climate-sensitive resources such as water resources and agricultural production systems. There is also a trend in the municipality of

Santchou towards significant increase in rainfall over the last four (04) decades with a saw tooth sequence. [21] found that the rainfall in Fonakeukeu, western Cameroon, had also increased. On the other hand, [22]-[25] instead found that the rainfall is gradually decreasing in the western Region and all agro-ecological zones of Cameroon. This further demonstrates the importance of much more localized studies on climate disturbances.

Despite what farmers in the municipality of Sancthou claim, namely that the volume of rain has decreased [26], an analysis of rainfall data reveals a significant upward trend over the last four decades. According to this analysis, the rainfall trend is rather increasing and not decreasing as they claim. But there is very variable distribution, which suggests that there may be some confusion among farmers about the number of rainy days and the quantity of rain, as the analysis suggests much more rainy days than before. Indeed, the shift of seasons (rains set late and start early), rainy days receive more rain, with more and more periods of storm, torrential rains, this could explain the fact that rainfall has increased, and the number of rainy days has decreased. This trend is observed throughout the study period.

Average temperatures increases have been recorded over the past four decades thus confirming the statements of the elderly. The Pettitt test applied to the 1971-2016 time series detects a rupture at $p = 0.0056$ in 1991, thus a significant rupture [18]. This rupture is confirmed by the Buishand test with a posteriori probability at the point of rupture of $p = 0.0039$ in the same year, therefore a significant rupture. In this respect, the results are like those of [22] [27], [21] in western Cameroon and [28] in the Sudano-Sahelian zone of Cameroon, who state that the temperature has rised over the past four decades. These results are also like those obtained in the Central African Republic, Benin, Mauritania, Chad, DRC respectively by [8] [29]-[33].

The Climatic disturbances in the municipality of Santchou cause enormous yield losses of about 30 per cent and more on agricultural production. These include flooding and prolonged droughts that make farmers' daily life difficult and lead to early harvests. As a result, products become scarce and lead to higher prices in the local market. The result is severe food insecurity in the area. [16] and [34] in a study conducted in Benin show that heavy rains cause flooding which causes early harvests, bud rot and severe losses in maize yield.

4.2. Consequence of Climate Disturbance on Cropping Systems and Yields

The main impacts of disturbances and climate change are primarily an increase in the annual seeding, lower yields, disruption to crop cycles and decrease in farmers' purchasing power, as confirmed by studies of [35] and [36] in western Niger, [14] and in Pakistan, [37] in north-central Burkina Faso and [33] in northern Kivu in the DRC. The number of sowings has increased from an average of 1 to 4 depending on the season, which means that farmers are most often exposed to situations where it is impossible to sow in case of rain, for having exhausted their stock of seeds or means of purchase and especially in some villages where improved varieties are rare on the local market.

These adverse climatic effects strongly influence seasonal accumulations and other rainfall characteristics, such as the intensity or frequency of rainy days [38]. Seasonal characteristics such as accumulation or number of rainy days, and intra-seasonal characteristics such as the start date of rainy seasons, for example, are of considerable importance in this region where the economy and the well-being of the populations are highly dependent on rain-fed agriculture ([14] [37] [39].

The results regarding the increase in market prices for these products are consistent with the findings of many studies ([14] [16] [34] [40] which showed that lower yields lead to higher market prices for the product. This price increase can be seen to some extent as an advantage for producers, but a disadvantage for consumers.

The production deficits recorded (maize, cassava, sweet potato, new cocoyam) are due to the following other constraints:

- lack of mastery of the crop's technical itineraries by farmers;
- the very high cost of inputs;
- the lack of supervision of farmers;
- soil degradation by silting and flooding;
- agricultural financing techniques are not adapted to target populations;
- low mechanization of agriculture.

5. Conclusions

The objective of the work was to assess the impacts of climatic disturbances on food crops in the municipality of Santchou. It appears that over the last four decades, farmers have experienced climate-related upheavals in their environment. For the rain, the changes do not spare any of the local seasons. Other changes such as the increased frequency of floods on the one hand and the drying up of certain water points and rivers on the other hand are also perceived as indicators of climate change experienced on their land. For temperature, farmers perceived upheavals that result in warmer weather throughout the year.

The results show that the consequences of climatic disturbances on the daily lives of agricultural producers mainly concern the reduction in the yields of the crops practiced. This decrease in yield varies with crops and seasons. The impacts of climatic disturbances on the crops of corn, cassava, macabo and sweet potato are likely to exacerbate the precarious state in which the populations of this region find themselves, and whose number will double by 2050. It is therefore imperative to raise awareness and support farmers in various forms, by promoting and improving flood plains through the implementation of hydro-agricultural developments.

Declarations

Author's Contributions

This work was carried out in collaboration among all authors.

Conceptualization: WAMBA Franck Robéan, MEYABEME ELONO Alvine Larissa, ESSOUMAN EBOUEL Flavien Pyrus, TEMGOUA Emile.

Data management: WAMBA Franck Robéan, ESSOUMAN EBOUEL Flavien Pyrus, TEMGOUA Emile.

Formal analysis: WAMBA Franck Robéan, ESSOUMAN EBOUEL Flavien Pyrus, TEMGOUA Emile.

Surveys and investigations: WAMBA Franck Robéan.

Methodology: WAMBA Franck Robéan, MEYABEME ELONO Alvine Larissa, TEMGOUA Emile.

Supervision: MEYABEME ELONO Alvine Larissa, TEMGOUA Emile.

Validation: MEYABEME ELONO Alvine Larissa, TEMGOUA Emile.

Visualization: WAMBA Franck Robéan, MEYABEME ELONO Alvine Larissa, NTANGMO TSAFACK Honorine, ESSOUMAN EBOUEL Flavien Pyrus, YEMELI Elida Joëlle, TEMGOUA Emile.

Writing, preparation of the original draft: WAMBA Franck Robéan, MEYABEME ELONO Alvine Larissa, NTANGMO TSAFACK Honorine, ESSOUMAN EBOUEL Flavien Pyrus, YEMELI Elida Joëlle, TEMGOUA Emile.

All authors have complied as applicable with the statement on "Ethical responsibilities of Authors" as found in the Instructions for Authors.

Competing Interests

Authors have declared that no competing interests exist.

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Conflicts of Interest

The authors declare no conflicts of interest.

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