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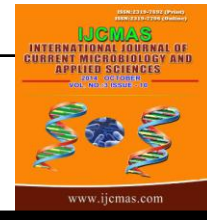


Original Research Article

Farmers' perceptions and adaptation strategies to mitigate impact of climate change scenario on sorghum production and diversity in North eastern of Benin

Innocent Dossou-Aminon[1*], Arlette Adjatin[1], Laura Yêyinou Loko[1], Alexandre Dansi[1], Vilas Tonapi[2], Kurella Visarada[2] and Abishkar Subedi[3]

[1]Laboratory of Biotechnology, Genetic Resources and Plant and Animal Breeding (BIORAVE), Faculty of Sciences and Technology of Dassa, Polytechnic University of Abomey, 071BP28, Cotonou, Benin
[2]Directorate of Sorghum Research, Rajendranagar, Hyderabad-500030, India
[3]Centre for Development Innovation, Wageningen UR P.O. Box 88, 6700 AB Wageningen, The Netherlandsth
**Corresponding author*

Keywords

Farmer perception, climate change, sorghum production, varietal diversity loss, North eastern Benin

A B S T R A C T

Agriculture is the main activity and source of income for rural communities in Benin and contributes actively to the country economy. Unfortunately, this sector, highly vulnerable to climate change, affects poor communities who depend on agriculture for their livelihoods. This study examined farmers' perceptions of long-term climate change and adaptation measures undertaken to cope its impacts on sorghum production and diversity. A total of 15 villages and 300 sorghum farmers were randomly selected and interviewed. The main instrument used in this study was questionnaires, helped to identify the issues on climate change in the area. The study showed that farmers have good perception of climate change (high temperature and rainfall fluctuation). These perceptions were correlated with meteorological data recorded. The most important impacts of climate change were low productivity, soil poverty, increase in insects' damage and diversity loss. The best adaptive strategies used by farmers to mitigate these impacts were growing of drought tolerance varieties, utilization of fertilizers, rotation and/or association of crops. The study results call attention of breeders and policy-makers who must create an enabling environment to support farmers' adaptation to climate change by increase access to resistant/tolerant sorghum varieties, information, credit and markets.

Introduction

In addition being an important staple food for millions of people, sorghum is a feed and forage crop grown in the semi-arid tropics of Asia and Africa. Sorghum is a cereal crop which has capability to produce even under water deficit conditions with limited soil fertility that makes it an important grain crop across global agro-ecosystem (Zegada-Lizarazu and Monti, 2012; Kausar et al. 2014). It is a nutritious cereal as a major source of energy (349 kcal in 100 grams of Sorghum), protein, carbohydrates and phosphorus (ElHag et al. 2013). It is cooked as porridge for breakfast or along with other dishes and has a good amount of calcium with small amounts of iron and sodium. For many years sorghum was the staple diet of Africans, and from approximately the early part of the twentieth century, maize gradually replaced sorghum (Isaacson, 2005).

Agriculture is the most important sector of the economy in Benin provides food and livelihood security to most of the population and plays an important role in national security and development. However, in Benin, sorghum (second important cereal of the country after maize) cultivation has declined very significantly over the past few decades. This could be primarily due to very low productivity, late maturing of local varieties and susceptibility to biotic and abiotic factors (Dossou-Aminon et al. 2014). Among abiotic stresses, drought and soil poverty are two major problems to agricultural land (Kausar et al. 2014; Dossou-Aminon et al. 2014).

One of the main causes of household food insecurity in Benin is the menace of agricultural production failure due to drought, high temperature and gale force wind, resulting in reduced harvest and farmers' income (Jalloh et al. 2013). More than 75% of factors affecting sorghum production and genetic erosion in the North eastern of Benin are related to climate variability (Dossou-Aminon et al. 2014). Therefore climate is one of the key components influencing agricultural production in Benin and has large-scale impacts on sorghum crop production. Understanding farmer's perceptions and knowledge in the presence of climate changes and environmental degradation designed to reduce a major source of production constraints is thus essential in designing an effective strategy for intensifying agricultural production.

The impact of climate change on agriculture has recently become a subject of increasing importance (Dhaka et al. 2010; Loko et al. 2013). In order to improve the ability of communities and households to adjust to ongoing and future climate change, a better understanding of the risk and identification of potentially useful practices by farmers is important to estimate future adaptation to climate change impacts.

This study undertakes to determine the ability of farmers to detect climate change and to ascertain how they have adapted to mitigate climate change risk on sorghum production and diversity. Therefore, the aims of the present research were to:

- Understand farmers' perception and experience of climate change in North eastern Benin;
- Evaluate long-term climate data (on precipitation and temperature) in order to determine variation in climate at the study area;
- Identify the impact and adaptive measures used maintain sorghum diversity and production in North eastern Benin.

Material and methods

Location

The study was conducted in the North-East of Benin which occupies a total land area of 52,098 km2 (46% of the total land area of Benin) with a population of 1.87 million people (INSAE, 2014). This region lies between latitudes 8°50' N to 12°50' N and between longitudes 2°15' E and 3°45' E.

