

Impacts of climate disturbances on crop productivity in the flood zone of Santchou, western Cameroon

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Abstract

This work addresses 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, 17 community's leaders were interviewed. Crop grow and agricultural systems were observed and describe directly in the field. Crop yields were obtained from the District Delegation of Agriculture and Rural Development (DAADR) of Santchou The results indicate that the increase in rainfall combined with drastic decreases in the number of rainy days caused flooding, leading to rotting of tubers 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 around 25 to 30% and a significant increase in prices products on the local market. The price per kilogram of maize, cassava, new cocoyam and sweet potato increases 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 adaptive strategies in order to reduce the vulnerability of farmers to climate disturbances.

1- Introduction

Climate change is a global issue, but each country has its vulnerability rating (IPCC, 2012). Cameroon and the rest of African countries are the most vulnerable, due to their great dependence on income from agriculture (UNDP, 2008). The consequences of climatic disturbances on agriculture vary according to the type of cover and the climatic conditions associated with the growing conditions for cultivated plants (FAO, 2007). But the general trend is clear: if temperate regions can expect sometimes positive and sometimes negative effects on yield, climatic variations will almost always have negative effects in tropical zones.

This is clearly evident from the large number of studies devoted over the past two decades to predicting the impact of global warming on agriculture on a global scale (Gildas et al., 2015; Atidegla et al., 2017; Meva'a et al., 2018; Rahut and Ali, 2018). Cameroon is no exception, the country is already facing an abnormal recurrence of extreme climatic phenomena such as violent winds, high temperatures or heavy rainfall which endangers human communities, ecosystems and services they provide. Several authors, including Issa (1995) and Ogouwalé (2006), 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 Boko (1988) and Ogouwalé (2006). The synthesis of their analyzes highlights the high variability of rainfall and the different seasonal contrasts characterizing the climate which determine the evolution of agricultural yields.

Such a context of strong climate dependence of agriculture will be aggravated by climate change in several agricultural basins of tropical Africa such as that of Santchou in western Cameroon (Fig. 1). This

compromising situation highlights the question of agricultural vulnerability and food insecurity, constituting a difficult problem in the peasant world, which is 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 site

Figure 1 represent the location of the study area, an integral part of the Mbo plain, located in western Cameroon belongs administratively to the Division of Menoua. It is circumscribed between 5°05' and 5°25' North latitude and 9°50' and 10°10 East longitude, 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 is subject to rains between 17 and 300 mm. September being the rainiest and January being the least rainy. Temperatures are ranged from 21.1°C to 23.9°C with an average of 22.5°C, so overall 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. According to a study conducted by Nguiffo in 2013, the vegetation is composed of the herbaceous layer, the shrub layer and the tree layer.

2.2- Data collection

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

Statistics on data about the price's evolution of maize, cassava, sweet potato and new cocoyam over the period from 2000 to 2010 were collected on the website of the Ministry of Agriculture and Rural Development of Cameroon.

The fieldwork provided mainly qualitative information. A total of 309 agricultural households (distributed in 11 villages grouped into 5 agricultural posts in the study area (Table 1)) were surveyed in the locality, on the basis of a random sampling. The individual interviews with the 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 by the xlstat 2014 statistical software.

For the determination of the size of agricultural households to be surveyed in each pre-selected village, a multi-step process was followed. Initially, the sums of agricultural households per village were collected from the heads of agricultural posts. The calculation from de Schwartz formula made it possible to determine the number of agricultural households to be surveyed throughout the Municipality. Which would have made a total of 226 households out of 3868 and therefore a percentage of about 6 per cent, but with a view to maximizing the diversification of information and limiting the redundancy of responses that is often possible in the case of significant homogeneity of the different households, this percentage has been revised upwards (10 per cent) (Table 1).

Schwartz formula : $n = t^2 \cdot p \cdot (1-p) / m^2$, where 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.

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

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

3- Results

3.1- Climate disturbances noted in Santchou

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

3.1.1- Interannual variation in average temperatures

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

It appears from these data that the average annual temperature of the study area from 1971 to 2016 oscillates between a minimum of 21.65°C (1981) and 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 general average temperature is 22.56°C with a standard deviation of ± 0.51 . The trend line is shown in Fig. 2A.

The Pettitt test applied to this time series (1971–2016), detects a break at the point $p = 0.0056$ in 1991, therefore a significant break (Paturel et al., 1998). The average of this temperature before the rupture according to this test is 22.31°C and that after is 22.78°C therefore a difference of 0.47°C, an increase in the average temperature annually of 0.017°C is noted. This break is confirmed by the Buishand test with an a posteriori probability at the break point of $p = 0.0039$ in the same year, therefore a significant increase (Fig. 2B).

Examination of Fig. 2 shows that between 1986 and 1998, 2009 and 2016, the average temperatures increased perfectly (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 are decreasing with slight fluctuations. The trend curve generally shows an increase in average temperatures over the past four decades, thus confirming the words of the elderly: “It is getting hotter and hotter, with an increase in the number of sunny days”. For old producers (over 45 years old). For the past three decades, even in the rainy season, with a slight sun, it is always hot (information collected by Wamba et al., 2021). With the persistence of increasingly high temperatures recorded, it is no longer just crops that suffer, the growth of domestic animals (goats, pigs and poultry in particular) is also hampered.

