

Full Length Research Paper

Effect of flooding and salinity as a result of climate change on tomato production in the coastal zone of Benin

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Received 9 April, 2014; Accepted 25 July, 2014

The production of tomato in the coastal regions is affected by flooding and salinity conditions. A survey was conducted in this region to know the impact of change in climate on tomato production. Two types of flooding conditions are prevalent: flash flooding and severe flooding where water remains stagnant for weeks. The results also show that climate change is exacerbating the existing a-biotic factors (flooding and salinity) by significantly affecting tomato development, growth and yield and yield components as reported by farmers. Flooding and salinity pose a serious threat to some producers and forced them to abandon their agricultural lands in severe cases. The repeated yield losses in some other areas caused tomato producers to move from their field close to the sea to the field far away. The producers said that flooding conditions commence at the end of June till middle of August. The producers previously grew their tomato in the areas of study in May but because of repeated flooding every year they were compelled to shift their sowing calendar. A total of 16 tomato varieties were recorded in the areas of study. Gbamingbo variety was moderately resistant to flooding conditions while Aclinkonkoui and Petomèche varieties appear to be moderately tolerant to salinity due to their average performance in terms of yield and yield components.

Key words: Coastal areas, tomato production, flooding, salinity, climate change.

INTRODUCTION

In recent years, global warming and its effect on crop production has become perceptible. As a matter of fact, agriculture is highly sensitive to environmental factors and weather extremes, such as flood, salinity, temperature and drought (de la Peña and Hughes, 2007). Human activity has already changed atmospheric characteristics

and such trends are expected to continue which will pose many problems to agricultural production and farmers will be faced with a lot of challenges. Ceccarelli et al. (2010) reported that climate change that are taking place at present will have – and are already having – a negative impact on food production and food quality with the poorest

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farmers and the poorest countries most at risk. Acquaaah (2010) stated that a-biotic environmental stresses are responsible for about 70% of yield reduction of crops in production. In recent years, Benin Republic has been devastated by flooding. Two-thirds of the country has been affected and all the growing crops in the regions were swept off by floods.

Flooding, saline soil, drought, and heat are major environmental factors crops must endure and overcome in order to produce good yields. Farmers' worries about these occurrences are for good reason. They cause massive crop-yield losses every year even more, in fact, than losses from insects and weeds (Serrano, 1999). The increase in salinity and floods negatively affect crop yields beyond the impacts of mean climate change. Climatic changes will influence the severity of environmental stress imposed on vegetable crops (de la Pena and Hughes, 2007). It seems obvious that any significant change in climate on a global scale should impact local agriculture, and therefore affect the world's food supply (IPCC, 2007). Extreme climatic conditions will also negatively impact soil fertility and increase soil erosion (Brinkman, 1990). 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 about high salinity in the coastal regions in Africa and particularly in Benin Republic.

Climate change will seriously affect crop production as years go on. More erratic rainfall patterns and increased salinity caused by climate change will consequently be expected to further reduce crop productivity, and developing countries in the tropics are particularly vulnerable. In these areas, increasing salinity and flooding will be major factors limiting sustaining and increasing vegetable production. Climate change effects on Benin's agriculture are evident in the coast, particularly in valley of Ouémé and Mono. A farm investigation conducted with producers to understand socio-economic factors related to innovation needs showed that all vegetable crops grown in coastal regions of Benin republic have been heavily impinged by salinity (Ezin et al., 2012).

A large majority of new varieties currently under cultivation have been bred for improved resistance to pest and diseases, as opposed to tolerance to abiotic conditions, the primary cause of crop loss (Wang et al., 2003). Habash et al. (2009) demonstrated that plant breeding might help in developing new cultivars with enhanced traits better suited to adapt to climate change conditions using both conventional and genomic technologies.

Climate change has started influencing greatly rainfall patterns where the suitability of land for different types of crops is affected. In the southern part of Benin rainfall water remains stagnant due to severe flooding.

Moderate water movement can reduce flood damage keeping them respiring and alive. Drainage within one to two days increases the chance of plant survival.

