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Agriculture and food security under climate change threat in Benin

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Vulnerability of agriculture to climate change has been a key issue due to its negative effect on human survival. This study aims to determine the effect of climate change on the production of crops to draw the attention of plant breeders on the paramount necessity to breed new varieties that are tolerant to abiotic stress (drought, temperature, salinity and flooding) for the happiness of farmers. Data on the experiments carried out, survey and temperature, and rainfall were used in this work. The results of the study revealed that high temperature caused abortion and drying of flowers, resulting in low yield. CL5 (*Solanum pimpinellifolium)* was found to be more tolerant to heat. The results also showed that there was increase in temperature and decrease in rainfall due to flooding and violent rainfalls. The result also showed that there was delay in the start of the first rain in the central and northern parts of the country, poor distribution of rainfall across the country, drought pocket during rainy season in the central and northern and flooding in the south. There is need to develop new crop varieties that are tolerant to drought, flooding, salinity and temperature.

Key words: Climate change, drought, flooding, crop production, food security, Benin.

INTRODUCTION

Agriculture which constitutes the key activity in Benin Republic and occupies nearly 60% of the workforce has a lot of challenges due to climate change effects. Majority of farmers rely only on rain-fed agriculture to produce crop for their subsistence. It is obvious today that climate change will significantly and harmfully impinge on crop production and food security in the world especially in developing countries by altering the pattern of rainfall (Food and Agriculture Organization (FAO), 2001). Lately, global warming and its effect on crop production has become a very serious issue. Amongst the continents, Africa will go through a severe climate change (Intergovernmental Panel on Climate Change (IPCC), 2007). Lane and Jarvis (2007) reported that many countries where food insecurity is already predominant will be dangerously influenced by the change in climate. Therefore, agriculture is highly sensitive to environmental stresses and weather extremes, such as flood, salinity, high temperature (heat), and drought. Our actions have already modified the atmospheric features and this will

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continue as years go by which will be a great problem to agricultural production and farmers will be faced with a lot of challenges.

Society for the Advancement of Education (2002) reported that, every year yield losses of crops due to abiotic stresses are more significant than those caused by insects and weeds. In Africa and Asia, most of economic important crops will decrease in yield due to the deleterious effect of climate change (Calzadilla et al., 2009). They further stated that the obvious effect of change in climate on food production will be more felt and more severe in Sub-Saharan Africa and South Asia. It was foreseen that global warming will cause the rise in sea level ranging from 0.1 to 0.5 m (4 to 20 inches), according to present estimates of the Intergovernmental Panel on Climate Change (IPCC, 2007). The increase in the level of sea and the high irrigation of water will definitely bring out high salinity in the coastal regions of Benin.

Besides, the growing world population requires more food, while the prospect of global warming threatens to make agricultural growing conditions more demanding (FAO, 2004). Climate change will seriously affect crop production as years go on (IPCC, 2007). More erratic rainfall and high temperature patterns and increased salinity and flooding caused by climate change will consequently be expected to further reduce crop productivity, and developing countries in the tropics are particularly vulnerable (de la Peña and Hughes, 2007). In these areas, increasing salinity and flooding will be major limiting factors in sustaining and increasing vegetable production (de la Peña and Hughes, 2007). Climate changes have impact on Benin agriculture, especially in the coast, valley of Ouémé, Mono.

In addition, our study on the impact of salinity on tomato production along the coastal regions of Benin Republic revealed that salinity is increasing due to the rise in the sea level which causes yield loss up to 60% in the regions (Ezin et al., 2012). Due to repeated yearly yield loss to salinity some producers were compelled to abandon their field. In the village called Avlo in Benin Republic, farmers have stopped growing vegetable crops in the field due to high salinity of their soil which is unsuitable for vegetable production. Farmers were asking for new varieties tolerant to salinity and flooding. Henceforth, breeders must assist farmers in coping with the climate change risk by developing adaptation strategies to abate its negative impacts on crop productivity.

Most of the varieties farmers use are bred for tolerance to pest and diseases while abiotic stresses are the main cause of crop-yield declines reducing by more than 50% the average yield (Boyer, 1982; Wang et al., 2003). Thus, measures to adapt to climatic changes, particularly development of salinity and flooding tolerant varieties, are critical in tropical agricultural production systems. Therefore, to lessen or overcome climate change effect, it is imperative to breed new varieties for improved tolerance to drought, high temperature, salinity and flooding. Developing countries are in dire need for new crop varieties tolerant to severe climate conditions. In view of the magnitude of the predicted climate change impact on crop productivity more attention must be given to breeding.

The objective of the present study was to use the data of the conducted experiments, survey, temperature, rainfall in Benin and literature review to project the threat of climate change on the production of crops in Benin Republic in order to draw the attention of plant breeders on the paramount necessity to breed new varieties tolerant to abiotic stress (drought, temperature, salinity and flooding) for the happiness of our farmers.

MATERIALS AND METHODS

Description of study area

This study was carried out in Benin Republic. Benin latitude ranges from 6°3°' to 12°3°'N and its longitude from 10° to 3°4°'E. The climate is of equatorial type with two rainy and two dry seasons.

