A Review of Climate Change Anomalies and Environmental Productivity of Resources in Northern Nigeria

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Abstract

This study reviewed climate change anomalies and environmental productivity of resources in Northern Nigeria. The study examined instances of shift of weather patterns which result to threat to crop production through increased instability of precipitation, raising sea levels, pollution of coastal freshwater reserves and increased the risk of disastrous flooding. Increasing warming of the atmosphere has aided the poleward spreading of pests and diseases that was once limited only to the tropics. The study used available meteorological data on surface air temperature and rainfall for all regions in Nigeria since 1920 to show evidence of climate change. The findings of the study reveals how changes in rainfall and temperature trends affect agricultural productivity. The study findings revealed that the anthropogenic causes of climate change coupled with economic development, urban expansion and fast growing populations are most likely to reduce per capita surface water availability in the country and the region entirely, and climate change is expected to worsen this situation especially in the seasonally dry areas. Nigeria experiences below average reduction in cereals production as a result of unpredictable temperature and rainfall patterns, which are exacerbating the impact of rising unemployment, rural - urban migration and increasing poverty amongst youths. Thus, Agriculture has been pushed by climate change into new era of uncertainty surrounded by shocks. The study concludes that climate change has serious implication on peasant farmer's livelihood and household food security in the region. Based on the findings, the study recommends the need to aggressively implement climate change adaptation strategies to minimize losses in farm output and income of rural farmers, carefully design climate change policy response which should be incorporated and implemented by both federal and state government in their development plan.

Keyword: Agriculture, Climate change, Economy, Vulnerability and Weather,

Introduction

Africa continent has been identified as one of the parts of the world most vulnerable to the impacts of climate change (Niang *et al*, 2014). Scholars have essentially believed that the earth weather conditions have continuously changed for millions of years. Many evidence has shown that human activities from industrial revolution in the past two centuries were mainly responsible for the recent rise in the level of greenhouse gases above usual limits. According to Intergovernmental Panel on Climate Change (IPCC), fourth assessment report (Parry *et al*,

2007), indicated that anthropogenic factors led to changes in the frequency and intensity of climate with consequent results in extreme and violent weather events. The extreme weather event is evidence as rising temperatures and carbon dioxide, heavy rainfall, drought, floods and cyclones. The aggregate shift in weather pattern is known as climate change; the impact of which together with rising world population poses a serious threat to vital sectors of world economy. The economic sectors most vulnerable to climate change are mainly water supply, ecosystems, coastal habitats, industries, health and agriculture. Climate change is our major challenge of this era. It is one of the major issues of the time; enhances a considerable stress to our existing society and to the entire environment. An effect of the changes arises on the fluctuation of weather conditions and patterns, causing threats to production of food, sea level rising that caused risk of catastrophic flooding. The impact of climate change is universal in scope and is unprecedented in scale. Without taking any drastic action today; it will be difficult in future to adapt to these impacts of the changes and it is costly (UNEP) (Hertwich *et al,* 2010). However, climate change has over time ceased to be a scientific inquisitiveness and is contempt to be no longer as one of the many environmental and regulatory concerns, but contemporary studies has shown that climate change is the major intervening environmental problems of our time and is the most single challenging issue that is facing environmental regulators. The impact is a growing crisis within sector of economics, health and safety, food production sectors, security, and other dimensions. The impact arises for instances in a slight shift of weather patterns which will result to a serious threat on crop production through increased instability of precipitation, raising sea levels, pollution of coastal freshwater reserves and increased the risk of disastrous flooding. Increasing warming of the atmosphere has aided the poleward spreading of pests and diseases that was once limited only to the tropics.

Possible blockbusting of greenhouse gas and global warming is real, and it has never been more apparent as present. The materials at our disposal must be used, applied immediately and aggressively. In different system of agricultural practices that were applied by farmers in practice to adopting and repatriating climate change variability either due to nature force or human activities, for vulnerability of agriculture may be viewed as a highly sensitive for agriculture to changes in climate, adaptive capacity of the farming system and degree of exposure to the hazards (McCarthy, 2001). Crop production in different regions of the world were affected by climate change, farmers may have potentials in managing climate change if expose to available options. Though, that is not the case in many African countries, rather agriculture activities are branded so vulnerable in particular (Haile, 2005). The major uncertainties on the larger fraction of African crop productions is it directly dependents on rainfall. Cooper (2004) cited an example that 89% of cereals in sub-Saharan African countries depends on rainfall. The key driver of food security on the continent of Africa is climate (Gregory *et al,* 2005; Verdin *et al,* 2005). The GIS Surface Temperature Analysis (Schmidt *et al,* 2016) team on temperature annual anomalies for land meteorological station indicate that the global temperature trends continued to rise with uncertainty over the century (Fig. 1). This is very important when we consider the fact that climate change phenomenon is global in nature and that agricultural production in all countries of the world is exceptionally vulnerable due to their dependence on weather conditions. Agriculture is the world's oldest activity that provides