The climate is tropical with a dry season from November to April and a rainy season from May to October (Jalloh et al. 2013). Average annual rainfall in this area varies between 805 and 1200 mm $year^{-1}$ (Adomou, 2005; Vissin, 2007). The flora is very diverse according to the climate and the land extensions. In this part of the country, agriculture is the main activity and the source of community livelihood.

Data collection and analysis

Fifteen villages were randomly selected for this study throughout the region. The study was based on focus group discussion, individual interviews survey and field observations as per Loko et al. (2013) and Nhemachena et al. (2014). Data were collected using a well-structured questionnaires and participatory research approach following Loko et al. (2013). Per village 20 to 40 sorghum producers of both sexes and different ages (at least ten years' experience in sorghum production) were identified and gathered with the help of village chief for the group survey. In each village a local translator was identified to facilitate the discussion and exchanges with farmers. Throughout the discussions, data collection was focused on farm history, memory of extreme climate events and the impact of more frequent anomalies in the village and community management responses to those anomalies (Tidjani and Akponikpe, 2012; Loko et al. 2013).

In all, three hundred sorghum producers (20 per village) were selected using transect method described by Dansi et al. (2010) as respondents to analyse the perception, understanding and local knowledge of climate change and variability at household level (Loko et al. 2013). Semi-structured questionnaire was used to enquire farmers whether they have noticed long-term changes in temperature, rainfall, relative humidity, gale force wind and change in natural resources over the past 50 years after recorded socio-demographic characteristics (sex, age, year of experience in sorghum production of the interviewee, number of people in the household, labor employed and size of area cultivated by the household). Questions included to investigate the impacts of climate change on sorghum production and varietal diversity, adaptations strategies adopted by the farmers to mitigate and cope with these changes following Dhaka et al. (2010).

Rainfall and temperature data in the study area over the past 50 years (1960 - 2010) following Gnanglè, (2009) were collected from Benin Department of Meteorology ASECNA (Agency for Safety and Air Navigation) for comparison between farmers' perception and scientific climate data.

The data collected from both meteorological stations and field survey were entered and analysed using descriptive statistics (mean, frequencies) with Stata SE version 10.0 software and Microsoft Excel 2010. The results were presented as tables and figures (Loko et al. 2013; Nhemachena et al. 2014).

Result and Discussion

Socio-demographic data

Population of sorghum farmers surveyed was mostly consisted of men (95%). The age of sorghum producers varied from 25 to 95 years old, with an average 48 years old. The most experienced producer had 57 years in sorghum production and the less experienced 10 years. Household size (number of people in the household) varied from one to thirty-five people with an average 11 people per household. Labor employment by producers varied from 1 to 20 persons in the study area. The farmer's cultivated areas varied between 0.25 and 10 hectares with an average of 2.45 hectares per producer.

Farmer perception of a favourable climate

Majority of farmers (96.08% of responses) felt that, the weather was better and favourable for crops production in the past (figure 1). The climate is characterized by regular rain (36.42% of responses), a less blazing sun (31.82% of responses), a favourable wind (23.58% of responses) and a lower temperature (figure 1). Farmers' appreciation of the climate varied according to the climate event.

Current status of rainfall and temperature variability in the study area

More than 95% of surveyed producers have noted rainfall variability during recent last years (figure 2). Reduction of rainfall (50.36%), delayed rainfall (18.84%), early onset and termination monsoon (10.14%), decrease in the number of rain days per year and prolonged dry season (7.25%) were the most important (figure 2). Variations relative to temperature were reported by 73.78% of sorghum producers. A total of five changes in temperature were identified by the producers in the Departments of Borgou and Alibori. Among them, the most important are the temperature rise (48.76% of responses), increased of sunshine duration (24.79% of responses) and for 22.31% of responses early beginning of winter (Figure 3).

Meteorological data on rainfall and temperature of past 50 years was obtained from ASECNA (Data of Kandi station) show lower serrated evolution of the rainfall from 1960 to 2010 followed by successive decrease from 1980 to 1988, 1992 to 1997 and from years 2000 (figure 4). The minimum and maximum temperatures graphs obtained using Kandi meteorological station data show difference variation between temperatures from 1960 to 2010 (figure 5). The temperatures evolved in serrated increase with maximum temperatures in the years 1973, 1987 and from 2009 (figure 5).

Climate variability and extreme events affected the story of surveyed villages

The groups of producers surveyed have mentioned the years dominated by extreme bad weather and the important events whose manifestations are negative effects on crop production (table 1). Farmers group commonly have agreed that the major events of climate change over the last 20 years have had a negative impact on the production of crops were flood, drought and gale force winds (table 1). The major flooding incidents were observed in years 1992 and 2012 in the villages Gbassè, Kokabo, Borodarou and Djéga (table 1). This was lead to high rainfall, successive rain on short time preceded or followed by drought, rise in water level and fields submersion and crop destruction, yield lower, house collapse and increase the living cost. Drought has been reported as important event in 3 villages (Binassi, Ouari, Sékalé) in different years 2003, 2007 and 2011 (table 1). Rain started normally and stopped early and the sun had high intensity. These provoked the reduction of seed germination rate, low productivity, famine and increase in cost of food products. The gale force winds were observed during the dry and rainy seasons and were started since the years 2000 to now (table 1). Their manifestations provoke material and financial damage, destruction of panicles and decrease in crops productivity (table 1).