3.1.2- Interannual variation in precipitation

Figure 3A shows significant inter-annual variability in rainfall over the past four decades, with the lowest annual average recorded in 1980 (1318.80mm) and the maximum annual average recorded in 2015 (3121.3mm), i.e. a difference of 1802.5mm, a mean of 1708.9mm with a standard deviation of ± 289.8811 mm. This variability is in line with the testimony of the Fombap village chief according to whom: “we no longer understand anything about the rains these days, one year, it can rain a lot, but the following year, it rains just a little. This is a phenomenon that was not known about thirty years ago” (Wamba et al., 2021).

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 3B). 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).

In view of the linear trend curve, we notice an increase in annual precipitation (Fig. 3A). In order to see if this upward rainfall trend is significant, the Mann-Kendall and Buishand trend tests were applied to the entire data series. This method has already been applied in a similar study conducted by Lubès-Niel et al. (1998) in West Africa, to detect a significant trend change in the rainfall time series. In this study, the trend of the average annual rainfall total 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. Given that, these manifestations differ significantly according to the seasons in the study area, the consequences are more developed according to the rainy seasons. The effects of rain delays/breaks, excessive rains as well as those of high temperatures characteristic of the ongoing climate change in the study area, the consequences are therefore exposed for the main crops which are maize (*Zea mays*), cassava (*Manihot esculenta*), sweet potato (*Ipomoea batatas*) and new cocoyam (*Xanthosoma sagittifolium*).

The needs for food products of the Cameroonian population have not ceased to evolve in general with an increasingly galloping demography, and yet, production is encountering enormous problems under the effect of climatic disturbances. Indeed, with heavy rains and given the morphology of the study area (plain), agricultural activities are slowed down. According to the report of the delegation of agriculture and rural development of the district of Santchou of 2015, the floods cause the early harvests of crops grown in the lowlands such as cassava, corn, sweet potato, the macabo, the okra, the pepper. The roots of the plants rot, are engulfed by water, no longer breathe and can no longer grow. Figure 4 shows the evolution of yields (in kg/ha) about thirty years to the present day as mentioned by more than 74 per cent of the farmers surveyed.

From Fig. 4, it appears that the new cocoyam is the crop that has recorded the most loss in terms of yield, due to the fact that this plant supports the least environmental conditions. The sweet potato did not drop significantly.

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 both for self-consumption and for sale. But with the current climatic disturbances, the corn crop is strongly affected with the result of crop losses and considerable reductions in yields.

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

Excess of water, however, is detrimental to it because it causes suffocation or even rotting of the roots. It emerges that maize is a crop that does not tolerate rain delays/breaks as well as excessive rains. Rain delays/breaks at the start of the rainy season cause sowing and re-sowing operations to be spread over unusual periods. These operations continue until the end of May for some farmers instead of mid-April as before. In this way, the technical route of maize is greatly disrupted. The result of this upheaval is the exposure of maize throughout its cycle during the rainy season to frequent periods of water and heat stress. During the off-season crop, the situation is more disastrous, given its short duration such that the prolonged sowing and re-sowing operations project the closure of the crop cycle outside the rainy period.

In addition, all the growers surveyed deplored the proliferation of caterpillars and stem borers, which are increasingly recurrent (Figs. 5b and 5c), as well as *Striga hermonthica* (Fig. 5a). These losses can go up to 40% in the rainy season and 50% in the off-season. Moreover, the Chief of the Fombap village farmer, testifies on the effects of the climatic disturbances by saying: "For a certain time, with the excess of rains on short duration, even the doses of fertilizers and pesticides that we put on the crops no longer have any effect. With the excess rains now arriving several weeks late, we rarely bring home intact ears of maize. Nowadays, if I harvest 60 bags of maize, it is because God is great, whereas I often harvested up to 100 bags".

The indirect consequence here is the increase in the price on the market in addition to a strong population growth. Figure 6 shows the evolution of the price (FCFA/kg) of maize on the West Cameroon market from 2000 to 2010. The trend curves a strong increase in the price per kilogram of maize, as it went from 95.67 francs in 2000 to 437.5 francs in 2010, with a difference 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 collected from 93 per cent of producers, the crop infestation rate is higher today than in the past (20 years ago). Indeed, with climatic disturbances, we notice in these tubers rotting of the leaves. According to the report of the Delegate of Agriculture of the District of Santchou, the floods (Fig. 7a and 7b) cause the early harvests of crops grown in the lowlands such as cassava, corn, sweet potato, the new cocoyam, the okra, the pepper... The roots of the plants rot, are engulfed by water, no longer breathe and can no longer grow. As a result, yields are falling sharply. Some crops like the Ibo cocoyam have completely disappeared. In the case of prolonged droughts, crops will suffer from water stress.

With falling yields associated with strong demand following population growth, prices will explode in the market. Figures 8a, 8b and 8c respectively show price trends (FCFA/kg) of sweet potato, cassava and

new cocoyam on the West Cameroon market from 2000 to 2010. From the analysis, it appears that regardless of the crop, the price has increased.