Experiment on high temperature

Three genotypes CA4 (*S. lycopersicum),* CL5 (*Solanum pimpinellifolium),* and CL5xCA4 (hybrid) were used in this study. The experiment was laid at randomized complete block design (RCBD) with 8 replicates. Treatments consist of two different temperatures: 40°C as high temperature and 27°C as normal temperature.

Other data collected

Two different data were used: one based on survey carried out amongst producers and the other ones from the meteorological data collected from different institutes namely Africa Rice, IITA, and ascena. Daily data of temperature and daily rainfall were collected from weather data recorded by automatic weather recorders installed nationwide.

Three different stations were chosen: one in the south (Cotonou), two in the Central part (Bohicon and Zagnanado) and one in the North (Natitingou).

Statistical analysis

Data collected from the heat experiment were subjected to variance analysis using SPSS16.0, and then the determination of the differences among treatments was carried out. Means separation was performed.

The meteorological data collected were subjected to descriptive statistics to determine means, min, maxi and standard deviation. The processing of data collected was performed with the aid of EXCEL 2007, and XLTAT. In depth statistical analyses were carried out such as trend analysis, T Test, confidence test, co-efficient of variation and Mann-Kendall analysis.

Statistical approach used to analyze trends

Trends of variables of water quality for the period 1999 to 2008 were analyzed using SAS version 9.1 software. Monthly median concentrations were used to perform various tests. The test of Kruskal-Wallis was used to determine the presence of seasonality in the data, and that of Durbin-Watson to verify the presence of autocorrelation. The trend test of Mann-Kendall was used when there was no seasonality or autocorrelation. The test of seasonal Mann-Kendall was chosen when the data included seasonality without autocorrelation and that of LettenMaier Spearmann when there was autocorrelation and absence of seasonality.

Finally, the approach of Hirsch-Slack was retained when there was seasonality and autocorrelation. For this test, missing data were replaced by the monthly median value calculated over the entire period. Trends were not considered significant when the probability level (p) was greater than or equal to 0.05. In the absence of seasonality, the slope of the regression line was estimated using the method of Sen, whereas in the presence of seasonality, it was estimated using the Seasonal Kendall Slope Estimator.

Mann-Kendall analysis: The Mann-Kendall statistic S (Mondal et al., 2012) is given as:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sign(x_j - x_k)$$

The application of trend test is done to time series x_i which is ranked from i = 1,2,3,……n-1 and x_j, is ranked from j = i+1,2,3,….n. Each of the data point x_i is taken as a reference point which is compared with the rest of the data point x_j so that,

$$sign(x_j - x_k) = 1 \; if \; x_j - x_k > 0$$
$$= 0 \; if \; x_j - x_k = 0$$
$$= \; -1 \; if \; x_j - x_k < 0$$

The variance statistic is calculated by the following equation:

$$VAR(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{g} t_p(t_p - 1)(2t_p + 5)\right]$$

Where n is the number of data points, g is the number of tied groups (a tied group is a set of sample data having the same value) and t_p is the number of data points in p^{th} group. A normalized test statistic Z was computed as follows:

$$Z = \frac{S-1}{[VAR(S)]^{1/2}} \; if \; S > 0$$
$$= 0 \qquad if \; S = 0$$
$$= \frac{S+1}{[VAR(S)]^{1/2}} \; if \; S < 0$$

Sen's slope estimator test: The magnitude of trend is predicted by the Sen's estimator. Here, the slope (Ti) of all data pairs is computed as (Sen, 1968; Mondal et al., 2012):

$$T_i = \frac{x_j - x_k}{j - k} \qquad for \; i = 1, 2, \ldots \ldots \ldots \ldots, N$$

Where x_j and x_k are considered as data values at time j and k (j>k) correspondingly. The median of these N values of T_i is represented as Sen's estimator of slope which is given as (Sen, 1968, Mondal et al., 2012):

$$Q_i = \begin{cases} T_{\frac{N+1}{2}} & N \; is \; odd \\ \frac{1}{2}\left(T_{\frac{N}{2}} + T_{\frac{N+2}{2}}\right) & N \; is \; even \end{cases}$$

Sen's estimator is calculated as Q_{med} = T (N+1)/2 if N appears odd, and it is regarded as Q_{med} = [TN/2+T (N+2)/2]/2 if N appears even. At the end, Q_{med} is computed by a two sided test at 100 (1-α) % confidence interval and then a true slope can be obtained by the non-parametric test. Positive value of Q_i indicates an upward or increasing trend and a negative value of Q_i gives a downward or decreasing trend in the time series.

RESULTS AND DISCUSSION

The life conditions of farmers relying mostly on rainfed agriculture in Benin have been affected due to climate change

Climate change impact

The following abiotic stress; Drought, temperature, heat, salinity and flooding are the consequences of climate change; though those abiotic stresses have always posed a significant menace to crop production even before the change in climate concept is known and are glaring to everyone across the globe. It is obvious that as the years go by, the effect climate change will increase in abiotic stress. Abiotic stress cause wide-ranging losses to crop production in the world. Developing countries like ours have contributed least to the atmospheric buildup of carbon dioxide and greenhouse gases associated with recent global warming but unfortunate we are most at high risk from climate change and we will be the most to undergo its negative effects.