Comparison of meteorological rainfall and temperatures data with farmers' perception events years revealed many coincidences (figure 4 and 5, table 1). The years 2003 and 2007 reported as drought years by farmers have actually presented on meteorological rainfall data well below the average (1008 mm) in the region with high level of temperatures indicating a rainfall deficit. The rate of concordance between farmers' perceptions of drought years (2003 and 2007) and climate data is 100%. For the flooding years, farmers' perception concordance rate with the climate data is 0% since the year 1992 presented an annual rainfall of 902 mm, below the average. Generally, producers have facility to remember recent extreme climate events (less than 10 years).

Impacts of climate change on sorghum production and adaptation strategies develop by farmers to mitigate these impacts

A total of seven adverse impacts of climate change on sorghum production were recovered. Producers perceived that major impact were the lower productivity (40% of responses), soil poverty (30.91% of responses), increased of insect damage (10.90% of responses), reduction of cultivated area (7.27% of responses) and for 5.46% of responses the seed rot underground (Figure 6). As sorghum has an economic importance in the study area, farmers develop several strategies to mitigate these impacts of climate change on the production. These strategies vary according to the type and the nature of the problem facing the producer and are related to drought, flood, decrease in the quantity of rain, temperature rise and soil poverty (figure 7 and 8).

In the region, 73.7% of surveyed producers developed strategies in response to drought. A total of 5 strategies were highlighted by farmers. Among them the most used are the growing of drought resistant cultivars (55% of responses), pre-sowing on small area for transplanting after rain (15.5% of responses) and for 14.1% of responses increasing of weeding number (figure 7a). In response to the unexpected excess of rain which provoked flood, 72.9% of the farmers surveyed developed three strategies: making corridor to drain water, growing cultivars tolerant floods and harvested early (figure 7b). Eighty seven percent of producers developed strategies in response to the decrease in the rain quantity. The most important are the re-sowing (40.2% of responses), growing drought resistant cultivars (26.4% of responses) and 24.1% of responses to the early sowing (figure 7c). A total of four strategies were developed by 23.5% of farmers surveyed in response to the temperature rise. As adaptation strategy re-sowing, use of drought resistant varieties and the hoeing and ridging are most popular (figure 7d). In response to soil poverty four strategies were used by farmers. Among them the most important are use of fertilizers (biological and chemical), rotating or inter cultivation of crops (sorghum and leguminous) and weeding number increasing (figure 8).

A total of 15 strategies develop by farmers to mitigate the impact of climate change on sorghum production were recorded in the study area (table 2). The most used and the best adaptation strategies to face climate change in this region are the growing of drought resistant cultivars, utilisation of fertilizers (NPK, Urea, Compost, Cowpat, etc.), re-sowing, making corridors to drain water, growing of high soil moisture tolerant varieties, rotation or inter cultivation of sorghum crop with leguminous, etc. (table 2).