The objective of the present study was to evaluate the impact of flooding and salinity on tomato production in coastal zone of Benin.

MATERIALS AND METHODS

Study sites

The study was conducted in the coastal regions of Benin Republic (Figure 1). All the four departments along the coastal regions were surveyed due to the fact that they are tomato producing areas. Benin is bounded by Togo to the west, Nigeria to the east, and the Bight of Benin to the south. Benin's latitude ranges from 6°30' N to 12°30' N and its longitude from 1° E to 3°40' E. The climate is of equatorial type with alternation of two rainy seasons (April-July and August end-November) and two dry seasons. Annual rainfall in the coastal area averages 1,360 mm. From December to January, there is harmattan: a dry and dusty West African trade wind.

Data source

The local governmental centers for agricultural development in the areas of study were identified and were approached to get information on tomato producers in the district. Then quantitative and qualitative data were collected through sampling method using questionnaires. Structure questionnaire was used in this study.

Sampling and data collection

During the exploratory phase, the production sites were visited. Group interviews were conducted with producers in different villages and cities visited to gather general information on the effects of flooding and salinity on tomato production. Additional information was obtained from local governmental centers for agricultural development on tomato production and the producers in each district surveyed.

Data were collected from 130 respondents of tomato producers. The respondents were selected randomly in each district. The in-depth survey was conducted based on interviews, observations, and structured questionnaires. Parameters such as gender, age groups, education level, social status, number of dependents, credit accessibility, agricultural technician's support obtained, input use, the number and diversity of cultivated varieties, land availability, cultivated area, cost price, effects of flooding and salinity on growth, development and yield of tomato, salinity and flooding control strategies, etc were collected.

Data analysis

Data collected were processed in Microsoft Access 2003(11). Then, the entered data were verified in order to avoid errors and inconsistencies. Descriptive statistics were essentially used in analyzing the data. Standard deviation, percentage of age, sex, education level, social economic status, input use, land availability, cultivated areas in 2011, and cost price were computed through descriptive statistics. SPSS (Statistical Package for Social Science) was used for descriptive analysis, correlation of independent variable.

