Vol. 18(2), pp. 80-88, February, 2022
DOI: 10.5897/AJAR2021.15765
Article Number: F55499268615
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

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African Journal of Agricultural Research

Full Length Research Paper

Analysis of climate change vulnerability and adaptation towards increase resilience among farmers in Borno State, Nigeria

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Received 27 August, 2021; Accepted 24 December, 2021

This study analyzed climate change vulnerability and adaptation among smallholder farmers in Borno State, Nigeria. The study was conducted in Sudan and Guinea savannah Agro-Ecological Zones (AEZ) of the state. Survey research design was employed for the study. Multi-stage sampling procedure was used in selecting 360 farmers for the study. Descriptive statistics such as percentages, frequencies, means and livelihood vulnerability index (LVI) were used in analyzing the data. Overall, based on IPCC-LVI explanations of climate change vulnerability, Sudan savannah was found to be the most vulnerable AEZ with vulnerability index of -0.0104 against Guinea savannah with LVI of -0.0416. A few factors can explain this low adaptive capacity: A deteriorating ecological base, inadequate capacity building and enhancement programmes widespread poverty arising from dwindling economic and livelihood activities and ravages of insurgency among others. In both AEZs, farmers do adapt to climate change through various farm level practices. These adaptation strategies, however, do vary slightly among the two AEZs. The adaptation strategies practiced by respondents in Sudan AEZ were multiple cropping (98.9%), early planting (63.9%), mulching/use of cover crops (36.1%) and increased fertilizer application (25.00%). In Guinea AEZ, the most widely used adaptation strategies include multiple cropping (93.30%), use of new crop varieties tolerant to the new climate regime (72.20%), increased application of fertilizer (47.20%) and application of chemicals (25.00%). The study concludes that Sudan savannah AEZ is the most vulnerable AEZ among the AEZs considered in this study. Major adaptation strategies practiced were technologically based. The study, therefore, recommends that farmers' adaptive capacity should be enhanced particularly in Sudan savannah zone.

Key words: Climate change, vulnerability, adaptation, Borno State, Nigeria.

INTRODUCTION

Vulnerability is one of the key terms in the literature that has many different definitions and is subject to various

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interpretations and usage. Several attempts have been made to define the concept. The Intergovernmental Panel on Climate Change (IPCC) is the leading scientific international body for the assessment of climate change, and consequently the starting point for this paper is vulnerability as defined by the IPCC. According to the IPCC (2007) definition, vulnerability in the context of climate change is “the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity”. Thus, agricultural vulnerability to climate change can, for example, be described in terms of exposure to elevated temperatures, the sensitivity of crop yields to the elevated temperature and the ability of the farmers to adapt to the effects of this exposure and sensitivity by, for example, planting crop varieties that are more heat-resistant or switching to another type of crop. The definition of the IPCC (2007) specifically highlights three components of vulnerability in the climate change context: exposure, sensitivity and adaptive capacity. The term exposure addresses the incidence of climate impacts, that is, the degree to which actors are in the “firing line” of climate change impacts. Sensitivity in turn addresses the capacity of actors to be wounded by climate change, while adaptive capacity addresses the ability of actors to shield them and to recover from adverse climate change impacts. Therefore, vulnerability to climate change is described as the probability that climate shocks will shift household income below a given minimum level (such as a poverty line) or cause income levels to remain below the minimum level if the household is already poor (Deressa et al., 2009).

Economic assets, capital resources, financial means, wealth or poverty, the economic condition of nations and technological advancement of groups clearly are the determinants of vulnerability to climate change (Kates, 2000). Adger and Kelly (1996) also observed attributes that can increase or decrease a system’s vulnerability include marginalization, inequity, presence and strength of institutions, food and resource entitlements, economics and politics. Seasonal climate variations including periodicity and amount of rainfall is one of the major sources of vulnerability faced by farming households (Ellis, 2000). At farm level, Blaikie et al. (1994) explains that households’ income, gender, number of children, age, level of education and access to information determine vulnerability. Karfakis et al. (2011) show that increasing the level of education of farmers can be an efficient means for reducing farmers’ households’ vulnerability to climate change. Literature on climate change adaptation argued that with adaptation, vulnerability can be significantly reduced (Gbetibouo, 2009).