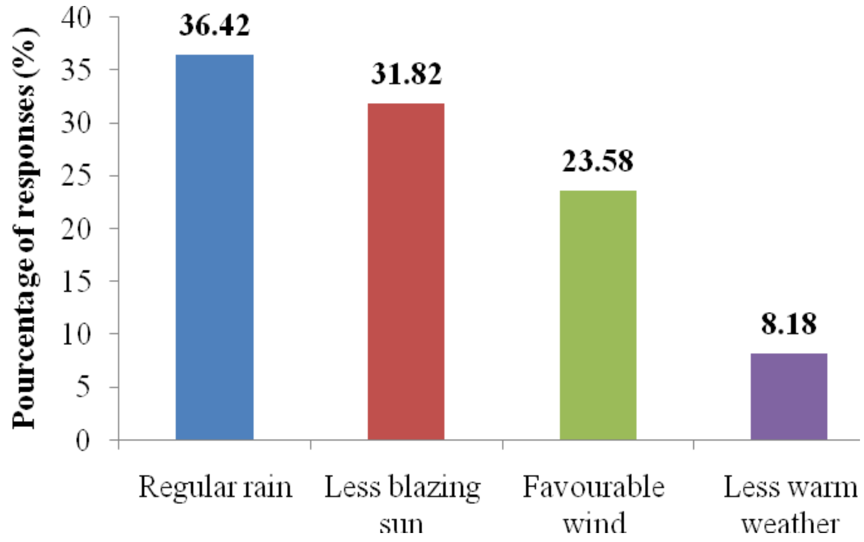


Figure.1 Farmer perception offavorable climate

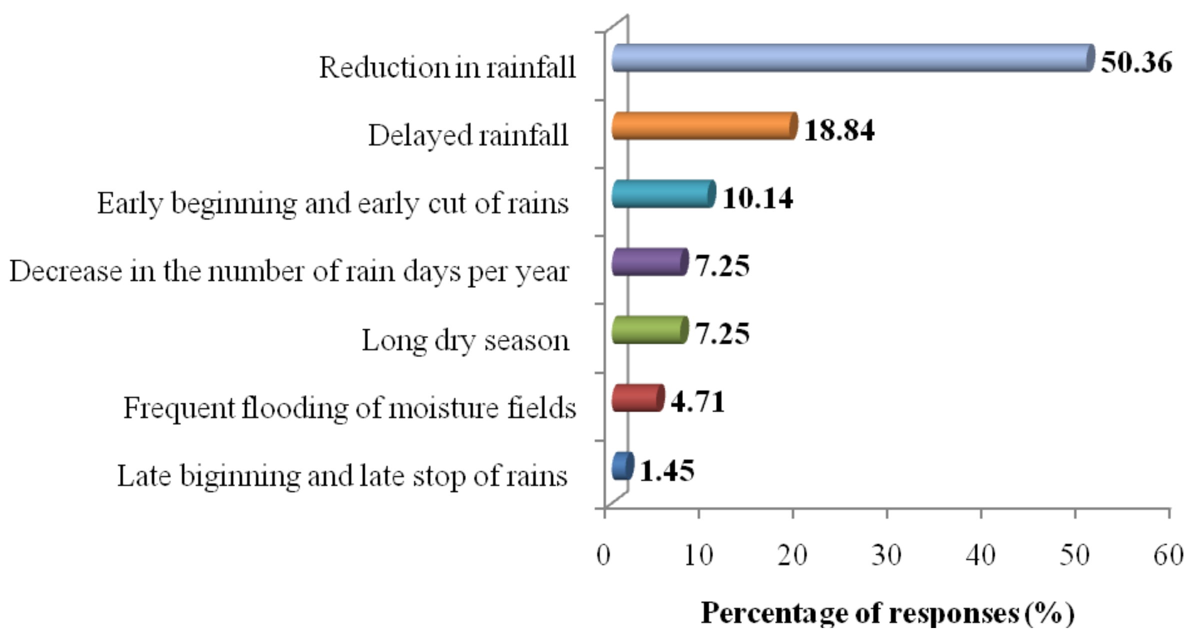


Figure.2 Farmer perception of climatevariability relative to rainfall

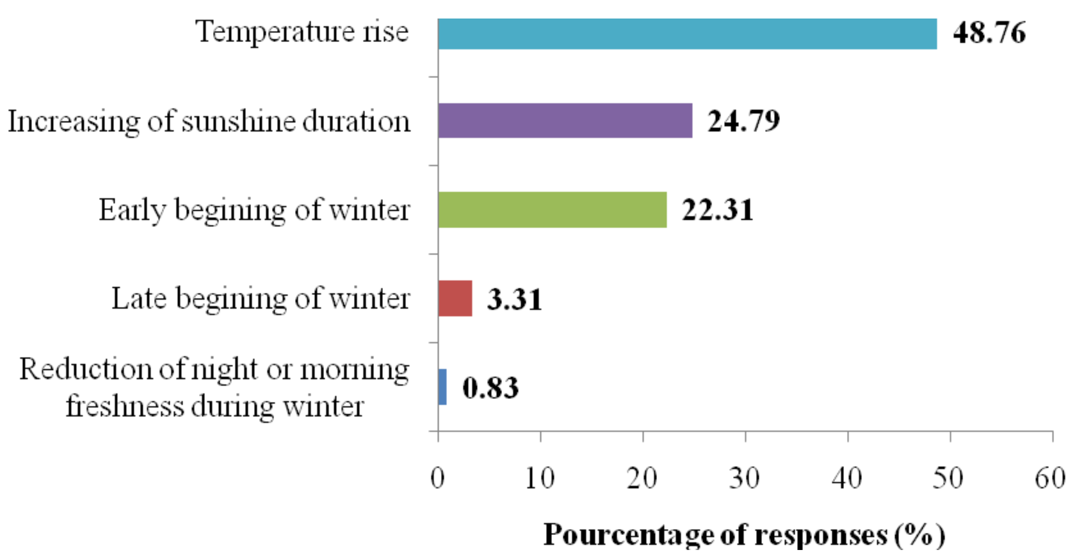


Figure.3 Farmer perception of climate variations relative to temperature