Pierre (1997) reported that, there would be a sharp difference in impact of climate change which is due to two main causes between the less developed countries (LDCs) and the developed countries (DCs). Firstly, the "physical" factor will be in favor of the DCs because of their geographical position on the planet which will benefit their agriculture owing to the longer growing seasons that a warmer climate will bring, while most LDCs would be negatively affected. Secondly, the "eco-structural" factor bound to the fact that the DCs have much greater resources that can be devoted to helping farmers adjust to climate change. Besides, the institutional structures of DCs appear to be more outstanding and efficient than those in LDCs in mobilizing resources need to pursue

Table 1. Kendall's analysis and estimated sen's slope.

Variable	Mean	Stdev	Confidence Test	S	Kendall's tau	p-value	Sen's slope
Rainfall N	1189.60	161.85	161.85±95.64	-15.00	-0.27	0.28	-21.13
Rainfall B	1100.02	224.23	224.23±72.25	182	0.28	0.02	8
Rainfall Z	985.30	204.56	204.56±73.20	37	0.09	0.52	2.43
Temp N	33.48	0.23	33.48±0.14	17	0.38	0.16	0.04
Temp B	27.9	0.39	27.90±0.39	197	0.47	0.0001	0.03

Rainfall N = rainfall of Natitingou, Rainfall B= rainfall of Bohicon, Rainfall Z= rainfall of Zagnanado, Temp N= temperature of Natitingou, Temp B= temperature of Bohicon, Stdev= standard deviation.

Table 2. Effect of temperatures on flowers and number of fruits from cluster 2 to 6.

Genotypes	Number of flowers		Number of fruits	
	T1	T1	T1	T2
CL5	50.67a	49.13a	31.83a	28.13a
CL5XCA4	44.63a	41.38a	39.11a	30.13a
CA4	28.29a	31.86a	10.15a	1.13b

social objectives, whether they are adjustments to climate change or anything else. Therefore, the poorest countries in the world are the most vulnerable and the richest countries will face the least harm from climate change due to the fact that they are also well equipped to deal with the little harm to encounter. In addition to problem attached to climate change we need to develop sustainable agricultural systems in Africa in general and Benin Republic in particular.

MEHU-PNUD (2008) in its planned assessment of vulnerability to climate change in the most susceptible geographic areas in the Republic of Benin pointed out environmental factors as a result of climate change namely (1) drought, inundation, late and violent rainfalls as three major climatic risks in Benin; (2) the occurrence of violent winds and high temperature heat as climatic risks capable of being serious in some areas, in some situations; and (3) the existence of localized climatic risks such as coastal erosion. They further stated that tributary basin, subsistence farming, small farmers, vegetable gardeners, biodiversity; fishers are highly exposed to climatic risks in Benin.

African countries will face more shortages of food, poverty, and hunger. This has started gradually because the price of all commodities has been increased in the past three years due to low yield of crops in the field. Currently, climates of most parts of the country have changed: delay in the arrival of the first rain, poor distribution of rainfall, drought pocket during rainy season, flooding, etc.

Increase in the temperatures

Table 2 shows the effect of temperature on tomato production. High temperature can cause low yield and even death of crops. Among the genotypes used CA4 variety was the most sensitive. CL5 genotype could be regarded as heat tolerant based on the fact that it produces better yield under high temperature. There was significant difference in number of flowers and fruit number among genotypes and within genotype. This indicates that high temperature impinges high yield. Our results are consistent with those of Maman et al. (2003), Firon et al. (2006), Wahid et al. (2007) and Blanc (2012). Hall (2001) reported that heat stress due to high ambient temperature is a serious threat to crop production worldwide.

The trend analysis of Natitingou in the northern part, Bohicon in the central part has been performed using Mann-Kendall and Sen's Slope Estimator. Table 1 demonstrates that the Sen's Slope of temperature in Natitingou and Bohicon is increasing in trend. This results project that temperatures are rising. The result of the present study is similar to the report of IPCC (2007). Mondal et al. (2012) also reported that research of various time series data provided evidence that the trend is either decreasing or increasing, both in case of temperature and rainfall.

Figure 1 shows that from 1971 to 2000 temperature varies around the overall average, 27.9°C in Bohicon. The average over this period was 27.84°C which is slimly lower than average temperature recorded in Bohicon. The average in the second period from 2001 to 2008 is 28.15°C. The last decade is warmer. The peak of annual average temperature was observed in 2000. In the second period from 2001 to 2008, the average annual temperature was always above 28°C. The average temperature recorded in Natitingou ranges from 33.1 to