food and raw materials to the entire world population. World Bank (2012) report indicated that the agricultural sector serves as the major source of employment to over 70% of the active world rural population and accounts for 30% of World GDP. Similarly, agriculture provides food security and a source of foreign exchange, industrial raw materials and savings in many countries.

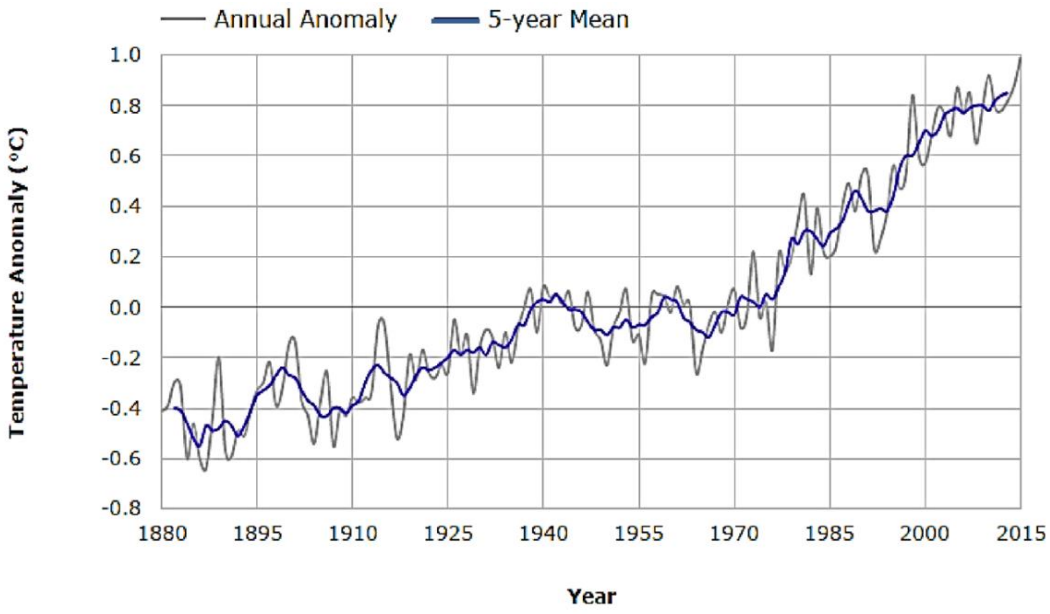

Figure 1: Global Annual Temperature Anomalies from Land Meteorological Station, 1880 – 2015 (Source: Schmidt *et al,* 2016)

Additional rainfall projected changes of +5 to -15% has been made in total rainy-days for tropical Western Africa with great uncertainties (Sillmann *et al,* 2013), particularly at the Guinea coast, "very rainy days that is the top (5%)" indicated even stronger escalations by 50–100% in Eastern tropical Africa, and by 30–70% in Western tropical Africa (Serdeczny *et al,* 2015). In Southern Africa, total rainy-days has been projected to decrease by 15–45% and very rainy-days precipitation to increase by around 20 – 30% over parts of the region. However, some localized areas along the West coast of Southern Africa are expected to see decreases in very rainy days (up to 30%). Here, increases in consecutive dry days coincide with decreases in heavy precipitation days and maximum consecutive five-day precipitation, indicating an intensification of dry conditions. The percentile changes in total rainy days precipitation, as well as in very wet days, are much less pronounced in the low-emission scenario RCP2.6 (Sillmann *et al,* 2013).

One estimate put losses in agricultural production from developed countries at 24% and developing countries will lose an estimated -10% to 24% of their total production (Table 1). In addition, more evidence of the impacts of climate change on world agriculture is emerging from growing body of literature. It was predicted that a 2.5^{o}C rise in temperature will hamper crop yields (Amiraslany, 2010). This coupled with growing human population will result in higher food prices. In the same way, historical temperature increases have had considerable

negative effects on agricultural value in developing countries. 1^{o}C increase in temperature in developing countries has been found to be associated with 2.66 % lower growth in agricultural output, leading to estimates of economic growth reductions by an average of 1.3% points for each degree of warming (Dell *et al*, 2012) and reductions in export growth by 2.0% – 5.6% points (Jones & Olken, 2010). Although agriculture sector employs 65% of Africa's labour force and the sector's output has increased since (2000), mainly due to an expansion of agricultural area (World Bank, 2013).