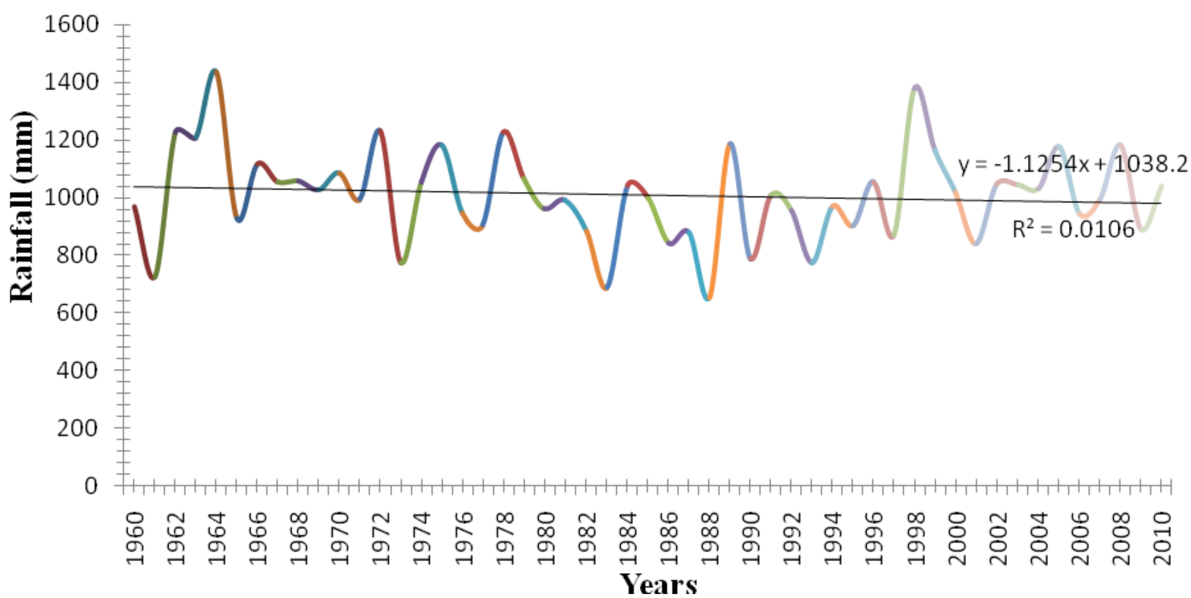


Figure.4 Evolution of rainfall between 1960 and 2010 in the study area (ASECNA Benin 2012)

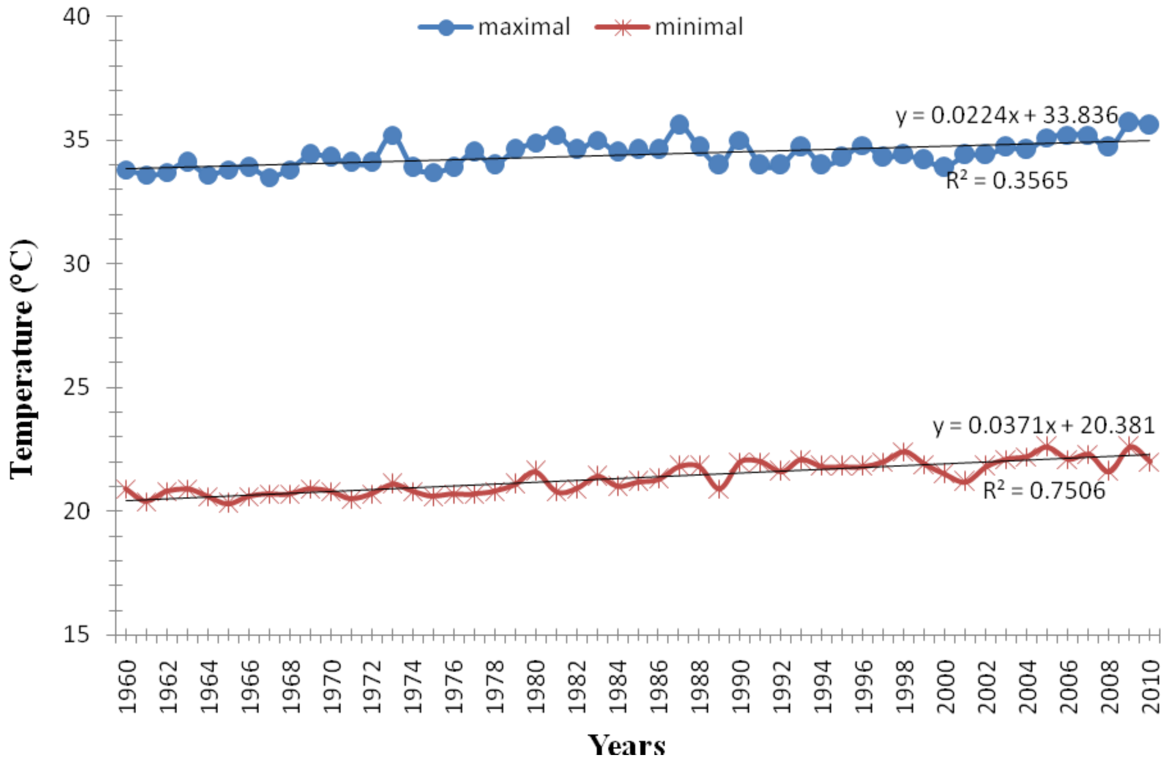


Figure.5 Evolution of maximum and minimum temperature between 1960 and 2010 in the study area (ASECNA Benin 2012)