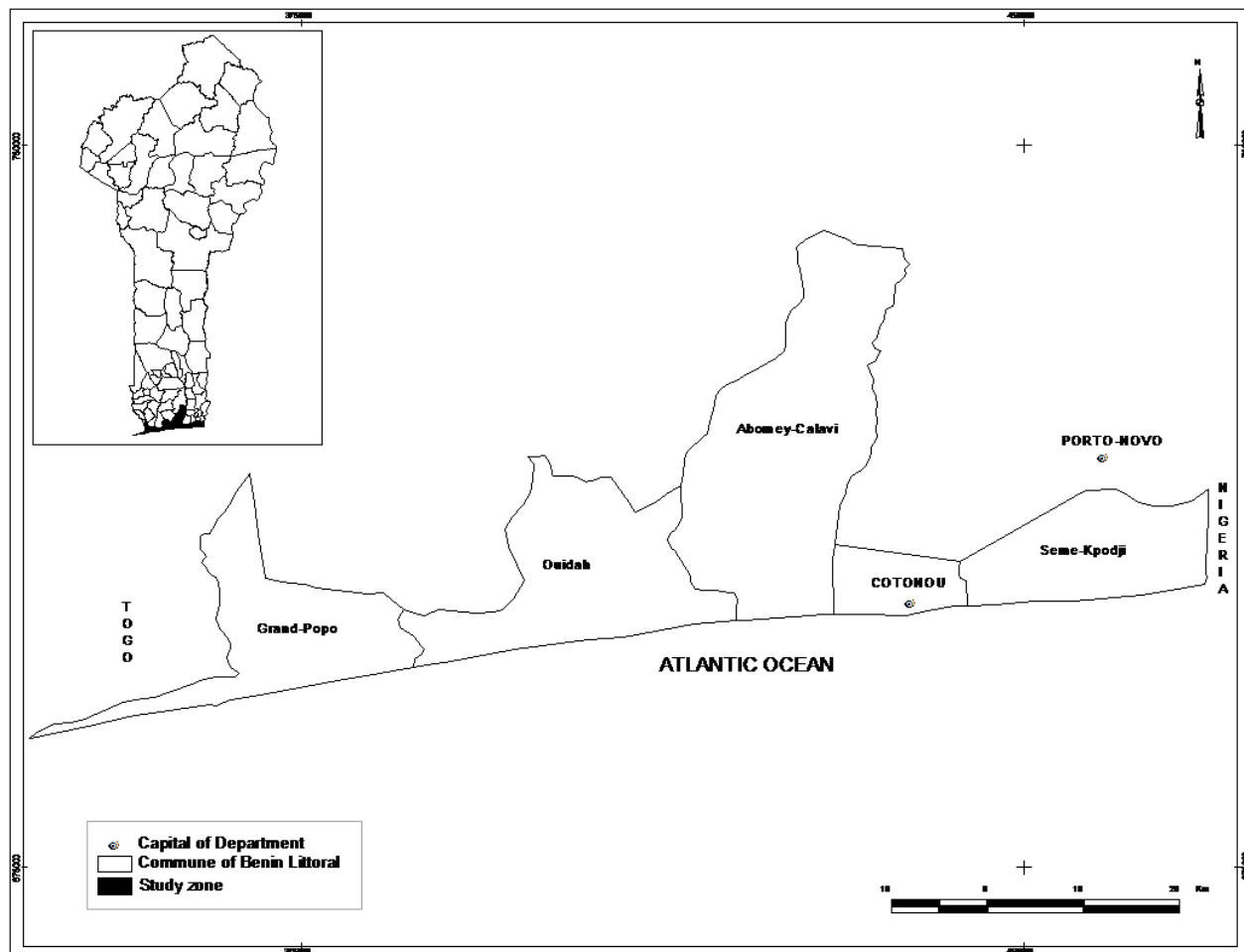


Figure 1. Benin Republic map and communes investigated.

RESULTS AND DISCUSSION

Coastal areas

The coastal regions (Figure 1) play a vital role in Benin economy. There are three main activities in the area: (1) agriculture is practiced in all the coastal areas while livestock is only practiced in Sèmè district, (2) Fishery is practiced throughout the coastal areas and has been a lucrative activity (3) the only sea port is in Cotonou city and is of huge important for Benin economy development.

Flooding and salinity have been a problem for agriculture activities. Over the last decade, many houses were lost due to flooding of sea water especially in Cotonou. Unfortunately, the protective embankment along the coastal areas that the government launched 4 years ago has failed due to lack of funding. Only 2 km out of 125 km was done. This protective embankment with big stones could help to some extent to prevent further loss of lands due to flooding of sea water.

Two types of lands characterized the areas of study: lowlands and medium lowlands. Most of lands encountered are low lands. Low land (75%) is higher than medium land (25%).

Characteristics of the respondents

The randomly selected respondents were tomato producers but occasionally some do the fishing. From the 130 respondents 82.5 and 17.5% were male and female, respectively. About 71.5% of producers were less than 45 years old, 24.2% from 45 to 60 years old, and 4.3% more than 60 years old.

The average cultivated lands for the production of tomato ranged from 1.3 to 0.75 ha. The production of tomato provides with the majority of farmers (59%) an annual income of less than 700000F CFA. Tomato contribution to annual income represents 1 to 65%. The average size of the household varies between 6 and 12 persons. Our results are consistent with that of Adorgloh-