The sweet potato went from 83.50 francs in 2000 to 117.67 francs in 2010, with a difference of 34.17 francs; for a mean of 104.06 francs and a standard deviation of ± 27.85 francs (Fig. 8a).

Cassava went 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 (Fig. 8b).

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

Of all these tubers, the macabo is the one with the most increased price, confirming the fact that this tuber was struck by a disease called "taro disease".

4- Discussion

4.1- Climate disturbances noted in Santchou

The impacts of climate change are already seriously affecting the environment, natural resources and the people who depend on them, in particular the poorest and most vulnerable communities (IPCC, 2018; Al Niasse et al., 2004), due to their limited adaptive capacities and their great dependence on climate-sensitive resources such as water resources and agricultural production systems. We also note in the Commune of Santchou a trend of significant increase in rainfall over the past four (04) decades with a sawtooth sequence, Marcoty (2019) found in Fonakeukeu in western Cameroon that rainfall had also increased. On the other hand, Tchindjang et al. (2012), National Climate Change Adaptation Plan (2015), Saha and Tchindjang (2017) and Saha et al. (2018) instead found that the rains are gradually decreasing in the West Region and in all agro-ecological zones of Cameroon, which further shows the importance of conducting much more localized studies when it comes to the climatic disturbances.

Despite what farmers in the Commune of Sancthou claim that the amount of rain has decreased (Wamba et al., 2021), an analysis of rainfall data reveals a significant upward trend over the past four decades, because after this analysis, the rainfall trend is rather increasing, and not decreasing as they claim. But we note a very variable distribution, which suggests that there is a possible confusion by the farmers of the number of rainy days with the quantity of rain because the analysis suggests rainy days much rainier than 'previously.

An increase in average temperatures over the past four decades has been recorded, thus confirming the statements of the elderly. Pettitt's test applied to the 1971–2016 time series detects a break at point $p = 0.0056$ in 199, therefore a significant break (Paturel et al., 1998). This break is confirmed by the Buishand test with an a posteriori probability at the break point of $p = 0.0039$ in the same year, therefore a significant break. On this point, the results are similar to those of Tchindjang et al. (2012), PNACC (2015)

and Marcoty (2019) in West Cameroon and Oumarou et al. (2017) in the Sudano-Sahelian zone of Cameroon who state that the temperature has increased over the past four decades. Also in the Central African Republic, Benin, Mauritania, Chad, DRC by studies conducted respectively by Doukpolo (2014), Agossou et al. (2012), Coulibaly (2012), Mbaiherem (2018), Teklewold et al. (2019) and Arsène et al., (2021).

Climate disturbances in the Municipality of Santchou cause enormous yield losses of around 30 per cent and more on agricultural production, floods and prolonged dry periods make the daily life of farmers difficult and lead to early harvests. As a result, the products become scarce and lead to an increase in the prices of these products on the local market. The result is severe food insecurity in the area. Ogouwalé (2006) and Gildas et al. (2015) in a study done in Benin show that heavy rains causing flooding cause early harvests, rotting of ears and heavy losses in terms of maize yield.

4.2- Consequence of climate disturbance on cropping systems and yields

The main impacts of disturbances and climate change are above all the increase in the number of sowings per year, the drop in yields, the disruption of crop cycles and a drop in the purchasing power of farmers, this is confirmed by studies of Diomand et al. (2009) and Nouhou (2012) in the western region of Niger, Rahut and Ali (2018) in Pakistan and Kaboré et al. (2019) in north-central Burkina Faso and Arsène et al., (2021) in North Kivu in the DRC. The number of sowings has increased from 1 on average to 4 depending on the season, which has the effect of exposing the farmer most often to situations where it is impossible for him to sow in the event of rain, for having exhausted his stock of seeds or means of purchase and especially in certain villages where improved varieties are rare in the local market.

These adverse climate effects strongly influence seasonal accumulations as well as other rainfall characteristics such as the intensity or frequency of rainy days (Camberlin et al., 2003). Seasonal characteristics such as the 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 rely heavily on predominantly rain-fed agriculture (Dixon et al., 2001; Rahut and Ali, 2018; Kaboré et al., 2019).

The results concerning the increase in the prices of these products on the market are in agreement with the results of numerous studies (Ogouwalé (2006), Aho et al. (2006) and Gildas et al. (2015), Rahut and Ali (2018) who showed that lower yields lead to higher product prices on the market. This price increase can be considered to some extent as an advantage for producers, but a disadvantage for consumers.

The recorded production deficits (maize, cassava, macabo, taro) are due to the following other constraints:

- Lack of mastery of the technical itineraries of crops by farmers;
- The very high cost of inputs;

- The lack of supervision of farmers;
- Soil degradation by silting and flooding;
- Financing techniques for agriculture not adapted to the target populations;
- Low mechanization of agriculture.

5- Conclusion

The objective of the work was to assess the impacts of climatic disturbances on food crops in the Commune of Santchou. It appears that over the last four decades, farmers have experienced upheavals related to the climatic factors of their environment. For the rain, the changes do not spare any of the seasons of the locality. Other modifications 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 in their land. For temperature, farmers perceived upheavals resulting in warmer weather during all seasons.