Table 1: Projected Impact for Maize Crop in global Regions and Sub-Regions

Region	Sub-region	Yield Impact (%)	Scenario	Reference
World		Maize up to -4 to -12	CSIRO (MIROC) 2050	Nelson et al, 2010
East Asia	China	-22	-CO_2	*CH 14
South Asia	South Asia	-16	2050	Knox et al, 2012
Africa	All region	-24	2090 +5^{o}C	Thornton et al, 2009
	East Africa	-3 to +15	2030;2050	Thornton et al, 2010
Central & South America	Brazil (NE)	0 to -10	2030	*CH 27
	Brazil (south)	-15	2080 +CO_2	*CH 27
	Central America	0/-10/-30	2030/2050/2070	*CH 27
	panama	-0.5/+2.4/+4.5	2020/2050/2080	*CH 27
	Chile	-5 to -10	2050 +CO_2	*CH 27
North America	US Midwest	-2.5	+0.8^{o}C	Hatfield et al, 2011
	US SE	-2.5	+0.8^{o}C	Hatfield et al, 2011
Europe	Boreal /Alpine/AtlN	+34 to +54	2080	Iglesias et al, 2012
	Alt C/Atl S/Cont N	+5 to 19	2080	Iglesias et al, 2012
	Cont S/Med N/Meds	+11 to +33	2080	Iglesias et al, 2012

*CH = Means IPCC WGII AR5 Chapter.
Source: Porter *et al* (2014)

The anthropogenic contribution of climate change coupled with economic development, urban expansion and fast growing populations are most likely to reduce per capita surface water availability in the country and the region entirely, and climate change is expected to worsen this situation especially in the seasonally dry areas (Niang *et al*, 2014; Cooper, 2004).

Crop Production in Northern Maize Belt of Nigeria

Agriculture in Nigeria depends on rainfall for crop production to a very large extent that the activities in rainy season are more affected by the uncertainty of the onset of rainfall. Since the 1970s drought disaster, crop production has been under uncertainty in Nigeria and other countries of Africa as shown in Table 2 (FAO, 2013). Crop production in Nigeria especially maize has been facing the negative impact of extreme event which continue to worsen over a long period of time. Nigeria have in the past decades experience some of its worst flood and drought conditions which destroyed farms and property worth millions of naira. The effect varies across different regions of the country. The dwindling seasonal variation results to rising temperature, rainfall shortage and its cessation at critical growth stages of crop. Consequently, this increasing seasonal variation has repeatedly results to a serious deficit in crop production especially maize. According to the United Nation Food and Agriculture Organization special report on assessment mission to Nigeria, indicates 20% decline in sorghum production, 10% for maize due to irregular rains for crop production (Murtadha *et al,* 2008). Nigeria experiences below average reduction in cereals production as a result of unpredictable temperature and rainfall patterns, which are exacerbating the impact of rising unemployment, rural - urban migration and increasing poverty amongst youths (Oseni & Masarirambi, 2011). This study examines the impact of climate change on crop yield in northern maize belt of Nigeria and the impact of farm input on crop production and its implication on peasant farmers and household food security in the region.

Table 2: Cereal Production (kg/ha) for Nigeria and other African countries

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Benin	1136.4	1125.2	1013.6	1248.0	1271.2	1200.6	1517.8	1373.2	1399.3	1460.3
Ethiopian	1361.4	1563.3	1439.0	1449.7	1682.5	1832.8	1961.6	2046.8	2193.1	2325.4
Ghana	1432.3	1334.5	1317.0	1598.1	1659.8	1814.3	1594.2	1768.1	1688.8	1703.4
Kenya	1646.3	1646.7	1773.4	1417.7	1242.7	1710.1	1514.6	1744.8	1661.5	1627.7
Malawi	777.8	1444.7	2467.0	1598.7	2124.3	1906.9	2094.3	2087.1	2068.8	2187.8
Nigeria	1421.7	1507.5	1399.8	1598.4	1531.1	1528.4	1337.9	1401.2	1236.4	1593.7
South Africa	3314.5	3159.1	2792.6	4061.5	4412.6	4143.0	4024.0	3689.4	3724.9	4320.4
Swaziland	1307.0	1413.9	555.6	988.8	1076.9	1196.2	1334.8	1329.5	1364.6	937.8
Zimbabwe	587.8	851.0	653.1	309.4	424.4	742.8	793.6	806.0	724.2	788.7