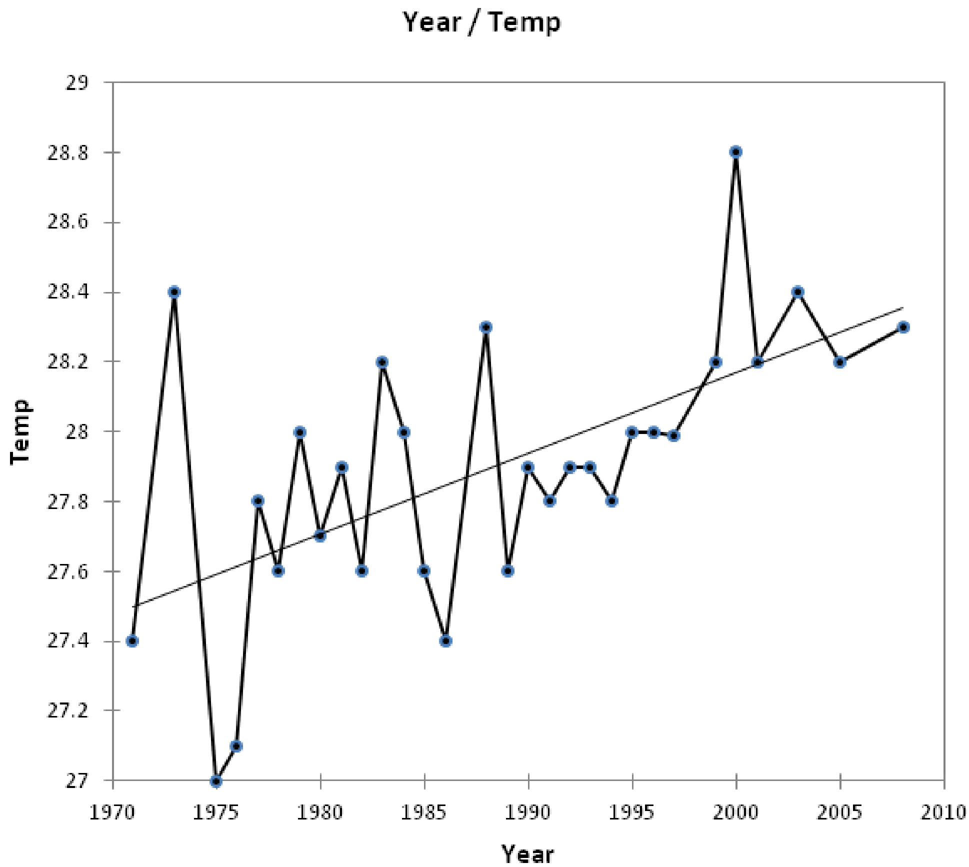

Figure 1. Annual average temperature from 1971 to 2000 in Bohicon.

33.6°C between 1993 and 2000 but from 2001 to 2004 there was slight increase (0.3°C) in average temperature and varies between 33.7 and 33.9°C.

It is obvious that the temperature actually increases each year. The trendline is an up trendline with positive slope indicating that the temperature rises as we move from left to right on the figure. As long as the trend is up, temperature will increase as years go by. But, it should be noted that there is break below the up trendline (Figures 1 and 2). Based on observations of increases in average temperature recorded from meteorological stations in our country, the deleterious effect of global warming is undeniable. According to ECOWAS-SWAC/OECD/CILSS (2008) in West Africa, observed temperatures have been increasing faster than global warming and the increase varied between 0.2 and 0.8°C since the end of the 1970s. IPCC (2007) reported that temperature of the earth is likely to increase by 1.1 to 6.4°C. It is also said that land area will warm than ocean in part due to the water ability to store heat. They further stated that most of North America, all of Africa, Europe, Northern and Central Asia, and most of Central and South America are likely to warm more than the global average.

Therefore, the rising temperature will have negative effect on crop yield. Peña and Hughes (2007) reported that temperature limits the range and production of many crops, and that in the tropics crops will be subjected to increased temperatures stress. Greater climate variability which incorporates the later onset, higher temperatures and increased potential evapotranspiration will make farming systems more highly vulnerable to climate change (Sarr, 2012) Temperature primarily affects the photosynthetic functions of higher plants (Weis and Berry, 1988). Plant development, growth, yield and crop production even seed germination will definitely and negatively respond to climate change. In our study, on effect of heat on tomato production under controlled environmental conditions (personal communication), we concluded that high temperature caused decrease in plant height, dropping of flowers and yield loss even total yield loss in some tomato varieties. It can also cause significant losses in tomato productivity due to reduced fruit set, and smaller and lower quality fruits (Stevens and Rudich, 1978). Pre-anthesis temperature stress is associated with developmental changes in the anthers, particularly irregularities in the epidermis and endothecium, lack of opening of the stromium, and poor pollen formation (Sato et al., 2002).