The results show us 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 drop in crop yield varies according to the crops grown and the seasons. The impacts of climatic disturbances on the crops of corn, cassava, macabo and sweet potato in the Commune of Santchou are likely to exacerbate the state of precariousness in which the populations of this region find themselves, the number of which will double by 2050. It therefore appears imperative to raise awareness and support of several kinds for farmers, through the promotion and enhancement of floodplains by carrying out hydro-agricultural developments.

Declarations

Author's contributions

This work was carried out in collaboration among all authors. The manuscript was written by Wamba Franck Robéan, Temgoua Émile and Meyabeme Elono Alvine Larissa directed the research, Ntangmo Tsafack Honorine and Yéméli Éléida Joëlle accompanied to collect data in the field. All authors read and approved the final manuscript.

Competing interests

Authors have declared that no competing interests exist.

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Availability of data and material

I, principal author of the manuscript, certify on the name of all authors, the availability of data and material.

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Figures

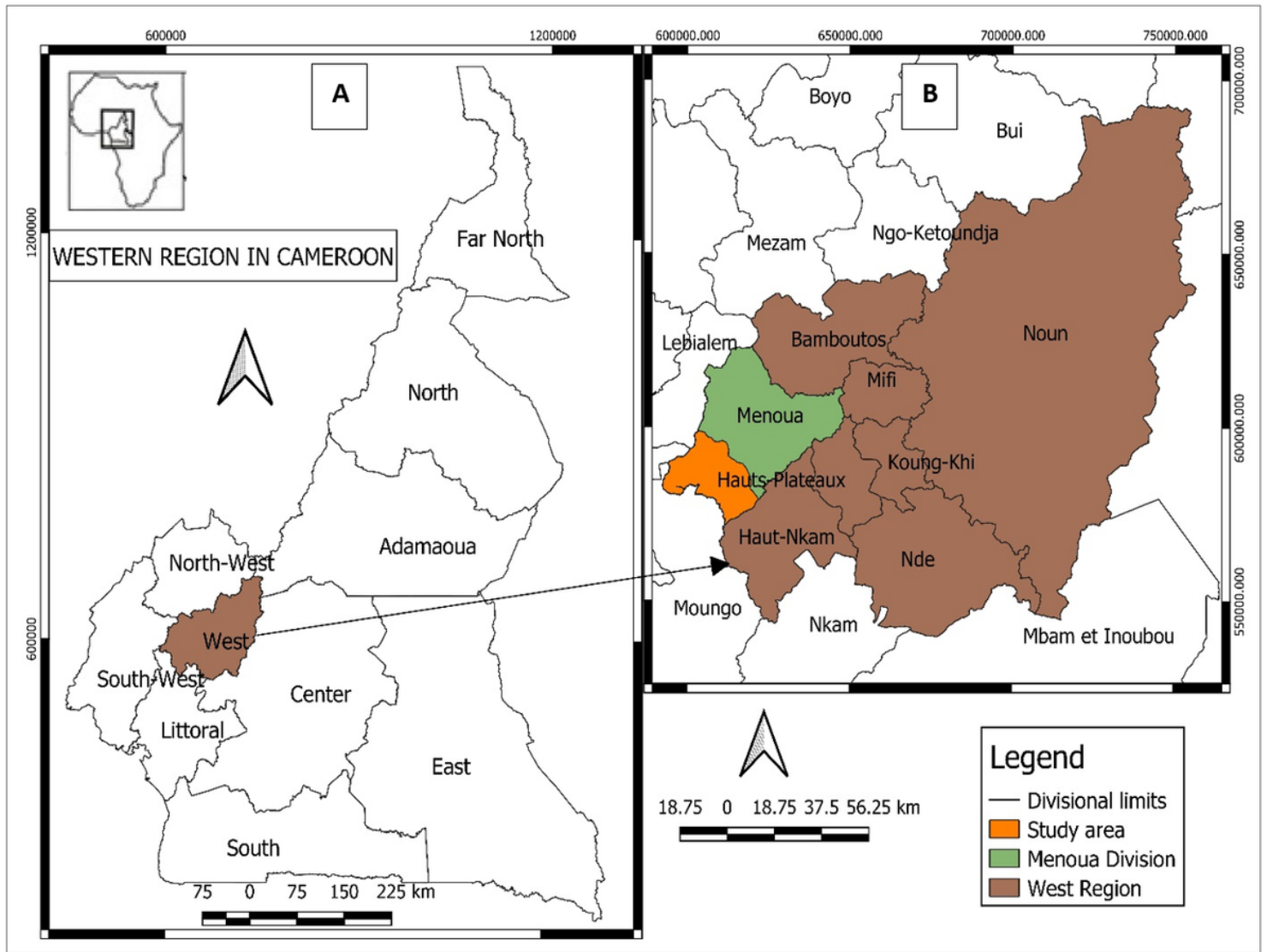


Figure 1

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

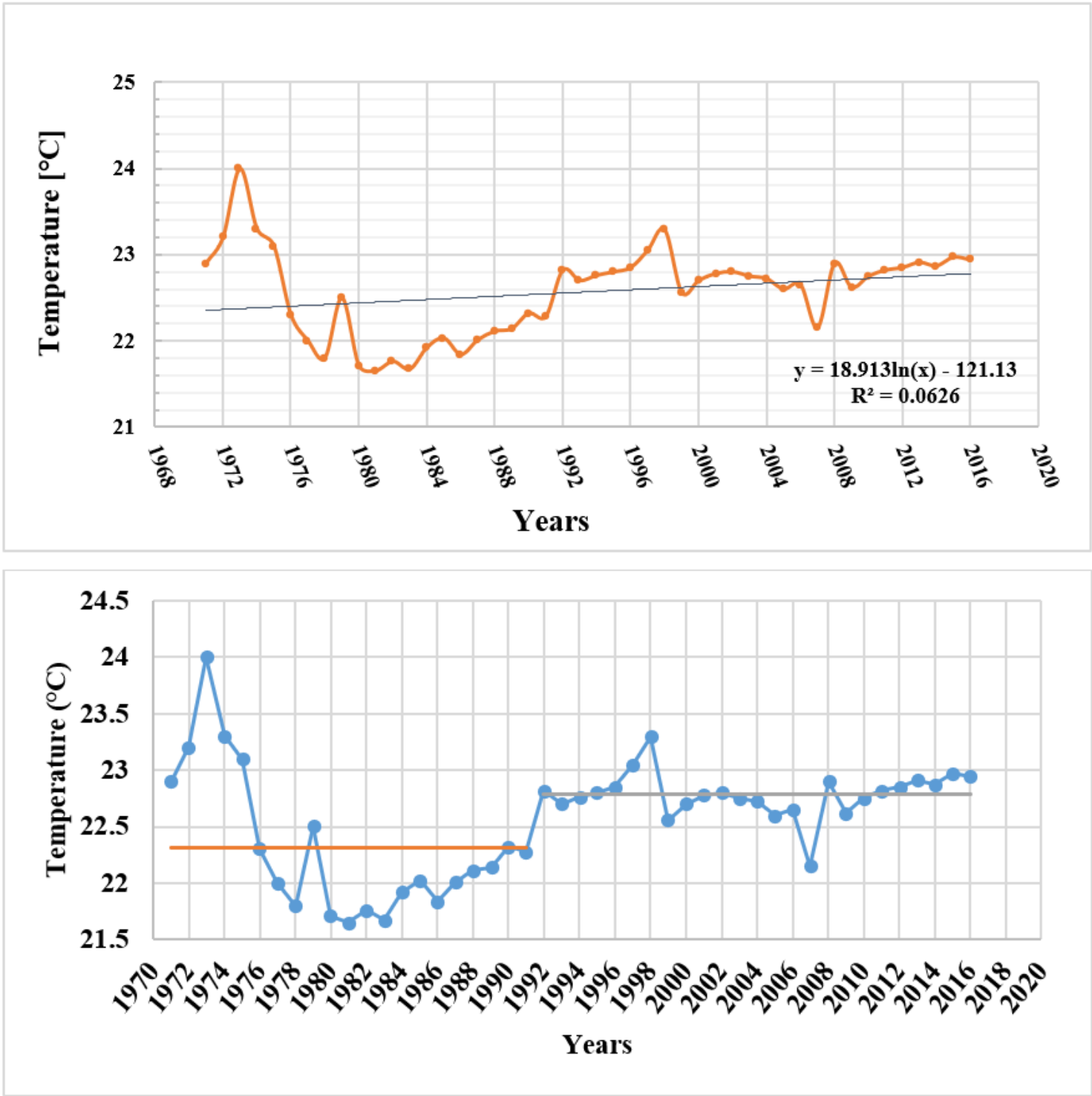


Figure 2

Annual change in temperatures (A) and breaks (B) in Santchou from 1971 to 2016

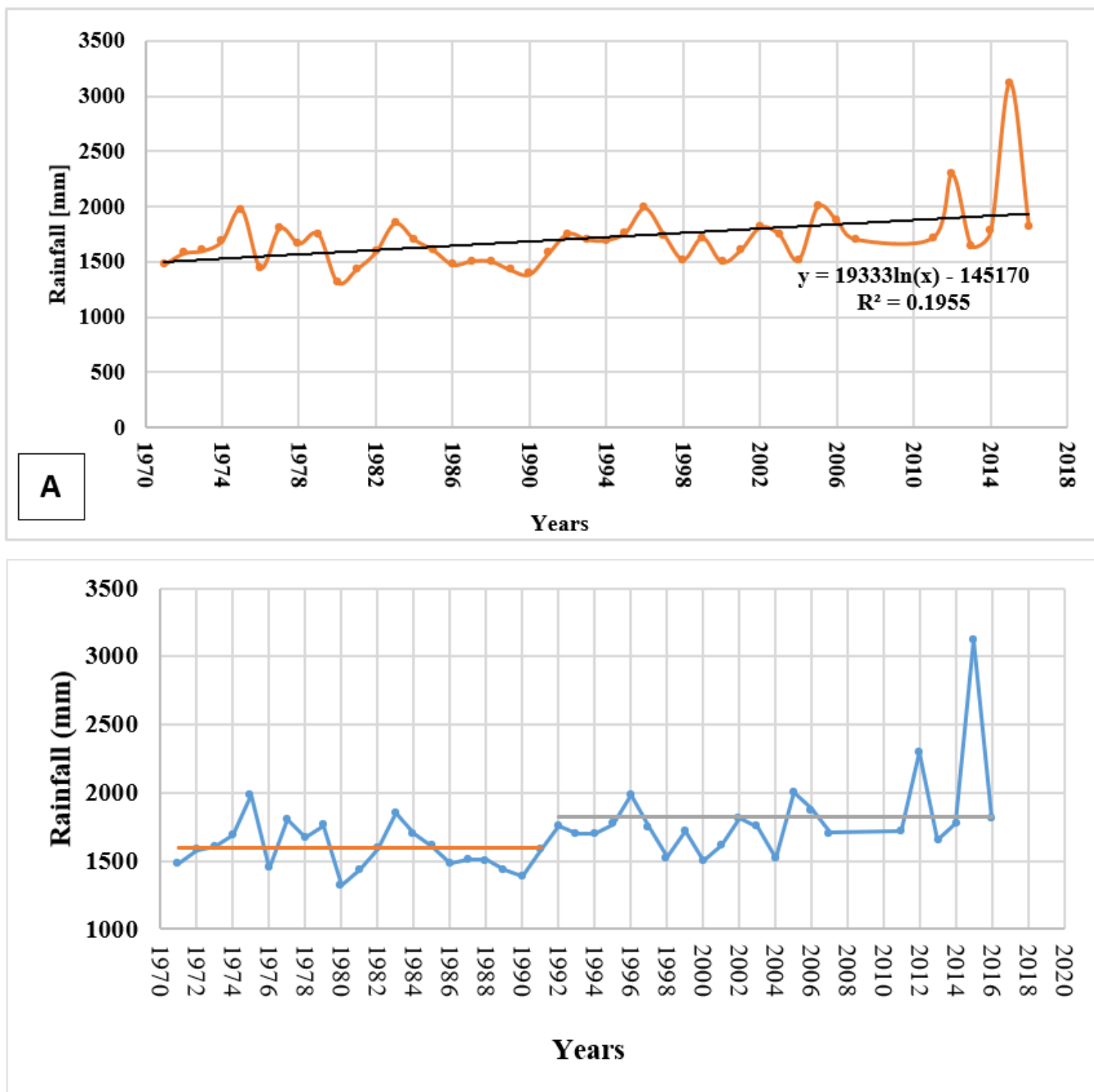


Figure 3

Evolution of annual rainfall (A) and breaks (B) from 1971 to 2016 in the Municipality of Santchou