Source: FAO data (2013)

Rainfall variability

Rainfall is one of the most variable climatic parameters. It is this variability that has resulted in the uncertainties associated with rainfall, both spatially and temporally. This has further been exacerbated by the onset of localized climatic variability which has resulted in anomalous behaviour in rainfall amounts and distribution. Hence, rainfall is important and cannot be over emphasized (Obot & Onyeukwu, 2010). Rainfall is one of the most important indicators of climate change (Novotny & Sfefan, 2007; Adger *et al,* 2003; Frich *et al,* 2002). Human

activities have tended to exacerbate the challenges of rainfall variability. World Bank (2004) established that an approximately 75% of total gas production in Nigeria is flared. It has been estimated that Nigeria accounts for about 17.2% of global gas flaring. Aside the beneficial aspect of rainfall, it can also be destructive in nature: extreme rainfall events are the major cause of flooding (Ratnayake & Herath, 2005; Ologunorisa, 2004; Folland *et al,* 1986).

Available meteorological data on surface air temperature for all regions in Nigeria show evidence of increasing surface air temperatures since 1920 (Federal Ministry of Environment, Nigeria, 2003). Also, there are indications that those other climate variables especially rainfall have been affected both in magnitude and temporal distributions. Analysis of monthly rainfall data from 1911 to 1980 reveals a changing pattern in annual precipitation, with rainfall decline between 1941 and 1980 (Federal Ministry of Environment, Nigeria, 2003). In fact, (Odjugo, 2010) established that total rainfall in Nigeria has decreased by $81mm^3$ in a period of 105years. Some localities are experiencing extreme weather conditions as a result of rainfall variations and an associated climate change (Odjugo, 2005; Olaniran, 2002). Nnaji and Mama (2014) have observed rainwater harvesting, that rainfall coefficient of variation (CV) is an important feature of rainfall distribution; the 30-year average coefficients of variation for all locations were presented in (Table 3).

Table 3: Characteristics of Northern Nigeria Locations With Respect to Rainfall Coefficient of Variation

Location	Geo Zone	Eco Zone	CV Behaviour	Mean CV
Adamawa	Northeast	MFG	Just > 1	1.1
Bauchi	Northeast	NGS	General > 1	1.36
Benue	North central	DGS	Just > 1	1.05
Borno	Northeast	A/SA	General > 1	1.59
Kaduna	Northwest	NGS	Just > 1	1.14
Kano	Northwest	NGS	General, clearly > 1	1.43
Katsina	Northwest	NGS	General, clearly > 1	1.62
Kebbi	Northwest	NGS	Just > 1	1.2
Kwara	North central	DGS	≈ 1	0.94
Niger	North central	SGS	Just > 1	1.14
Plateau	North central	MFG	Mostly > 1	1.3
Sokoto	Northwest	A/SA	General, clearly > 1	1.53
Taraba	Northeast	MFG	Just > 1	1.09
Zamfara	Northwest	A/SA	General, clearly > 1	1.31

GeoZone geopolitical zone, *EcoZone* ecological zone, *A/SA* arid/semi-arid zone, *DGS* derived guinea savannah, *MFG* montane forest/grassland, *SGS* southern guinea savannah, *NGS* northern guinea savannah, *RF* rainforest.
Source: Nnaji et al., (2016).

Climate Change Impact on Agriculture

Agriculture crop production in Nigeria and most rural community in developing countries remain the main sources of livelihood. Maize production and the entire agricultural produce in Nigeria has provided employments opportunity for over 60% of mostly rural population and contributed to about 30% of the country gross domestic products (Kandlinkar & Risbey, 2000). Climate changes were mostly the determinant on the performance of agricultural production in

the regions. Different parts of the world experience different climate change effect. The effects depend on climatic factors such as rainfall received and daily atmospheric conditions, as well as the trend of changes and the available means and infrastructure to help in facing the challenges.