Hazra et al. (2007) summarized the symptoms causing

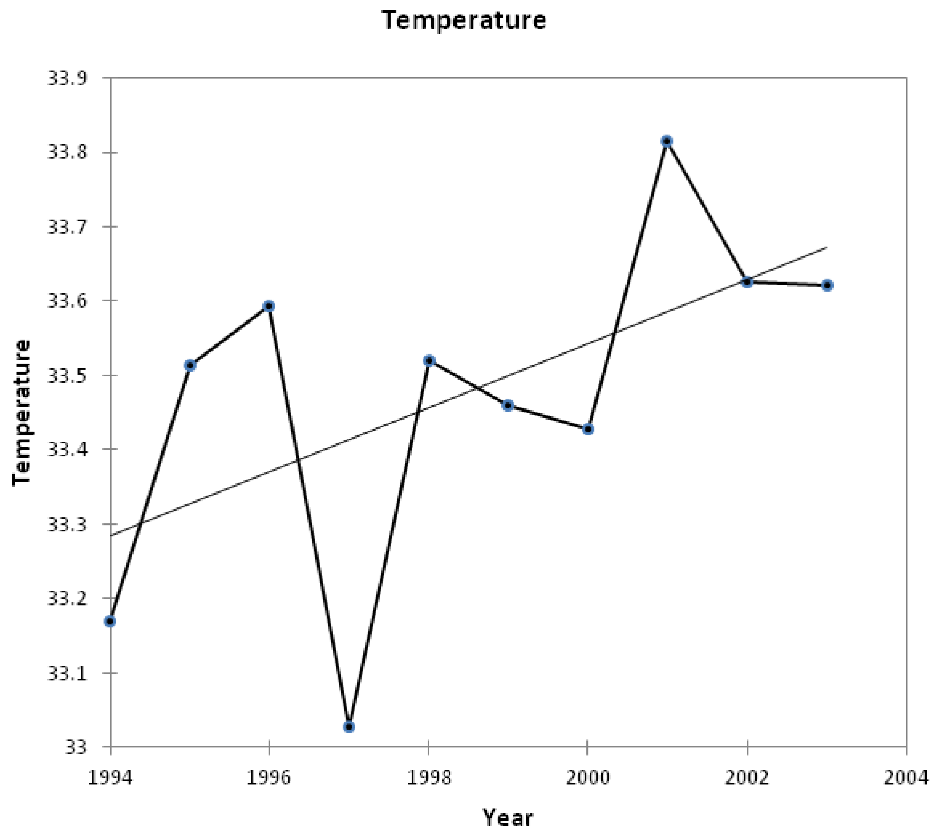

Figure 2. Annual average temperature from 1994 to 2004 in Natitingou.

fruit set failure at high temperatures in tomato; this includes bud drop, abnormal flower development, poor pollen production, dehiscence, and viability, ovule abortion and poor viability, reduced carbohydrate availability, and other reproductive abnormalities. This is similar to the results presented in Table 1 owing to the fact that despise the high number of flowers recorded especially in the sensitive, few fruits were recorded. This demonstrates the fact that there was flower drop. In addition, significant inhibition of photosynthesis occurs at temperatures above optimum, resulting in considerable loss of potential productivity. Challinor et al. (2005) reported that brief periods of high temperature which occur near flowering can severely reduce the yield of annual crops such as wheat and groundnut.

Challinor et al. (2007) observed that high temperature stress was not a major determinant of simulated yields in the current climate, but affected the mean and variability of yield under climate change in two regions which had contrasting statistics of daily maximum temperature. Changes in mean temperature had a similar impact on mean yield to that of high temperature stress in some locations and its effects were more widespread (Challinor et al., 2007). Where the optimal temperature for development was exceeded, the resulting increase in duration in some simulations fully mitigated the negative impacts of extreme temperatures when sufficient water was available for the extended growing period. For some simulations, the reduction in mean yield between the current and future climates was as large as 70%, indicating the importance of genotypic adaptation to changes in both means and extremes of temperature under climate change (Challinor et al., 2007).

Drought

Drought is an abiotic factor which limits crop yield. It will increase in importance with climate change. IPCC (2007) reported that, between 75 and 250 million across Africa could face more severe shortage of water by 2020. The monthly data collected on rainfall shows that yearly rainfall period has been reduced in the last five years in the center and northern parts of the country; it ranges from 5 to 4 months, respectively. Irrigation systems are most practiced in the north of Benin due to lack of rain and inconsistent frequency of rainfalls. Thus, flooded irrigation could lead to salinity of soils in the regions due to the buildup of sodium chloride. To avoid an addition of salinity of soils where drought is almost settle and predominant, our farmers must be taught about drip irrigation which is one of the best irrigation system