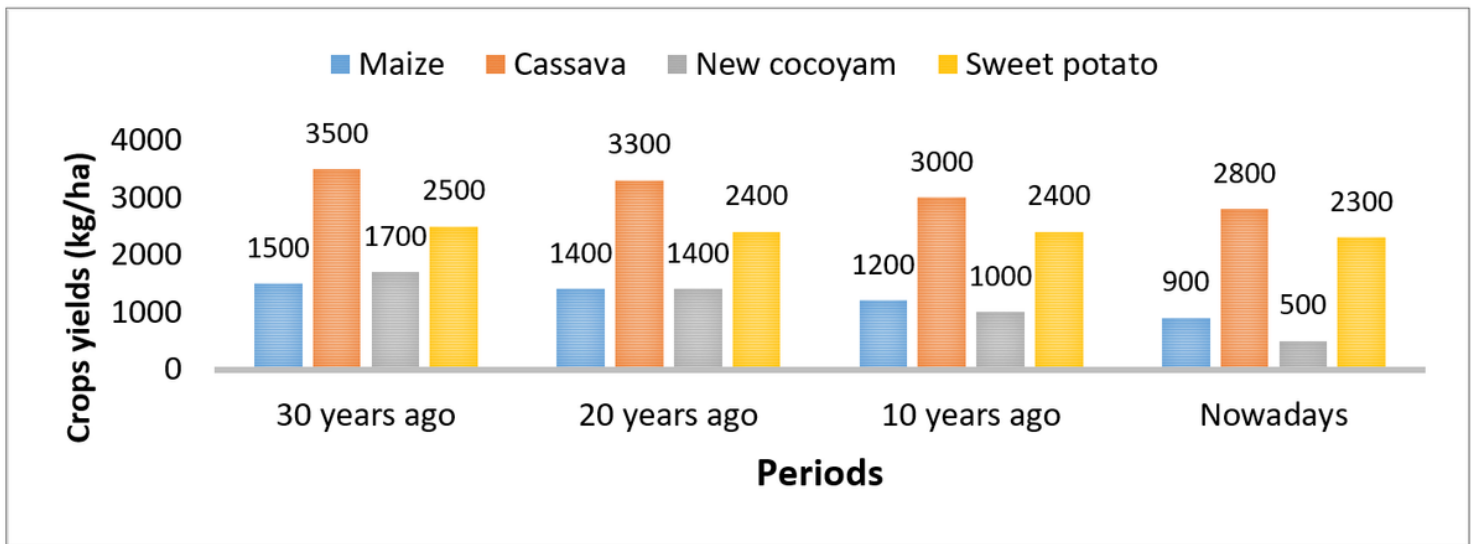


Figure 4

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

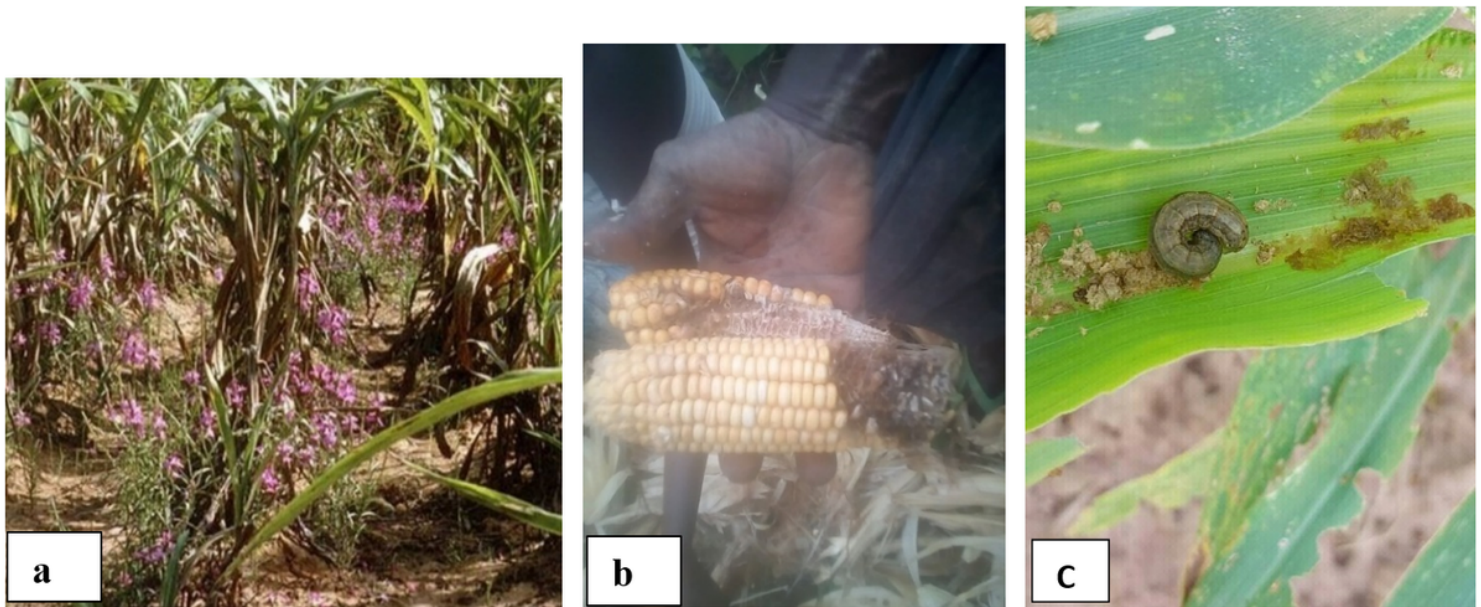


Figure 5

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)