Adaptation to climate change is the adjustment of practices, processes and structures to reduce the negative effects particularly, the unavoidable ones, and takes advantage of any opportunities associated with climate change (IPCC, 2007). Although African farmers have a low capacity to adapt to changing climate, however, have survived and coped in various ways over time. Better understanding of how they have done this is essential for designing incentives to enhance private adaptation. Many studies have been conducted on adaptation to climate change in Nigeria (Apata et al., 2009; Oyerinde and Osanyede, 2010; Nzeadibe et al., 2011; WEP, 2011; Idrisa et al., 2012; Adebayo et al., 2012, 2013), limited knowledge however, exist on climate change vulnerability among farmers. Moreover, agricultural systems are often assessed with respect to vulnerability and adaptation differently. Their integrated study can provide more complete portrayal of the behavior of farmers in the changing climate. Climate change impacts differently among different regions, generation, age, classes, income groups and gender (IPCC, 2001). Agro-climatic regions are not alike in their vulnerabilities. This could be as a result of climate peculiarities and resource endowment of different agro-climatic zones. From the foregoing, the study is designed to fill the gap in knowledge by providing answer to the following research questions:

(1) What is the level of climate change vulnerability of communities across agro-ecological zones of the study area?
(2) What are the climate change adaptation strategies practiced by respondents?

METHODOLOGY

The study was conducted in Borno State. The state has a land area of 69, 435 km^2 (Amaza et al., 2007). The area lies between latitudes 12° - 00N and 14°, 00N and Longitude 10° - 00E and 14°- 00E of north eastern Nigeria (Figure 1). There are 27 Local Government Areas (LGAs) in the state spread over three agro-ecological zones viz, the Sahel (S), Guinea Savanna (GS) and the Sudan Savanna (SS) (Amaza et al., 2007). The state has a population of 4,151,193 (NPC, 2006) with a projected 2017 estimate of 6,001,901 based on a 3.2 population growth rate. It has climatic peculiarities characterized by erratic and unreliable rainfall patterns. The rains are of short duration followed by a long dry spell.

Temperatures are high all year round, with hot season mean temperatures ranging between 39 and 40°C in the northern part of the state. The annual precipitation ranges from less than 600 mm in the north to 1500 mm in the south. Rainfall, however, varies from year to year but has tended to decrease over the last two decades (Amaza et al., 2007). Droughts are endemic. Borno State is one of the desert front line states of Nigeria (WEP, 2011). The main livelihood activity of the people is agriculture, producing a variety of crops, livestock and fish.

Data for this study were mainly from primary sources, obtained through household survey. Multi-stage random sampling technique was used in selecting respondents in the two Agro-ecological Zones (AEZs) selected for the study. In the first stage, three (3) LGAs were purposely selected from each AEZ based on the