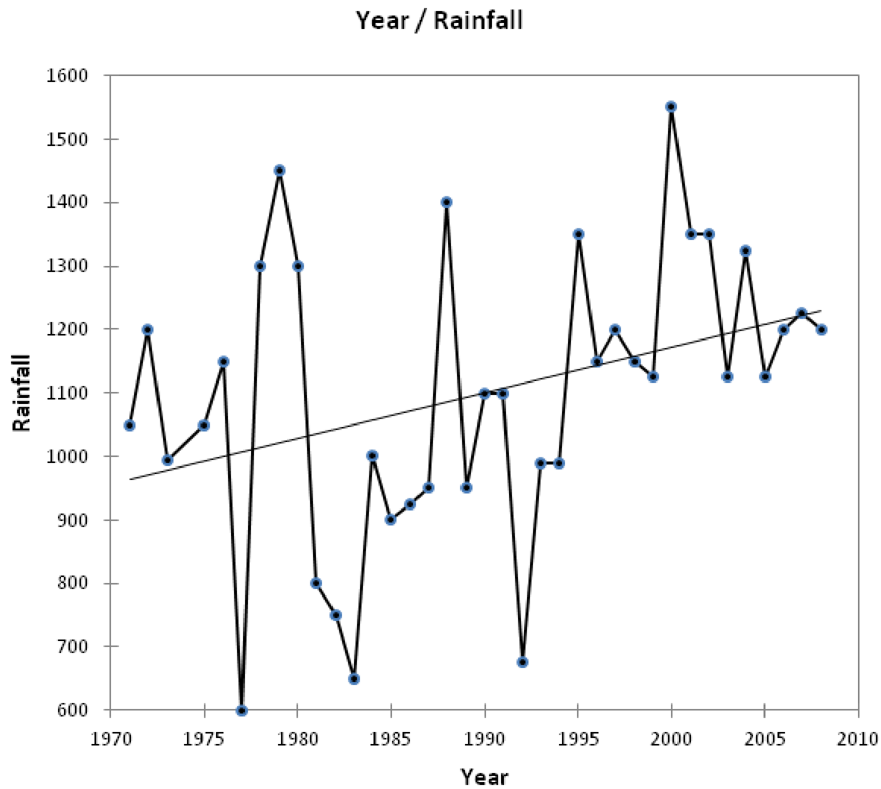

Figure 3. Annual average of rainfall from 1971 to 2005 in Bohicon.

but very expensive when compared to the flooded irrigation practiced to date. In one way or the other we are beginning to feel the effect of climate change because, farmers reported that the rain is not frequent and has become unpredictable, resulting to decrease yield in crop production. These are the sign of hunger and food security problems.

In some part of Africa such Somalia, Soudan, and Ethiopia drought rate has been increased lately and many have left their countries to seek refuge elsewhere. Millions face death due to the ravaging horn of Africa drought. It is therefore expected that many crops will not be able to be resilient to drought with the increase in temperature of the climate as time goes on. Country STAT-Benin reported that annual variation of yield from 1987 to 1997 and 1997 to 2007 are 5.7 and 3.2% for cassava, 0.5 and 0.1% for yam, 7.0 and 1.1% for maize, respectively. This results show that there is yield reduction in cassava, yam and maize due to the effect of climate change in crop production in Benin.

Drought stress causes the solute concentration of plant cells to increase, thus lowering water potential and disrupting membranes along with essential processes like photosynthesis. These water-stresses affect plant, making them exhibit poor growth and resulting to plant death in severe cases. Water stress also causes abortion of flower bud and then reduction in fruit setting.

Rainfall variability

In the non-parametric Mann-Kendall test, there is variability in the trend of rainfall recorded across the country as shown in Figures 3, 4, 5 and 6 respectively.

The rainfall during 1971 to 2000 (Figure 4) fluctuated around the overall average (1100.02 mm) in Bohicon. It rained an average of 1078.52 mm / year over this period. On the other hand, from 2001, we observe that the rainfall exceeded the average. The average rainfall was 1231.66 mm against 1078.52 mm during the first period. From 2001, it began with more rain than usual in Bohicon. It is also warmer than in previous years. The periods 1971 to 2000 and 2001 to 2008 therefore deserve to be taken apart, to show the actual existence of climate change. This result is consistence with those of IPCC which reported that the current climate changes have been observed from the 2000s.

The average rainfall in Natitingou (Figure 4) was 1270.33 mm per year between 1994 and 1999 against 1098.4 from 2000 to 2004. These results showed that from 2000 the precipitation has significantly reduced in this locality. The same trend of results was obtained with meteorological data from ascena on rainfall at Zagnanado (Figure 5). In this locality, from 1986 to 1989, 1994 to 1998, and 1999 to 2000 the graph 5 show that there was high precipitation but from 2000 significant

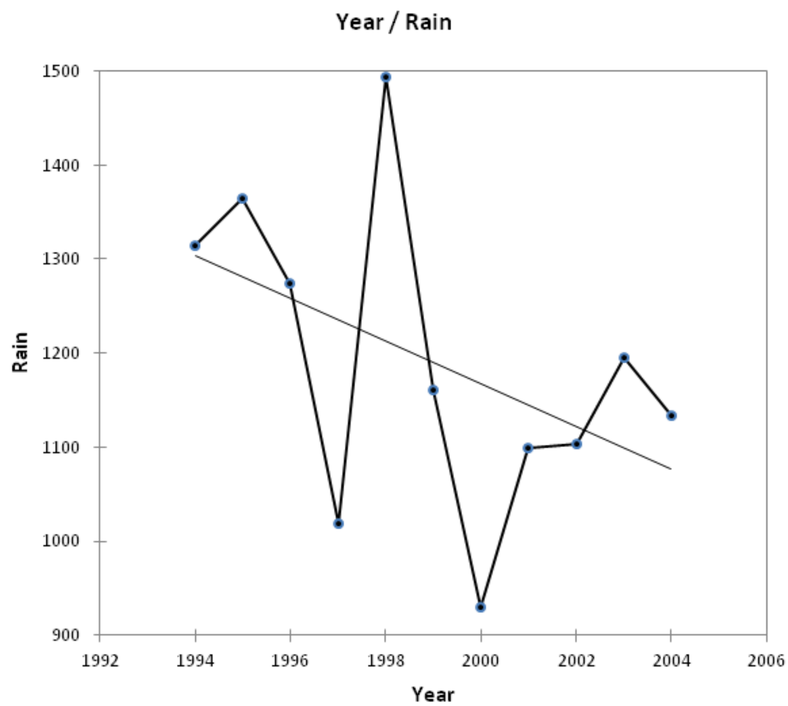

Figure 4. Annual average rainfall from 1994 to 2004 in Nattitingou.