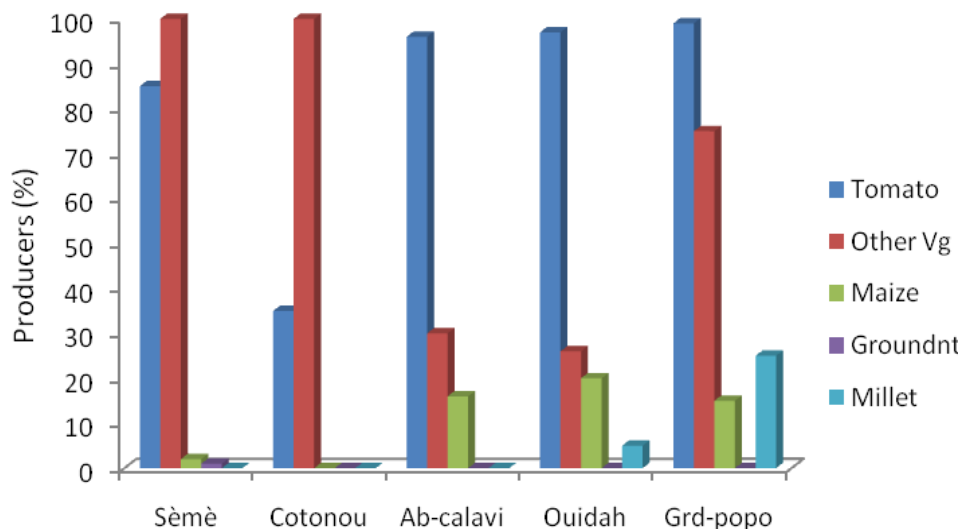


Figure 2. The main crops grown in the study sites.

Hessou (2006) who reported that tomato production plays a vital role in the economy of its producers in the South of Benin.

Crops grown in the area of study

Figure 2 shows the types of crops grown and demonstrates that tomato was grown in all the communes investigated. All the producers surveyed in Abomey-calavi, Ouidah and Grand-Popo mainly cultivated tomato while in Sèmè and Cotonou other vegetables are majorly produced when compared with tomato. Similarly, FAOSTAT (2012) reported that tomato crops are produced in urban and peri-urban areas of Benin.

Tomato varieties cultivated

Sixteen varieties were recorded in the communes investigated during our study: tounvi, gbataki, aclinkon, kekefo, pomme, adaka, gbamingbo, sonafel, ouaga, karaibo, ps royal, petomèche, mongal, tropimèche, 3fs and Brondelle. According to the respondents, ouga, ps royal, petomèche, mongal, tropimèche, 3fs, karaibo and Brondelle were imported from Ghana recently. Aclinkon, gbataki, kekefo and tropimèche were recorded in Cotonou; gbamingbo, kekefo, sonafel, adaka, tounvi in Abomey-calavi; Brondelle, tropimèche, ps royal, petomèche, 3fs, tounvi, karaibo in Ouidah, and other varieties Grand-popo, Sèmè et others.

Flood from 2010 to 2013 in Benin

The impact of climate change on abiotic stress such as flooding has been remarkable over the past five years. The flooding that has been occurring since 2010 is

dramatic and devastating. In 2010, the following areas (Figure 3): Ketou, Zangnanado, Ouinhi, Adja-Ouere, Bonou, Adjohoun, Akpro-missereté, Dangbo, So-Ava, Abomey-calavi, Sèmè-Kpodji, Cotonou, Ouidah, Grand-popo, Come, Kpomassè, Athiéme, Lalo were seriously affected. More than 130,000 hectares of crops were lost due to the heavy flooding across the country. All the tomato crops produced in those areas were damaged by the flood. Severe crops losses recorded lead to food insecurity and high food price. Some farmlands in those areas are still uncultivable. Our study is consistent with that of Khan et al. (2012) who reported that recent year of flooding in Hoar areas of Bangladesh were severe and damaged agricultural crops in a large amount. They further stated that 2010 flood in this region severely damage huge amount of agricultural production. Cumhur and Malcolm (2008) reported that environmental factors such as flooding will negatively impact agricultural crops.

Municipalities and communes of Lokossa, Bopa, Athiéme and Cotonou, were most affected by flooding in 2011 leading to the destruction of farmland and crops. Our results are in agreement with that of Thomas and Prasad (2003) who reported that the modified environment resulting from global warming and climate change, will drastically affect the production and productivity of food crops.