Nigeria is one of the fast developing regions of the world with over one hundred and eighty (180m) million people, having a great agro-ecological and cultural diversity. The regional population of Africa is projected to approach 1.5 billion people by 2050 with profound need for agriculture production which has implication in meeting their food demand due to climate change. The current undernourished persons in the region of sub-Saharan Africa which Nigeria is included were about 223million, but climate change effect could increase that number by about 132 million by 2050. Estimates indicate that, there is higher importation of staple crop in the region. There will be additional requirement of 360% as much food production in the year 2050 as witness in the years (2006) to feed its fast growing population (Searchinger *et al,* 2014). Peasant farmer are the major producers of maize in northern maize belt of Nigeria and all other agricultural outputs in the other regions. There population account for about 80%, of all the farms and cultivated small land which are regularly ruined and there is no access to reliable irrigation. They do not have access to sufficient labour and are sometimes classified as 'resource poor' and most of them do not have access to monetary and other financial credit. They normally don't participate in marketing of their farm produce. Most peasant farmers' practice subsistence farming characterised by low input and low output in production which fall short of global averages. Productivity in labour and income from agriculture are also very low relative to global average of between two United State dollars ($2.0) per day or less. Typically, the farmers mostly spend an average of about 60% of their hard earning on food for the family (Vanlauwe *et al,* 2014).

Climate change impacts contribute greatly to the challenges facing peasant farmer in trying to produce enough food for the continent growing population. Climate change is worsening the situation of already tight resource constraint that is facing the peasant farmers. Weather pattern is extreme and more erratic, thereby decreasing the average crop yields. Nigeria is confronted with a range of climate risks that could have far-reaching consequences for its agriculture systems in the future. Rainfall is fast changing and temperature patterns are evidently posing effects to crop production that leads to price shocks, increasing the vulnerability and accentuate rural poverty. $2^{o}C$ increase in temperature can cause variation in water availability across the region which could become more pronounced (Waha *et al,* 2013). On the other hand, the length of growing period (LGP), which serve as indicator on the adequacy or level of moisture availability, temperature level and soil condition for crop growth were projected to decrease by up to 20% for most parts of the region by 2050 (Sarr, 2012; Thornton *et al,* 2011).

Projected shifts in Africa's ecosystem could lead to extension of savannah grasslands, thereby reducing the availability of forage for grazing animals. Impact of high temperatures interrupt the food intake of animals and can also impair their reproductive system. Most livestock survive comfortably in temperature zones of $10\text{-}30^{o}C$. If the temperature exceeds this level the animals reduced their feed intake by 3-5% for each degree Celsius rise in temperature (Thornton & Cramer, 2012). Climate change impact can cause the emergence of pests and

diseases that were once a minor problem becoming major livestock and crop production constraints. The intensity and pervasiveness of pests and disease may increase and move to area where they don't exist before, consequently the overall ecosystem will be severely impacted (Waha *et al,* 2013). Generally, plants growth and development depends on its surrounding temperature with each of the plant species having its own required temperature range of minimum to maximum and optimum range. Hatfield *et al,* (2011) summarizes the different species ranges of crop and fruits. The feature changes expected on temperature over the next 30 – 50 years are predicted to be between 2 – 3^{o}C (Parry *et al,* 2007). Extreme temperature or heat waves are projected to become more severe than what is known in past years (Meehl *et al,* 2007). The forecasted extreme temperature will last for a period of short term in few days with temperature increase by over (5^{o}C) higher than the normal temperature. However extreme event occurring during summer period would have high impact on plant productivity; though few studies have been conducted on these effects as found by (Kumudini *et al,* 2014). Also in a recent related study by (Barlow *et al,* 2015) on the temperature extreme effect, heat and frost on wheat (*Triticum aestivum L*) confirm that frost is causing abortion and unproductiveness of formed grains, while extreme heat is causing reduction in number of grains and reduced duration of the grain filling period. An analysis by Meehl *et al* (2007) find out that daily minimum temperature, can increase faster than the increased daily maximum temperature which caused increase in daily mean temperature and would result to extreme heat which has detrimental effects on grain yield. Increasing temperature for period of 30 years would results to possible impact on plant growth and development. These will help improve adjustments on policies to offset these impacts (Hatfield & Prueger, 2015).

Climate Change Effect on Potential Production of Maize

As global emissions of anthropogenic greenhouse gases (GHGs) continue relatively unabated, their impact on climate is already being felt (temperature change, rainfall fluctuation and rise in carbon level). Furthermore, the acceleration of climate change in coming years is virtually assured, due at least in part to the long half-lives of most GHGs. While many of the impacts on people are projected to be modest in the short run (with the exception rate of increased and intensity of weather extreme events), the adverse consequences remain projected to accelerate as climate change accelerates. The projection of climate change is likely to affect agriculture production more than any other sector, which means that populations that depend most on agriculture could be the ones most adversely affected. This is especially true in most African countries and Nigeria in particular. Most of these countries have limited resources that will enable them prepare for climate change adjustment, or to recover from adverse climate shocks to crop yield in the extreme weather condition. Willenbockel (2012) present a summarized assumed yield shocks for each of the crop along with the historical year in which yield deviations have been observed (Table 3). In each case, adverse weather events are the only plausible explanation for the huge drop in average yields over the whole geographical region.

