International Journal of Biological, Life and Agricultural Sciences
ISSN: 2415-6612
Vol:11, No:6, 2017

A Review on Climate Change and Sustainable Agriculture in Southeast Nigeria

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Abstract**—**Climate change has both negative and positive effects in agricultural production. For agriculture to be sustainable in adverse climate change condition, some natural measures are needed. The issue is to produce more food with available natural resources and reduce the contribution of agriculture to climate change. The study reviewed climate change and sustainable agriculture in southeast Nigeria. Data from the study were from secondary sources. Ten scientific papers were consulted and data for the review were collected from three. The objectives of the paper were as follows: to review the effect of climate change on one major arable crop in southeast Nigeria (yam; *Dioscorea rotundata*); evident of climate change impact and methods for sustainable agricultural production in adverse weather condition. Some climatic parameter as sunshine, relative humidity and rainfall have negative relationship with yam production and significant at 10% probability. Crop production was predicted to decline by 25% per hectare by 2060 while livestock production has increased the incidence of diseases and pathogens as the major effect to agriculture. Methods for sustainable agriculture and damage of natural resources by climate change were highlighted. Agriculture needs to be transformed as climate changes to enable the sector to be sustainable. There should be a policy in place to facilitate the integration of sustainability in Nigeria agriculture.

Keywords**—**Agriculture, climate change, sustainability, yam.

I. Introduction

THROUGHOUT human history, the climate has been known to change; however, the change has been more evident in recent times [1]. The Intergovernmental Panel on Climate Change (IPCC) [2] defines climate change as any change in climate over time due to natural climate variability or due to human activity. Climate change, food security and loss of genetic resources are attracting global concern today. As in [3], man's life is unimaginable without the natural environment to supple him with his basic needs such as air to breathe, water to drink, food to eat, solid minerals, plants and animals. Man has directly or indirectly inflicted substantial damage in the environment either by cultivation, grazing, mining or by deforestation and contamination of aquatic habitat.

Global warming is caused by several Greenhouse Gases of which carbon dioxide (CO_2), methane (CH_4) and Nitrous oxide (N_2O) are the most important [4], [2]. Not all climate change impacts are projected to be negative. There will be regions where beneficial impacts are projected. The experience of global warming differs from region to region. Some with increase seasonal rainfall while others more erratic weather changes. These include heatwave, droughts, storms and floods [1]. Regions with lower relative humidity due to decreased rainfall will favour more incidences of insect vectors and viruses, while regions with the reverse will favour increased bacterial and fungal infections.

In the oceans, increasing temperatures, acidification and changing currents will impact on fisheries. Rising sea levels are already leading to salt water intrusion and loss of available land in many coastal areas. Climate will also impact on livestock production through heat induced stress and reduced water availability as well as changed availability, quality and prices of fodder.

Agriculture is regarded as a 'victim' of climate change but the impact of agriculture itself on global warming cannot be overlooked. About 14% of the human-generated green-house gases (GHG) are estimated to come directly from agriculture [1]. For example, almost half of all methane and nearly 60% of nitrous oxide emissions are generated by agricultural activities including livestock production, fertilizer and pesticide applications. Again, green-house gases come from land use changes (e.g. clearance of forests for crops and pasture), soil erosion or machine intensive farming methods, which also contribute to increased carbon dioxide concentrations in the atmosphere. As in [5], climate change is predicted to have adverse effects on the agricultural sector of the poorer parts of the world especially sub-Saharan Africa. A significant effect of climate due to increased levels of $C0_2$ would be reflected in the production of both C_3 crops (cassava, yam, cowpea, wheat, soybean, Rice and Potato) and C_4 crops (millet, sorghum, sugarcane and maize). Most of these crops are endemic in Nigerian agriculture.

Evidences are bound in scientific literature that higher temperatures and changing precipitations are unfavourable for agricultural production, especially crops [6]. Increased production is required to meet the projected world population of 9 billion people by 2050. Climate change will make the task more difficult. Even a 2 °C rise, which has been projected as a median, will lead to dramatic changes in agricultural productivity and water availability. The challenge is to produce more but in ways that will protect the environment, especially soil and water, while minimizing agricultural contributions to climate change.

As in [7], agricultural production is sustainable when it produces food, fibre or other plant or animal products using natural resources and farming techniques that protect the environment, public health, human communities and animal welfare. This form of agriculture enables us to produce healthy food without compromising future generation's ability to do same. Sustainable agriculture has two dimensions:

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spatial and temporal, spatial looked at the availability and use of natural resources to achieve maximum economic needs, while the temporal dimension looks at possibility of use of available resources to provide for the present and future generation in a fair manner [8].

The main changes in climate parameters in Nigeria are the late onset and early cessation of rainfall, and rising temperatures [9]. These have consequences for farmers' decision and management including enterprise choice and management. These are postulated to have implications for choice of crops to be planted, date of planting and harvesting, post-harvest treatment, livestock rearing among others. There have been numerous studies of climate change, the bulk of these were conducted in temperate and highly industrialized countries [10]. Developing countries like Nigeria do not contribute much to climate change but there is evidence of the huge impact to the country's agricultural productivity. Studies in developing countries considered the effects of one or two aspects of climate change on maize [11]. Reducing agricultural contribution to greenhouse gas emissions and also increasing productivity in a sustainable way is the challenge that lies ahead. As the effects of climate change become evident, there is a need to get informed and devise a means for a sustainable agricultural production for this generation and the next. On this note therefore, this paper reviewed the effect of climate change on one major arable crop in Nigeria (yam; *Dioscorea rotundata*); evidence of climate change impact; and methods for sustainable agriculture in adverse weather conditions. About 10 scientific papers were consulted and secondary data for the review was collected from three.