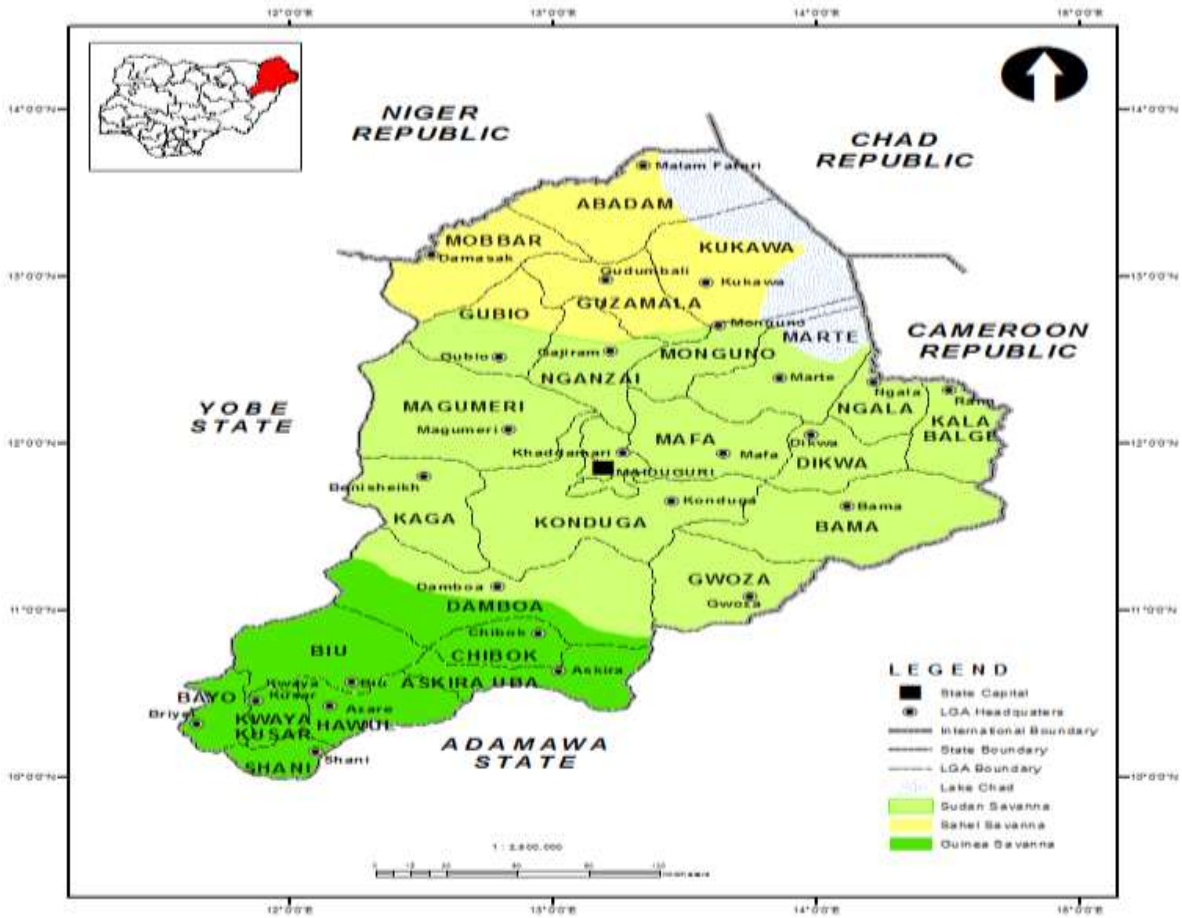

Figure 1. Map of Borno State showing ecological zones.
Source: Department of Geography, University of Maiduguri (2019).

intensity of agricultural production practices and accessibility to communities. The second stage involved random selection of three (3) communities from each LGA, giving a total of eighteen (18) communities. Lastly, from the lists of registered farmers obtained from Borno State Agricultural Development Programme (BOSADP), farmers associations and community leaders, farmers were proportionally selected from each community, making a total of 360 respondents for the study. Descriptive statistics such as mean, frequency and percentages and Livelihood Vulnerability Index (LVI) were used in analyzing data obtained.

Livelihood vulnerability index (LVI)

The LVI taking into consideration Intergovernmental Panel on Climate Change (IPCC) explanation as the functions of exposure, sensitivity and adaptive capacity of a system to climatic impacts, developed by Hahn et al. (2009) was used to estimate the level of vulnerability of farmers to climate change. The LVI was derived for the two agro-ecological zones. It made use of seven major components, namely: socio-economic profile, livelihood strategies, social networks, health, food, water and natural disaster and climatic variability. Each component is made up of several indicators measured on a different scale. It is therefore necessary to standardize each as an index using Equation 1:

$$Index_{sr} = S_r - S_{min} / S_{max} - S_{min} \quad (1)$$

where Sr = observed sub-component indicator for zone r_i, i = 1 and 2, Smin and Smax = the minimum and maximum values of the indicator, respectively.