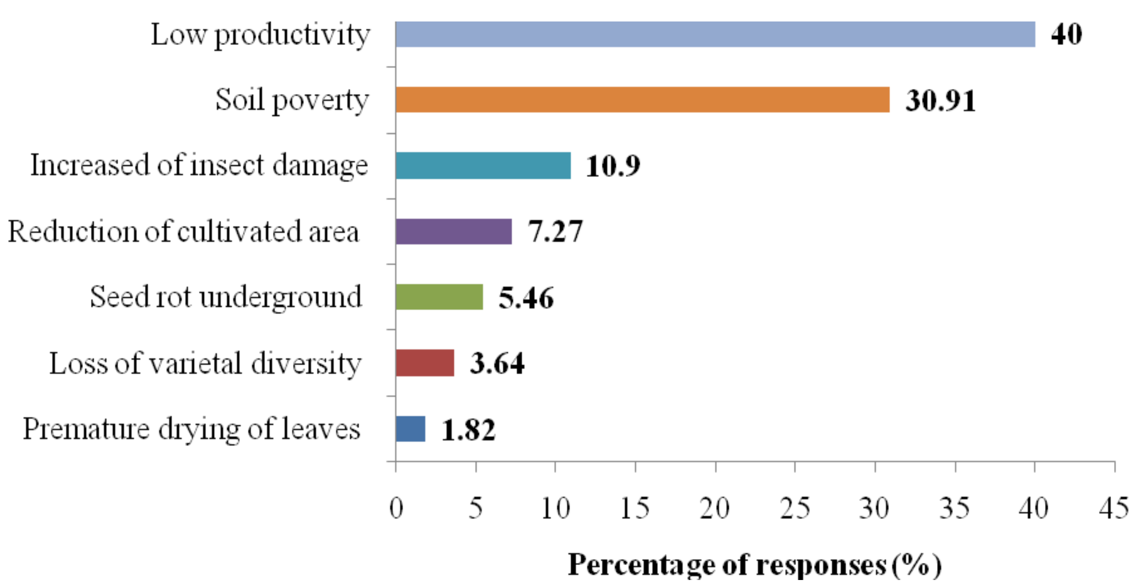
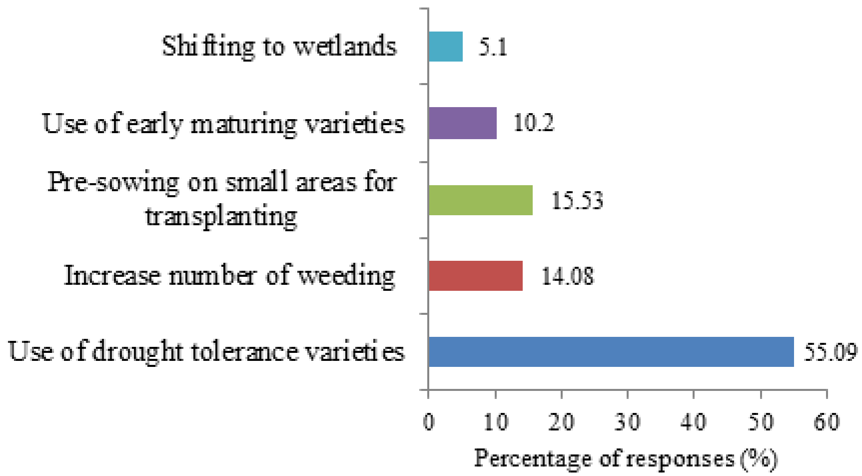
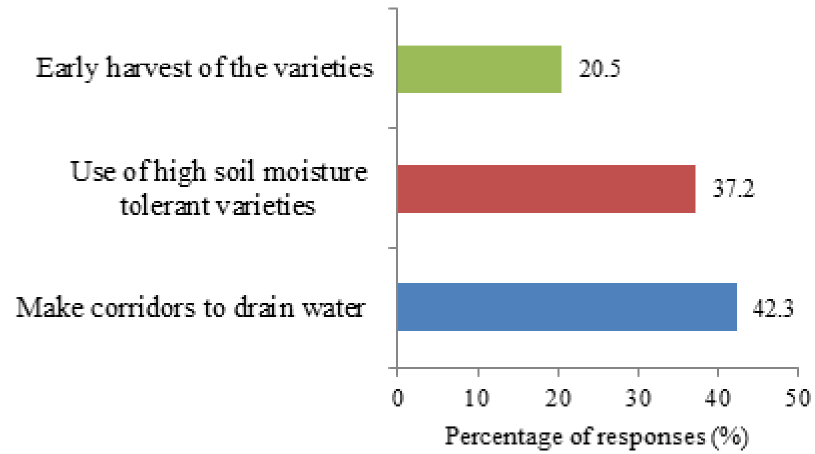


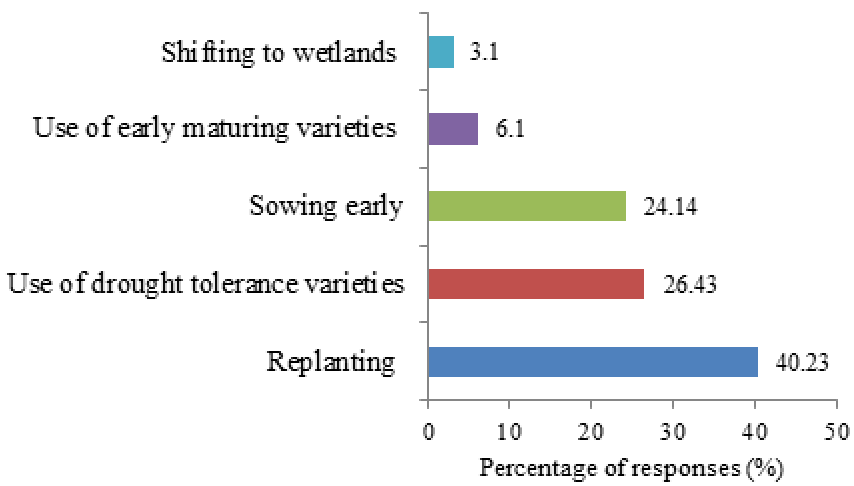
Figure.6 Farmer perception of the impact of climate changes on sorghum production