In 2012, the southern and the northern parts of the country were severely impeded by flooding causing the destruction of crops and farmlands. In each case, many lives were lost and roads and infrastructures devastated. As years go by the flooding is a serious problem in Benin causing food price to rise even in the rain season where the price of commodities is supposed to come down. The effects of flooding have significantly increased and get worsened as a result of climate change. Atkinson et al. (2008) reported that climate change will impact negatively food production, food quality and food security. Altieri and

Areas affected by flooding

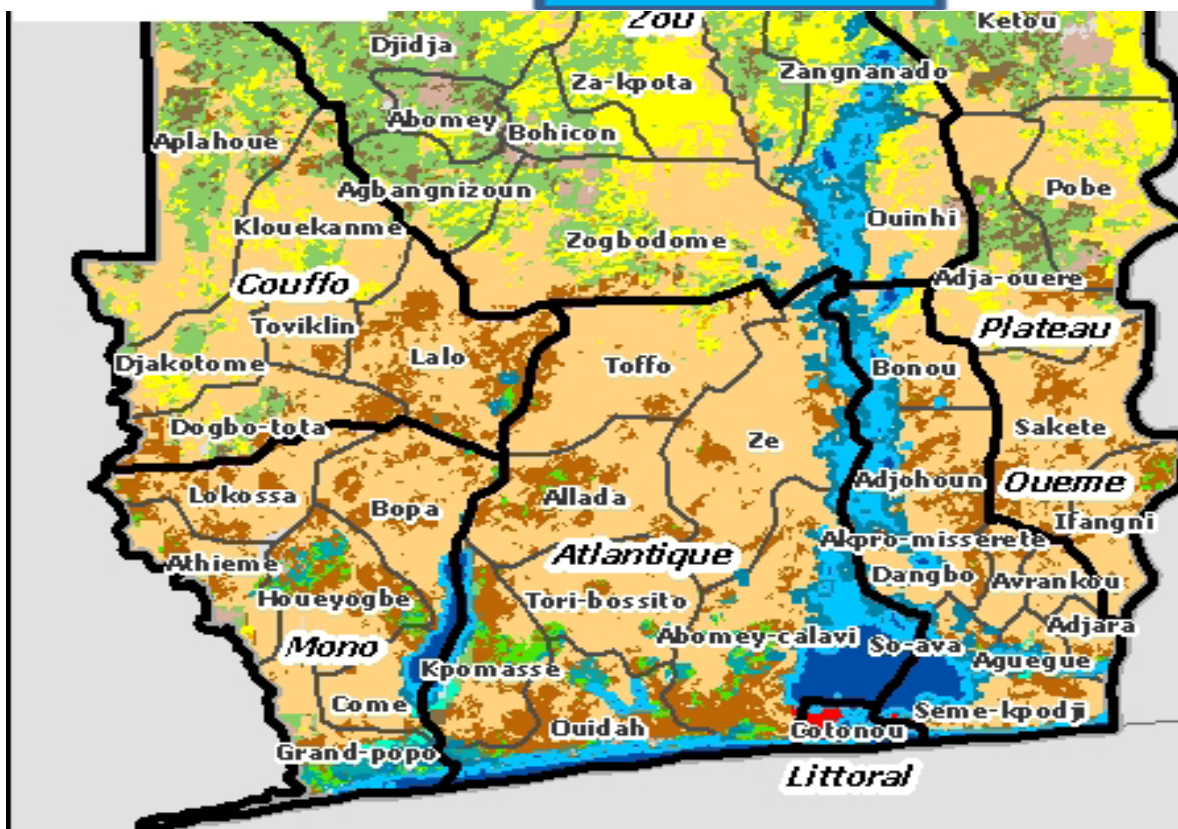


Figure 3. The villages and cities affected by flooding in 2010 and 2011.

Koohafkan (2003) also stressed that food security is potentially in danger than ever before.

Types of flooding

Most of tomato producers (87.3%) investigated said that flooding of their crops is mainly due to rainfed flood while 12.7% of respondents said it is due to ocean storm and tidal waves. They further stated that it does occur from the end of June till middle of August. The producers grew their tomato in the areas of study in May but because of repeated flooding every year they have shifted the sowing calendar. Till 2008, they still grew tomato in May but from 2011 their planting period has been August in order to avoid heavy rainfed flooding and losses of their crops. It is obvious to everybody now that climate change is occurring and the threat has become real and the question about this climate change occurrence is how to cope with it. Sidi (2012) reported that the flooding of September and October 2012 in Nigeria disrupted various sectors in the country and damaged crops like cassava, rice, yam, maize and tuber crops.