After each is standardized, the sub-component indicators were averaged using Equation 2 to calculate the value of each major component.

$$M_r = \frac{\sum Indexsri}{n} \quad (2)$$

where Mr = one of the seven major components [Socio-Demographic Profile (SDP), Livelihood Strategies (LS), Social Networks (SN), Health (H), Food (F), Water (W), or Natural Disasters and Climate Variability (NDCV)] for region r; indexsri = the sub-components indexed by i, that make up each major component, n = number of sub-components in each major component. Once values for each of the seven major components for a region are calculated, they were averaged using Equations 3 and 4 to obtain the region-level LVI:

$$LVI_r = \frac{\sum Wmi\ Mri}{\sum Wmi} \quad (3)$$

where Wmi = weights of each major component, determined by the number of sub-components that make up each major component and were included to ensure that all sub-components contribute equally to the overall LVI.

Following from Equations 3 to 5, Hahn et al. (2009) calculated a new variable, LVI-IPCC; this takes into consideration IPCC definition of vulnerability. The LVI-IPCC diverges from the LVI when the major components are combined. Rather than merge the major components into the LVI in Equation 5, the major components were first combined according to three categories namely exposure, adaptive capacity and sensitivity using the following equation.

$$CF_r = \frac{\sum W_{mi} M_{ri}}{\sum W_{mi}} \quad (4)$$

where CFr = IPCC-defined contributing factor (exposure, sensitivity, or adaptation capacity) for region r, Mri = major components for region r indexed by i, and Wmi = weight of each major component.

Once exposure, sensitivity, and adaptation capacity were calculated, the three contributing factors were combined using equation v:

$$LVI\text{-}IPCCr = (e_r - a_r) \times s_r \quad (5)$$

where LVI-IPCCr = LVI for region r expressed using the IPCC vulnerability framework, e_r = calculated exposure score for zone r (equivalent to the natural disaster and climate variability major component), a_r = calculated adaptation capacity score for zone r (weighted average of the socio-demographic, livelihood strategies, and social networks major components), and s_r = calculated sensitivity score for zone r (weighted average of the health, food, and water major components).

The LVI-IPCC is scaled from -1 (least vulnerable) to 1 (most vulnerable). Microsoft Office Excel 2010 was employed in estimating the LVI of farmers in the two agro-ecological zones.

RESULTS AND DISCUSSION

Climate change vulnerability

Households socio-economic and environmental vulnerability indicators based on AEZ

The sub-components contributing to households' vulnerability are shown in Table 1.

The result on sub-components indicators under socio-economic main component revealed that 16% of the households in Guinea savannah were headed by female while 24% of the households' head in Sudan savannah had no formal education. The result further indicated that 56% of the respondent's households in Sudan savannah had no access to adequate farmland. This result might not be unconnected to the fact that *Boko Haram* activities are more prominent in the Sudan zone. Result on livelihood main component shows that 69% of the respondents' households in Sudan savannah did not depend on agricultural income alone but other sources such as trading, civil services etc. Seventy six percent (76%) of the respondents' households in Sudan savannah do not belong to association. This may weaken their capacities. Result on the water main component indicated that all respondents' households in the two agro-ecological zones had access to water. However, 24% of the households in the Sudan savannah zone had no water throughout the year in adequate quantity. Again, all households in the two agro ecological zones had access to health ranging from pubic to private health centres. However, 46% of the respondent's households in Sudan savannah revealed that there is no relationship between health problems and the environmental challenges the zone is facing. All the respondent's households in the two agro-ecological zones had access to food. Sources of food included own production, purchase from market and gifts from wealthy individuals and NGOs. Ninety percent of the respondents' households in Sudan savannah did not rely on food from their own production and 88% had no food storage/reserve. This is perhaps because of the *Boko Haram* insurgency that deterred farmers' access to farmlands.

Results on the Natural disaster and climate variability main component indicated that all respondents' households are aware of climate change and noticed change in temperature and rainfall in recent years. Respondent households in Guinea savannah (6%) however, revealed that they had no dry spell experience in recent years and 97% and 96% had no experience in flooding in Guinea and Sudan savannah zone respectively. Furthermore 58% and 53% of the respondent's households in Sudan savannah had no access to early warning information and had no experience in pest and disease infestation in recent years respectively.