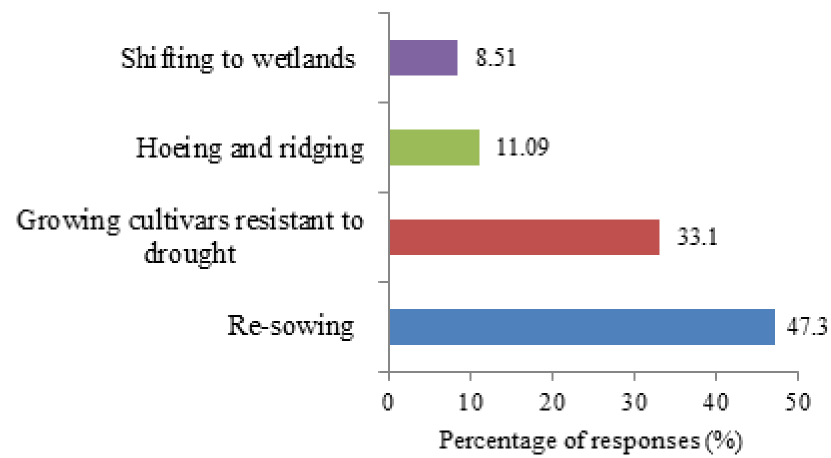
a) Adaptation strategies in response to drought



b) Adaptation strategies in response to unexpected excess rain (flood)



c) Adaptation strategies in response to the decrease in rain amount



d) Adaptation strategies in response to high temperature

Figure.7 Adaptation strategies in response to the climate variability's

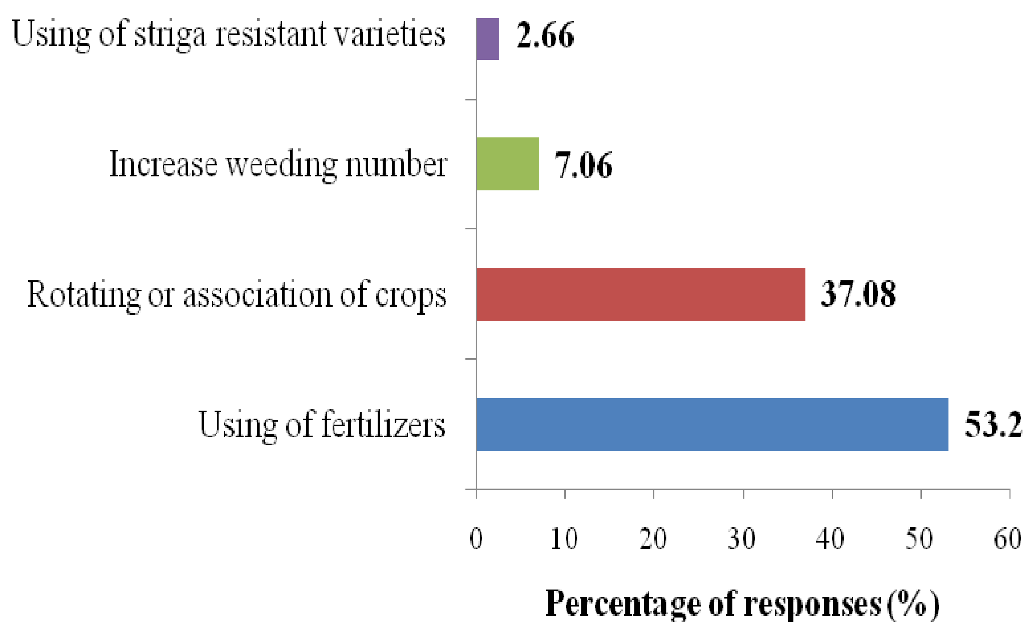


Figure.8 Adaptation strategies in response to soil poverty

Table.2 Best adaptation strategies developed by sorghum farmers in the study area

Different types of strategies	Percentage of responses (%)	Rank
Growing of cultivars resistant to drought	15.78	1
Utilisation of fertilizers (NPK, Urea, Compost, Cowpat)	14.64	2
Re-sowing	12.45	3
Making corridors to drain water	8.88	4
Growing cultivars tolerant to soil moisture	7.48	5
Rotating or association of crops with leguminous	7.28	6
Sowing early	6.64	7
Harvest early	6.28	8
Pre-sowing on small areas for transplanting	5.5	9
Increase weeding number	5.33	10
Hoeing and ridging	4.66	11
Sowing of early maturing cultivars	4.5	12
Moving to wetlands for new farm	3.18	13
Sowing Striga resistant cultivars	2.82	14
Changing of cultivated land or abandonment of fields in fallow	1.86	15