All the respondents acknowledged that due to flooding of sea water, a lot of lands were lost and the sea is progressing at alarming rate.

Flood damages tomato crops

According to tomato producers, flooding conditions caused the reduction of plant height and yield, total crop failure, yellowing of leaves, fruit rot and reduction of tomato market value and death of sensitive varieties. The same results were obtained by Kramer (1951), Kozlowski (1997), Núñez-Elisea et al. (1999), Ashraf (2003), Walter et al. (2004) and Ezin et al. (2010) who stressed that 2 days of flooding caused reduction of plant height, wilting, leaf senescence, yield reduction and 8 days of continuous flooding lead to the death of tomato genotypes.

As shown in Figure 2, tomatoes and vegetables are the main crop grown in the areas of study. All of the tomato producers surveyed said that tomato and other vegetables were devastated by flooding. Table 1 show that only Gbamingbo is moderately tolerance to flooding amongst the 16 tomato varieties recorded. Farmers

Table 1. Evaluation of tomato varieties by farmers.

variety	Flooding effects	Salinity effects
Brondelle	Sensitive	Sensitive
Gbamingbo	Tolerant	Sensitive
Aclinkonkoui	Sensitive	Moderately tolerant
Kekefo	Sensitive	Sensitive
Touinvi	Sensitive	Sensitive
Gbataki	Sensitive	Sensitive
Sonafel	Sensitive	Moderately tolerant
Petomèche	Sensitive	Moderately tolerant
Ps royal	Sensitive	Sensitive
Mongal	Sensitive	Sensitive
tropimèche	Sensitive	Moderately tolerant
Ouaga	Sensitive	Sensitive
Adaka	Sensitive	Sensitive
3FS	Sensitive	Sensitive
Pomme	Sensitive	Sensitive
Karaibo	Sensitive	Sensitive

further said that severe flooding kill Gbamingbo variety as well. The other tomato varieties are very sensitive to flooding even 2 days of flooding are enough to damage them or render them unproductive. At 3 to 4 days of flooding, the performance of tomato varieties including Gbamingbo was poor and farmers failed to harvest tomato crops in the field, that is, there was complete crop failure.

Normally as from June the price of tomato, the most consumed vegetable, is affordable even to the poor households but unfortunately the price of tomato across the nation is still high for many reasons. On the one hand, the farmlands affected by previous flooding are yet to be available for crop production, and producers have shifted their sowing calendar due to the fact that across the country precipitation patterns have changed. On the other hand, the supply does not meet the demand due to the growing population.

In the recent survey conducted in June in the areas of study, due to the cultural practices put in place by farmers to avoid the deleterious effects of flooding on tomato, they are growing maize in the lands which were used for tomato production 4 years ago. The adjusted timing of sowing allows producers to steer clear of the flooding conditions but it is not beneficial to people who are expecting affordable tomato price. Therefore, adequate measures must be taken to avoid food insecurity now that climate change is inevitable. This study is similar to that of Sasson (2012) food security for Africa which is an urgent global challenge.

Salinity

Out of the 16 varieties recorded, only aclinkonkoui, petomèche and sonafel (Table 1) were moderately

tolerant to salinity while the other varieties are sensitive. The key hindrance to the increase of crop production in the coastal areas is seasonally high content of salts in the root zone of the soil (Haque, 2006). In our study, the wet breeze from high tide and soil salinity were limiting factor to normal production and high yield as reported by farmers. For this study, soil samples were not collected and analyzed in order to determine the electrical conductivity.