Household's main and sub-components of vulnerability

Table 2 shows the computed vulnerability score for each indicator and the aggregated main components and overall households' vulnerability.

Socio-economic profile

Boko Haram insurgency is more famous in Sudan savannah agro-ecological zone, thus, has affected socio-economic activities of farming households. Access to adequate farmland and credit facilities become a problem. This led to higher vulnerability of the zone in terms of socio-economic profile. Overall, Sudan savannah showed greater vulnerability on the socio-economic profile index than Guinea savannah (0.464 Sudan vs 0.364 Guinea).

Livelihood profile

Given that Guinea savannah is more economically active

Table 1. Values for main components for LVI for Sudan and Guinea Savannah AEZs.

Main component	Sub-component	Sudan	Guinea
Socio-economic	Percentage of respondents who are male	0.130	0.160
	Percentage of respondents who had education	0.240	0.200
	Percentage of farmers who had access to land	0.560	0.070
	Percentage of farmers who had credit	0.850	0.790
	Percentage of farmers who had extension contact	0.540	0.600
	Socio-economic Index	**0.464**	**0.364**
Livelihood	Percentage of households that depend on Agriculture	0.690	0.660
	Percentage of households' income from other sources	0.320	0.290
	Livelihood Index	**0.505**	**0.475**
Social	Percentage of households belonging to association	0.760	0.590
	Social Index	**0.760**	**0.590**
Water	Percentage of households who had access to Water	0.000	0. 000
	Percentage of households that had water available throughout the year	0.240	0.040
	Water Index	**0.240**	**0.040**
Health	Percentage of household that had access to health	0.000	0.000
	Perceived Relationship between environment problems and health	0.030	0.460
	Health Index	**0.030**	**0.460**
Food	Percentage of respondents who had no access to food.	0.000	0.000
	Percentage of households that don't rely on food from own production	0.900	0.830
	Percentage of respondents who had no food storage/reserve	0.880	0.884
	Food Index	**0.890**	**0.857**
Natural Disaster and Climate Variability	Percentage of respondents who are not aware of climate change	0.000	0.000
	Percentage of households without drought experience	0.020	0.060
	Percentage of households with flood experience	0.960	0.970
	Percentage of households who do not perceived change in tempt.	0.000	0.000
	Percentage of households who do not perceived change in rainfall	0.000	0.000
	Percentage of households who had no early warning information	0.580	0.090
	Percentage of households who had no pest and diseases infestation	0.530	0.210
Natural disaster and climate variability index		**0.523**	**0.333**

Table 2. Index for the main components contributing to households vulnerability.

Main component	Index	
	Sudan	Guinea
Socio-economic	0.464	0.364
Livelihood	0.505	0.475
Social	0.760	0.590
Water	0.240	0.040
Health	0.030	0.460
Food	0.890	0.857
Natural disaster and climate variability	0.523	0.333
Overall index	0.487	0.446

Source: Field Survey (2018).

Table 3. IPCC-LVI contributing factors for Sudan and Guinea savannah zone.

IPCC contributing factor	Main components	Sudan	Guinea	No. of main components in contributing factor	Contributing factor values		IPCC-LVI value	
					Sudan	Guinea	Sudan	Guinea
Exposure	Natural disaster and climate variability	0.549	0.384	1	0.549	0.384	-0.0104	-0.0416
Adaptive capacity	Socio-economic	0.464	0.364	3	0.576	0.476	-	-
	Livelihood	0.505	0.475	-	-	-	-	-
	Social	0.760	0.590	-	-	-	-	-
Sensitivity	Water	0.240	0.040	3	0.387	0.452	-	-
	Health	0.030	0.460	-	-	-	-	-
	Food	0.890	0.857	-	-	-	-	-

Zone I: Sudan Savannah; Zone II: Guinea Savannah.
Source: Field Survey (2018).

than Sudan Savannah, unsurprisingly Sudan savannah was shown to be more vulnerable than Guinea savannah in this regard (0.505 Sudan vs 0.475 Guinea).