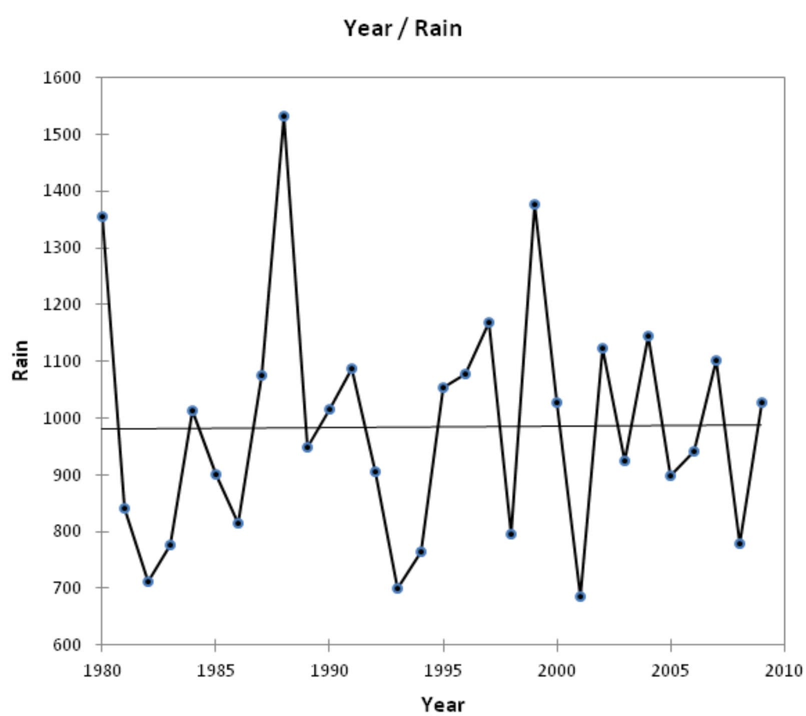

Figure 5. Pluviometric diagram of ASECNA data from Zagnanado (1980 to 2009).

reduction in rainfall was observed. Figure 6 shows monthly rainfall in 2007, 2008, 2009, and 1968 to 2008. The total rainfall in March 2009 was 32.2 mm in 3 days VS 72 mm as the total rain in the month of March 2008. The total rainfall from January to March 2009 was 48mm VS 75.5mm in 2008. The average rainfall from 1968 to

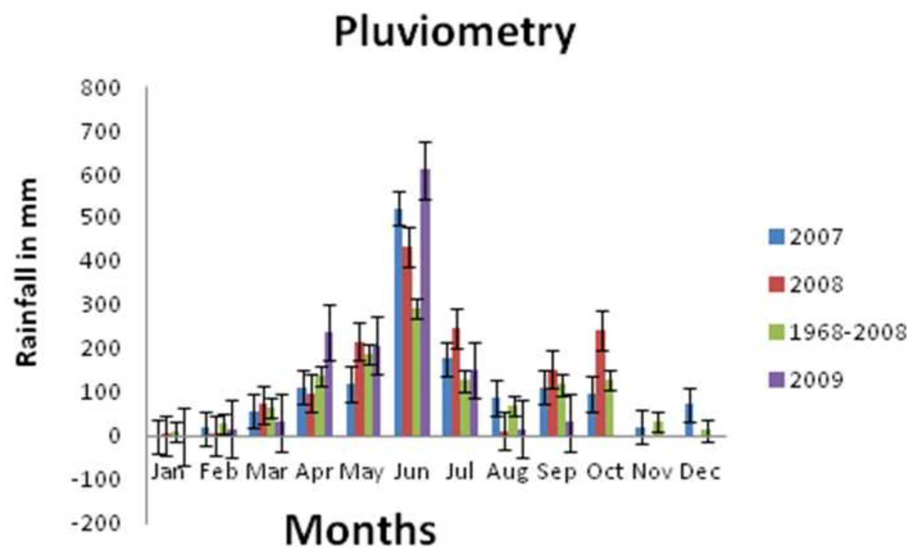

Figure 6. Monthly Rainfall 2007 versus2008 versus 2009 versus 38years in Cotonou.

2008 was 34.84mm. There was heavy rain in June 2009 when compared to other years but the rainy season was short (4months) compared to others years. The results demonstrate that the annual rainfall decreased as the years go on.

The Observation on rainfall in the Save (central part of the country) this year is alarming because the rainfall stopped in June and most farmers who grew maize, tomato, other crops lost their production to the drought which came suddenly. The rain started again in late September to last for just three weeks. Absence of rain leads to drought which implies significant losses of yield and production. This year, there is no water in the rivers for irrigation in order to grow crops in dry season.

Salinity

In our previous study on impact of salinity and flooding along the coastal areas of Benin it was revealed that: (1) The coast of Benin lies on a wide bay in the Gulf of Guinea called the Bight of Benin, about 125 km between Togo and Nigeria covers part of the cultivable lands of the country; (2) salinity and flooding cause unfavorable conditions that restrain the normal crop production (personal communication).