Figure 4 illustrates the annual income of some tomato producers. Field 1 is the field where tomato was grown close to the sea while field 2 is where tomato was grown far away from the sea without the effect of salinity. From the graph annual incomes recorded in field 2 were significantly higher than those obtained and recorded in field 1. This indicates that salinity reduced the yield of tomato and lead to the reduction of tomato market value and consequently low income. In the last survey carried out some farmers have abandoned some fields where they produced tomato 4 years ago due to the repeat of low yield recorded. Salinity causes unfavorable environment and hydrological situation that limits normal crop production throughout the year (Haque, 2006).

Solutions used by producers to alleviate salinity effects

Farmers are still using their former methods to mitigate the deleterious effect of salinity on tomato production along the coastal regions despite the fact that climate change get more severe with time. They expressed their deception on the lack of improved varieties which could withstand the effect of climate change. Three different methods: fence with palisade (Figure 5), fence with maize/sorghum and intercropping are still employed to alleviate the effect of the tidal breeze loaded with salt which settled on tomato production in the coastal areas of the country. Most of the respondents (60%) used fence with palisade while 12 and 2% used fence with maize/sorghum and intercropping, respectively, to reduce the deleterious effect of tidal breeze which constitutes a constraint for tomato production in the regions. Only 26% of producers grew tomato in an open air without any measure of protection. Well-read people were amongst the respondents investigated and said that the rising of the sea level and waves are evident to them because the strategies of the fencing with palisade is no longer as efficient as before. They further stated that the level of the sea is higher between June and September as compared to past years. In Benin, more 10% of agricultural land in the area of study got lost due to the projection of sea and soil salinity. This is consistent with the results of Nicholls and Leatherman (1995): a 1 m sea-level rise would affect 6 million people in Egypt, with 12 to 15% of agricultural land lost, 13 million in Bangladesh, with 16% of national rice production lost, and 72 million in China and "tens of thousands" of hectares of agricultural

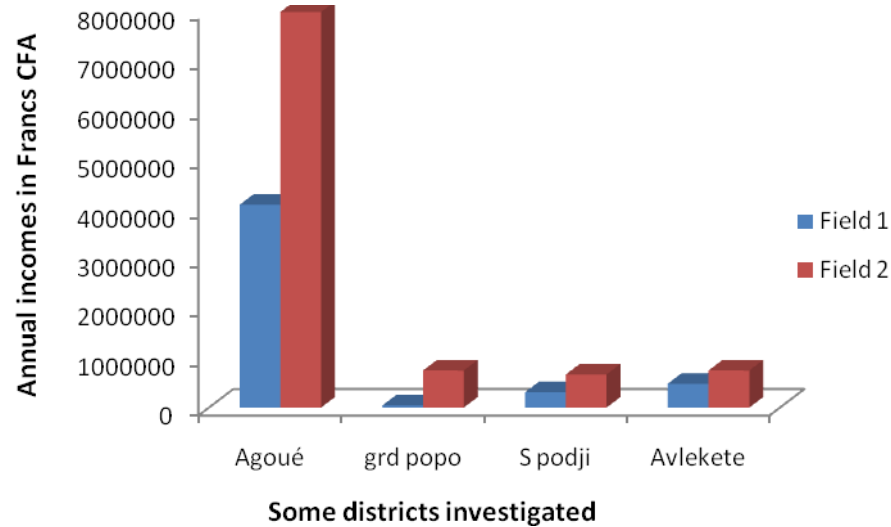


Figure 4. The Annual incomes at different locations, field 1: close to the sea and field 2: far away from the sea.



Figure 5. Method of palisade set up to abate the effect of tidal breeze

land. Tomato producers are desperate about getting other varieties which could withstand the negative impact of salinity on tomato production. Avlo district in the commune of Grand-Popo is yet to start growing vegetables and tomato in particular after they have given up their production due to high level of soil salinity.

Conclusions

The impact of climate change is real and preventive and adaptive measures must be taken to lessen its effects. Adequate cultural practices need to be adjusted and applied to avoid losses of tomato production to flooding and salinity. More tomato production is required to meet

the demand of the growing population. New tomato varieties tolerant to flooding and salinity are needed to intensify the production of tomato. Tomato varieties that are resistant to both flooding and salinity will be of great advantage to the producers in the areas of study.

Conflict of interests

The authors did not declare any conflict of interests.

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