Social

Being a more indigenous community, Guinea savannah proved rightly to have better social capital compared to the more migrant population in Sudan savannah. Sudan savannah was shown to be more vulnerable with respect to social capital (0.760 Sudan vs 0.590 Guinea).

Water

Overall Sudan savannah showed a greater vulnerability on the water profile (0.240 Sudan vs. 0.040 Guinea). This could be as a result of relatively aridity of the Sudan savannah zone more than the Guinea savannah, which led to the water table going down as the dry season advances.

Health

Overall Guinea savannah had a greater vulnerability on the heath profile (0.030 Sudan vs. 0.460 Guinea). This may not be unconnected to the proximity of the Sudan savannah communities to Maiduguri for accessing health services.

Food

Households in Sudan savannah were more vulnerable than their counterpart in Guinea savannah (0.890 Sudan vs. 0.857 Sudan). This may reflect the poorer socio-economic profile of Sudan savannah compared to Guinea. This could be as a result of inaccessibility to agricultural land as a result of *Boko Haram* activities in the zone.

Natural disaster and climatic variability

Sudan savannah is a drier zone than the Guinea savannah. More respondents 'households in Sudan savannah zone experienced dry spell and were affected by the drought events compared to their counterparts in Guinea savannah. Sudan savannah showed more vulnerability with respect to natural disaster and climatic variability index (0.549 Sudan vs. 0.384 Guinea).

Vulnerability of communities by the IPCC definition

The vulnerability of the communities based on the IPCC definition of vulnerability as a function is showed in Table 3. Based on IPCC-LVI explanations, seven major components were considered. These include socio-economic, livelihood strategies, social network, health, food, water and natural disaster and climate variability. From the result, agro-ecological zone I (Sudan) is the most vulnerable agro-ecological zone with a Livelihood Vulnerability Index (LVI) of -0.0104. This is followed by agro-ecological zone II (Guinea) with LVI of -0.0416. The reason for the high vulnerability exhibited by Sudan savannah is

Table 4. Distribution of respondents based on adaptation strategies.

Adaptation strategy	Sudan savannah (n= 180)		Guinea savannah (n=180)	
	Frequency*	Percentage	Frequency*	Percentage
Multiple cropping	178	98.9	168	93.3
Application of chemicals	12	6.7	45	25
Early planting	115	63.9	33	18.3
Increased application of fertilizer	45	25	85	47.2
Mulching/Use of cover crops	65	36.1	25	13.9
Use of new crop variety tolerant to new climate regime	16	8.9	130	72.2
Increased cultivated land	25	13.9	21	11.7
Application of organic manure	32	17.8	18	10
Irrigation supplementation	5	2.8	14	7.8

*Frequency based on multiple responses.
Source: Field Survey (2018).

attributed to the prevailing climatic conditions and to a large extent the low adaptive capacity. A number of factors can explain this low adaptive capacity (Mohammed, 2021): a deteriorating ecological base, lack of relevant institutions, inadequate capacity building and enhancement programmes, lack of access to relevant and basic information on climate related hazards, lack of early warning systems, widespread poverty arising from dwindling economic and livelihood activities and ravages of insurgency. This result was in line with the findings of Makondo et al. (2014) who reported that rain dependent smallholder farmers in Zambia are highly vulnerable to weather related shocks which impact greatly on their food production; and that the levels of vulnerability vary across gender and per agro-ecological zone. As evidenced by the results, agro-ecological zone I (LVI of 0.149) was the most vulnerable zone. The reasons for such a level of vulnerability of zone I may be explained by low rainfall, as well as poor road infrastructure which indirectly influenced accessibility to farm inputs and market for farm produce. Zone II is the least vulnerable among the zones and has easy access to inputs, markets while probably engaging in other livelihood activities, that is, diversification of livelihood activities. This finding was in line with previous results of Evangelista et al. (2015) and Tesso et al. (2012), who found that social factors, poverty, living in highland areas are responsible for vulnerability of communities.