The factors that contribute significantly to salinity were soil salinity, wet breeze from high tide especially between June and September, and direct watering of crop with saline water. The wetted foliage of growing tomato absorbed the salts directly. The results also show that salinity in the coastal areas of Benin affects tomato growth, leaf length, and number of leaves, which reduces yields and in severe cases total yield is lost. Producers in the areas affirmed that wet breeze has been increased and are compelled to move far away from the sea for those who have much land to avoid crop failure.

Meanwhile those who were not natives continue to face the problem but by providing some temporary solution through the setting of palisades and avoidance of planting crops during the period when the wet breeze is high. Due to heavy loss in crop production some producers have abandoned their fields in favor of fishing. Producers have self-observed the changes in climate over a period of time i.e. they mentioned a significant differences between nowadays climate and past climate. Global warming is predicted to lead to thermal expansion of sea water resulting in a rise of sea level which may range from 0.1 to 0.5 m (4 to 20 inches) according to present estimates of the Intergovernmental Panel on climate change (IPCC, 2007). The increase in the level of sea and the high irrigation of water will definitely bring out high salinity in the coastal regions in Benin.

The producers in the areas were not educated enough to predict climate change and agricultural extension officers have not been able to teach them adaptive measure to overcome adverse effects of climate change on crop production and train farmers on how to adjust timing of sowing in the field.

Owing to the short period of rain in the northern parts (Kandi, Karimama, Malanville districts etc) of the country, irrigation system has been extensively applied to agricultural lands which will result in salinity in a long run due to the accumulation of toxic compounds in the soils. Moreover, the survey carried out on soil salinity showed that the entire Avlo district and part of Gbahoué district in the commune of Grand Popo have high soil salinity unfavorable to the production of market gardening and other crops.

Henceforth, producers in the regions do not grow vegetable any more. François and Maas (1994) reported that it is estimated that worldwide about 20% of cultivated lands and 33% of irrigated agricultural lands are affected by high salinity. The causes of salinity can be natural, clearing of the natural vegetation, or irrigation. Plant sensitivity to salt stress is reflected in loss of turgor, growth and yield reduction, wilting, leaf curling and epinasty, leaf abscission, decreased photosynthesis, respiratory changes, loss of cellular integrity, tissue necrosis, and potentially death of the plant (Jones 1986; Cheeseman, 1988). Salinity also affects agriculture in coastal regions which are impacted by low-quality and high-saline irrigation water due to contamination of the groundwater and intrusion of saline water due to natural or man-made events.

Flooding

Flooding has been a major factor contributing to total and complete loss of production of crops in the recent years in our country. Many efforts have been made to develop crops resistant to biotic factors such as fungi, virus, and bacteria; at the same time nothing is done to breed crops tolerant to drought, flooding, heat, and salinity. It should be noted that breeding crops take many years before its release, thus much attention must been given to the breeding of crops tolerant to abiotic stress which will go on causing massive crop-yield losses every year as a result of climate change.

In our study carried out in the six departments of the south, in Benin Republic namely: Plateau, Ouémé, Littoral, Atlantique, Mono, Couffo, producers affirmed that there is always total crop-yield losses during flooding even waterlogging. None of the producers were able to harvest his crops after flooding. Excess rainfall causes 100% yield losses of crops such tomato, pepper, carrot, maize, beans according to the farmers. But unfortunately, this recurrent problem has not been drawing breeders ‘attention in the country to tackle it in order to provide lasting solution or mitigate it to a certain extent. For instance, Benin Republic that is thought previously not to be vulnerable to flooding has been devastated by 2010 flooding. The two-third of the country has been affected and all the growing crops in the regions were swept off by flooding. There has been flooding which has more rains fall in short periods and with longer gaps between, this is observed in the center of the country. The increase in soil erosion which results from heavy rainfalls will negatively affect soil fertility.

Vegetable production is often limited during the rainy season due to excessive moisture brought about by heavy rains (Peña and Hughes, 2007). Most vegetables are highly sensitive to flooding and genetic variation with respect to this character is limited, particularly in tomato. In general, damage to vegetables by flooding is due to the reduction of oxygen in the root zone which inhibits aerobic processes. The severity of flooding symptoms increases with rising temperatures; rapid wilting and death of tomato plants is usually observed following a short period of flooding at high temperatures (Kuo et al., 1982).

Conclusion

Climate change will negatively impact agriculture and reduce food supply. Drought, salinity, flooding, high temperature will consequently reduce crop productivity. Necessary steps must be taken to lessen the effect of climate change and avoid food insecurity in our country. To achieve this, new varieties capable of resisting drought, salinity, high temperature, and waterlogging even flooding must be created. Wild relative species are thought to be rich in resilient genes to abiotic stresses, thus a program to identify, collect and preserve the wild relative species of our crops must be carried out in order to prevent them from extinction under a variable climate.

It should be noted that, a single method is unlikely to overcome the effect of climate change. Integrated methods will be the most appropriate, effective and durable so as to mitigate the effect of climate change in Sub-Sahara Africa, the most vulnerable parts of Africa to change in climate. All hands must be on desk to hope avoiding food insecurity in our country because change in climate is real and will worsen as years go on. A thick collaboration amongst policymakers (government), farmers, and researchers is needed to put in place adaptive measures adequate for risks associated with climate change.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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