Generally climate change implies warmer temperatures besides changes in precipitation patterns, with more extreme weather events and shifting seasons (Jalloh et al. 2013). According to the farmers, weather more than 20 years ago was favorable for agriculture through regular rain and less blazing sun that resulted in high yields of cultivated crops. The present study show that current agriculture facing a reduction in rainfall, delayed rainfall, rise of temperature, increasing of sunshine duration and early beginning of winter. These changes are already affecting rainfall, its distribution and intensity in many regions. Certainly, this has direct effect on the season's timetable of crop growing with simultaneous impacts on plant growth (Thornton and Lipper, 2014). Higher temperatures involve more evaporation and probably more intense rainfall in some regions which can lead to flooding. The meteorological data from ASECNA station between 1960 and 2010 showed a gradually decrease in the rainfall and a warming trend for the temperatures. According to Jalloh et al. (2013), the variations in the average maximum temperature observed in Benin are also highlighted in the Republic of Côte d'Ivoire. The rising temperature can irreparably damage reproductive organs and young seed embryos (Hertela and Lobell, 2012) and increases sterility of plants that involve low productivity. The results of this study showed concomitant between farmers' perception and trend of meteorological data in rainfall and temperature. This result was expected since the interviewed producers are an average of 48 years old and great experience in sorghum production. Similar results were obtained in the Republic of Benin (Gnangle, 2009; Loko et al. 2013), Republic of Ghana (Fosu-Mensah et al. 2010; Kemausuor et al. 2011) and Federal Republic of Nigeria (Apata et al. 2009; Nzeadibe et al. 2011). According to previously mentioned authors' farmers with more than 35 years old and over than 30 years experiences have a good perception and appreciation of climate variability. Same observations were made by Maddison, (2006) who suggested farmers' experience as the key parameter in the documentation of indigenous perception of climate variability.

Recent years were characterized by greater interannual variability than previous 50 years. The extreme climate events recorded in the study area are droughts, floods and gale storms that lead to low productivity, loss of varietal diversity, decrease of rural community livelihood and in some cases crop failure. Globally this study showed that farmers have a good memory of recent extreme climate events. Similar results were obtained in North western part of the country by Loko et al. (2013). However, extreme climate events request attention, and these are gradually demanding prompt and credible scientific explanations.

The impacts of climate change on cultivated crops and natural systems have been highlighted in many countries including Benin (Thornton and Herrero, 2014). Sorghum like other crops crop is vulnerable to effect of climate variability as showed through the low productivity, soil poverty and diversity loss in the region. Several impacts related to climate change have been identified as affecting sorghum production and involve loss of sorghum varietal diversity and production reduction by farmers in the study area. Similar results were observed on sorghum in the Republic of Kenya (Onwonga et al. 2010) and Republic of Ghana (MacCarthy and Vlek, 2012), on maize and yam in the Republic of Benin (Tidjani and Akponikpe, 2012; Loko et al. 2013) and for key crops in the Republic of Côte d'Ivoire (Jalloh et al. 2013). The impacts of climate variability on agricultural will have certainly substantial effects on smallholder and subsistence farmers of the tropics and subtropics who depend to this activity for their livelihood (Thornton and Lipper, 2014).

In the study region, sorghum producers developed several strategies to cope climate variability. These strategies were relative to drought followed by unexpected excess rain, decrease in rain amount, high temperature and soil poverty. If according to Peterson et al. (2013), droughts have become less frequent, less intense, or shorter in some Africa's regions that are not the case in Benin. Growing of drought resistant sorghum cultivars is the most and the best strategy used by farmers to mitigate droughts frequencies in the area. Agriculture employs rural populations who have generally poor resources and produce less than a subsistence level. Utilization of fertilizers as second strategy to cope climate variability by farmers revealed the level of soil poverty that involved Striga proliferation. Unfortunately the lack of arable land and financial resources limit cruelly the ability of poor farmers to use much fertilizer, herbicides and pesticides that will certainly increase their agricultural production (Jalloh et al. 2013). Further, rotation and/or association of crops with leguminous is a good strategy to maintain soil fertility and manage pests damage as Striga. Several of adapted strategies used by sorghum farmers in the study area are similar to those used by maize farmers (Tidjani and Akponikpe, 2012) and yam producers (Loko et al. 2013). Agricultural research system must continue its efforts in developing tolerant or resistant crop varieties to changing climatic conditions of temperature, rainfall and soil. In Benin, low productivity, diversity loss and poverty are already severe problems for rural communities, and there will be more severe in future if present scenario continues as smallholder farmers do not have adequate strategies and financial support to adapt agricultural activity to climate change. Nevertheless, access to Government agricultural extension services and/or Non-Government Organizations regarding current climate variability by farmers will increase their perception of climate change (Bryan et al. 2009) and improve likelihood, production and crops varieties diversity conservation by communities.

The study found that farmers' in the different surveyed villages were able to recognize that temperatures were increased and several fluctuations were observed in the rainfall pattern. Farmers' perceptions of climate variability were in line with meteorological data records. The changes in climate scenarios involved low productivity, soil poverty, increase in insects' damage, soil poverty and sorghum varietal diversity loss. Faced these impacts, sorghum producers developed several coping strategies among which the most important are sowing of drought resistant varieties, utilization of fertilizers, re-sowing, rotation and/association of sorghum production with leguminous. To enable farmers to adequately manage crops so that optimize sorghum production level, organization of information campaigns and institutional strengthening including farmers, agricultural extension agencies, NGOs, decision makers, and public investment programs are needed.

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