Adaptation strategies practiced by farmers

To respond to the perceived changes in climate, farmers employed adaptation strategies in order to reduce the negative impacts on crops. The farm level adaptation strategies practiced by respondents in the two agro-ecological zones are presented in Table 4. Majority of the farmers use multiple adaptation options.

In Sudan savannah agro-ecological zone, the result revealed that 98.9% of the respondents adopted multiple cropping as adaptation strategy, 63.7% practiced early planting and 36.1% of the respondents employed mulching and use of cover crops as adaptation strategy. Only 25% of the respondents practiced increased application of fertilizer and 17.8% adopted application of organic manure. The results on adaptation strategies adopted by farmers in Guinea savannah zone revealed that almost all (93.3%) of the respondents practiced multiple cropping, 72.2% of the respondents employed new crop varieties tolerant to new climate regime, 25% of the respondents practiced increased use of chemical and 18.3% employed early planting.

The use of multiple cropping or crop diversification is considered as a tradition for smallholder farmers as reported by many authors (Enete et al., 2011; Mohammed et al., 2014). The practice however, has been intensified as a result of climate change. Multiple cropping is aimed at spreading climate risk over two or more crop enterprises as climate factors affect crop enterprises differently. This is because different crops have different levels of resilience to climate variability; hence, planting many crops could ensure that farmers get some output in the face of extreme climate situations.

Early planting is an age long adaptation strategy practiced by crop farmers. The main thrust of the strategy is to ensure that critical growth stages do not coincide with the harsh climate conditions usually experienced at the end of the wet season. Farmers reported that as soon as the wet season starts, they plan their crop. However, the strategy requires replanting as not all the seeds germinate as a result of moisture deficiency in the soil at the beginning of the rainy season. Mulching/Use of cover crops is aimed at conserving moisture content of the soil. Couple with soil characteristics, the rainfall regime in the Sudan savannah is scanty, therefore, farmers resort to adopt the strategy in order to conserve the little moisture in the soil by covering the soil either with cover crops (cowpea, groundnut) or some non- crops materials (thatch, farm waste). This will ensure the soil surface is not directly exposed to the sun radiation thereby minimizing the rate of evaporation (Kwaghe and Mohammed, 2013).

The use of new crop varieties tolerant to the new climate regime has been practiced by farmers in Guinea savanna agro-ecological zone of Borno State. New crop varieties such as maize, cowpea and soybean are promoted by IITA, IFAD and government agencies in the zone (Idrisa et al., 2012). This paved the way for farmers to adopt it as an adaptation strategy to climate change. The main thrust of using new crop varieties as an adaptation strategy could be two-fold: grow fast to meet up the shortened wet season and yield high to ensure that farmers get income in the face of climate change. The use of chemicals as an adaptation strategy is gaining ground among farmers in Guinea savannah zone evidenced from the result of the study. Chemicals such as herbicides application is a substitute for labour in farm business. Considering the cost of labour in farm business and the adverse effects of climate change on crop production, farmers lessen the cost of labour by adopting the strategy hence reduced cost of crop production leading to increased profitability of farm business.

CONCLUSION AND RECOMMENDATIONS

The study concludes that Sudan savannah AEZ is the most vulnerable zone among the AEZs considered in this study. The vulnerability of the zone could be explained by the low adaptive capacity: a deteriorating ecological base, lack of relevant institutions, inadequate capacity building and enhancement programmes, lack of access to relevant and basic information on climate related hazards, lack of early warning systems, widespread poverty arising from dwindling economic and livelihood activities and ravages of insurgency. Major adaptation strategies practiced were technologically based and adaptation strategies practiced by small holder farmers varied slightly based on agro-ecological zones. The study, therefore, recommends that towards increased resilience to the menace:

(1) Farmers adaptive capacity should be enhanced particularly in Sudan savannah zone;
(2) Technologically adaptive capacity should be encouraged and supported.
(3) The security situation of the study area should be restored.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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