Table 4: Shocks to Staple Crop Yields in the Extreme Weather Event Scenarios (Percentage Deviation from 2030 Baseline Yields)

Regions	*Years	Maize	Wheat	Rice
North America	1988	-24.8	18.2	-0.8
South America	1990	-17.3	-8.0	-9.0
Oceania	2002	-4.2	-44.3	-4.3
Indian	1979	-7.4	-4.9	-16.9
Other East Asia	1980	-9.1	-18.3	-13.5
West Africa	1983	-19.1	-11.5	-4.2
Central Africa	2004	-6.2	-19.3	-5.2
East Africa	1992	-25.9	-13.1	-3.8
Southern Africa	1995	-42.4	-23.9	-10.0

***Historical year in which negative deviations of annual yields from long-run trends over the period 1979 to 2009 of this size have been observed.**
Source: Willenbockel., (2012)

In order to help African peasant farmers, policy makers, researchers, non-governmental organizations and donors agencies need to have a better plan in preparing for the impact of climate change. The national level study on these field were recently undertaken to provide spatially refined analyses on the impacts of climate change on some key crops. These national level studies were published by International Food Policy Research Institute (IFPRI) on climate change agricultural alteration in West Africa (Jalloh *et al,* 2013).

Climate change impact on agriculture is more understood on the biophysical and phenological features of maize and other crops. The processes of maize biophysical and phenological are highly climatic dependent on climatic variables including solar radiation, temperature, and regional variation of moisture. Given an example with photosynthesis rate in plants, it depends on the photosynthetically active amount of radiation and carbon dioxide rates in atmosphere. The determinant of plants progressive growth rate is temperature. The phenological stages up to maturity in plant progress are determined by the temperature level. The biomass accumulation is constrained by the availability of surface moisture and soil nutrient to a growing plant (Rosenzweig & Liverman, 1992).

Agriculture has been pushed by climate change into new era of uncertainty surrounded by shocks. The unpredictability on wanting resilience on the agricultural food system globally is a new radically and apparent improved straightaway needed solutions (Garnett *et al,* 2013). Globally, people have converted virtually 3.8 billion hectares of land, which is a third of the entire landmass on Earth, mainly to agriculture and urban areas. Roughly 85% of the land dedicated to agriculture contains areas of soil degraded by rising salt in groundwater, excessive compaction and erosion. In the past three centuries, 300 million tons of topsoil have been lost each year, in just the last fifty years period, that rate has additionally doubled to 760 million tons per year, and some estimates say that this soil degradation has decreased global agricultural productivity by about 15 percent (Fitzgerald, 2016).

Conclusion

This study has reviewed climate change anomalies and environmental productivity of resources in Northern Nigeria. The study examined instances of shift of weather patterns which result to threat to crop production through increased instability of precipitation, raising sea levels, pollution of coastal freshwater reserves and increased the risk of disastrous flooding. Increasing warming of the atmosphere has aided the poleward spreading of pests and diseases that was once limited only to the tropics. The findings of the study revealed that losses in agricultural production is estimated at -10% to 24% of their total production. Thus, crop production in Nigeria especially maize has been facing the negative impact of extreme event which continue to worsen over a long period of time. The study findings show that Nigeria have in the past decade's experience some of its worst flood and drought conditions which destroyed farms and property worth millions of naira. The study concludes that climate change has serious implication on peasant farmer's livelihood and household food security in the region.

Recommendations

1. Since Northern Nigeria is located in sub-Saharan African with different climatic transition zone, measures to cope with a changing climate need to be implemented aggressively to minimize losses in farm output and income.

2. Enhanced perception is a necessary step that needs to precede the adoption of effective adaptation mechanisms; hence, policymakers need to consider these growing challenges carefully in order to design and execute appropriate policy response.

3. Even though there is a practice on local independent adaptation option by choosing short-duration crops, fruits and vegetable cultivation, they may not be able to fully offset the escalating climate change effects. For this purpose and to achieve long-term benefits, planned adaptation also should be incorporated and implemented by state government in their developmental planning.

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