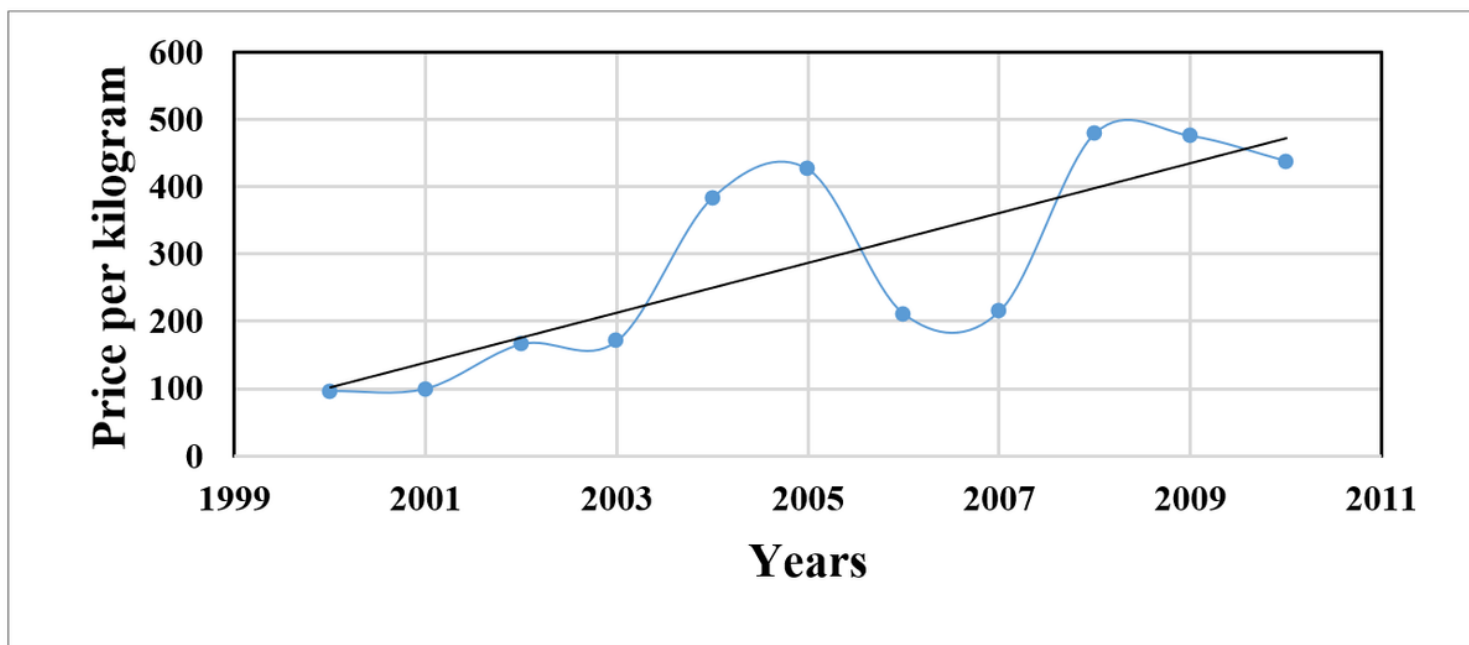


Figure 6

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



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)

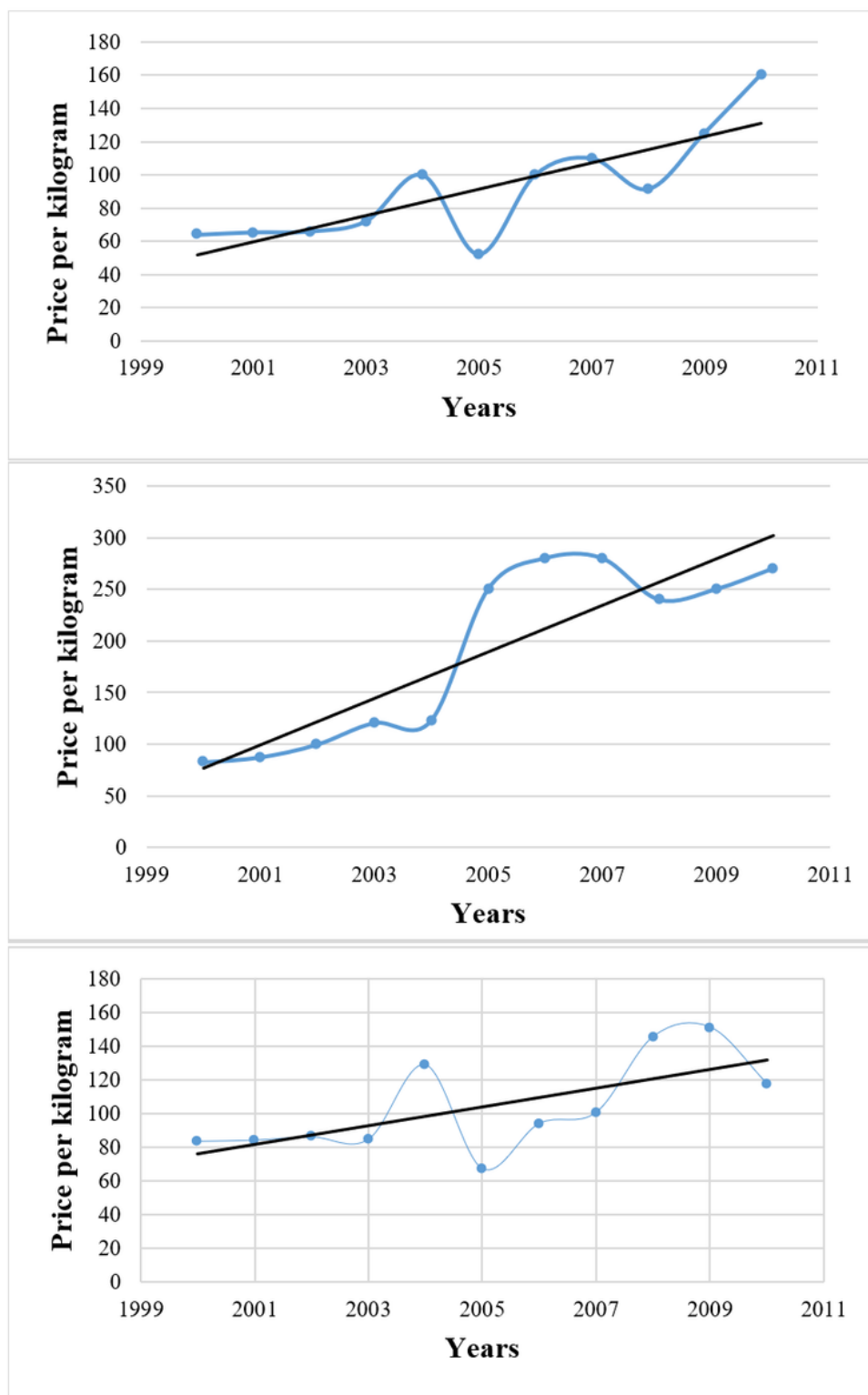


Figure 8

Annual evolution of the price (in FCFA/kg) : a= of sweet potato; b= of new cocoyam; c= of casava