II. Effect of Climate Change on Yam Production

In order to determine the effect of climate change on yam yield, a model was subjected to regression analysis in three functional forms (linear, semi-log, and double-log). The semi-log form was chosen as the lead equation ($Y=601554 - 12113X_1 +187255.9X_2 +20200.9X_3 – 4758.372X_4$) because it has the highest R^2 value (0.548), as shown in Table I. The coefficient of multiple determinations (R^2) has a value of 0.548 (54.85%) implying that the independent variables accounts for 54.8% of the variation in yam yield. Multicollinearity was ruled out since the correlation values did not reach 0.5.

Rainfall (X1), relative humidity (X3) and sunshine (X4) have a negative relationship with yam yield, and is significant at the 10% probability level, while temperature (X2) has a positive relationship with yam yield – as temperature increases, yam yield increases and vice visa. This implies that as rainfall decreased, yam yield increases. This result agrees with [5] which stated that climate change will impact on C3 crops, of which the yam belongs. This has an impact on food and agricultural sustainability in Nigeria. The writer reported that the coefficient of multiple determinations was 0.548, which means that the estimated variables accounted for approximately 55% of the variation in yam yield. Other variables which might have a significant impact were not reported. For instance, the yam specie, length of growing period and soil type were not taken into consideration; these have significant impact on yam yield.

TABLE I
Regression Estimates of Climatic Elements and Yam Yield

Variables	Semi-log		Linear form		Double log form	
Constant	Coeff	t-ratio	Coeff	t-ratio	Coeff	t-ratio
	-601554	-2.408**	-162822	-2.223**	-73.507	-2.117**
Rainfall (X1)	-12113.3	-1.867*	6.316	1.714*	-1.679	1.862*
Temperature (X2)	187255.9	2.845***	6907.379	2.781***	23.483	2.567*
Humidity (X3)	-20200.9	-0.877	-256.962	-0.831	-1.576	-0.492
Sunshine (X4)	-4758.372	-0.416	-845.275	-0.308	-0.249	-0.156
R^2	0.548		0.276		0.248	
R^{-2}	0.476		0.160		0.128	
F-Ratio	2.574*		2.383*		2.063	

***significant @ 1% level
** Significant @ 5%
* Significant @ 10% level
Source: Data from Imo ADP and Abia ADP (Adapted from [12]).

III. Climate Change Impact on General Agricultural Activities

The writer reported the general impact of climate change on agricultural activities without highlighting the contribution of each activity to the phenomenon. For instance, crop productivity decline -this is most likely to happen in developing countries like Nigeria, where crop production depends heavily on rain-fed production. Less rain favours yam production, as seen Table II. This disagrees with [5], which predicted that climate change will have adverse effect in poorer parts of the world agriculture and in agreement with [1] that not all climate change impacts are negative, some are beneficial. Extreme winds have negatively impacted on yam production in some parts of Nigeria, for instance, southeast, where yam tendrils are staked for more sunlight. There prevalence of high humidity, which leads to incidence of diseases in livestock production, but the writer fail to report the contribution of pastoralist to climate change as they move from place to place - contamination of inland water and disease spread causing lose and damage to crop production. The writer also fails to capture the migration of coastal residents due to rising sea levels. This has an implication on

the sustainability of fishery production.

TABLE II
DISTRIBUTION ACCORDING TO CLIMATE CHANGE IMPACT ON AGRICULTURAL ACTIVITIES [13]

Climate effect	Agriculture	Impacts
Warming more/less and erratic rainfall Sea Level rise	Crop	• Dry land, crop productivity likely to decline by 25% per hectare by 2060 • Decreases in productivity of rain fed and semi-arid systems due to decreased length of growing period • Extreme winds
Increase in extreme weather events Warming- seas	Livestock	• Increased spread of both livestock diseases, pathogens and vectors through changes in moisture and temperature • Increased drought incidence will reduce viability of pastoralist production systems • Heat stress will impact on animal health
Storm surges	Fisheries	• Temperature rises of 1.5 to 2°C enough to reduce fisheries • Changes in fresh water flows and greater intrusion of salt water into lagoon will affect the species that are the basis of inland fisheries or aquaculture • Extreme wind and turbulence could decrease coastal fisheries productivity by 50% -60% while turbulence will bring a 10% decline in productivity in the spawning grounds

TABLE III
DISTRIBUTION ACCORDING TO NATURAL RESOURCES, DAMAGE AND REMEDY [14]

Natural Resources	Damage/effects	Remedy
Water supply and use	Salinization and contamination of ground and surface water by pesticides, nitrates and selenium	• Build drainage to remove water and salt • Convert the farmland to other uses • Planting drought tolerant forages • Restoration of wildlife habitat • Use of agroforestry to minimize the impacts of salinity and high water tables • Management techniques
Wild life	• Destruction of riparian habitats within watershed • Reduction of fish and wildlife- erosion, sedimentation, pesticide and water diversion	• Maintenance and support of wildlife and riparian (ecosystem)
Air- many agricultural activities affect air quality	• Smoke from agricultural burning • Dust from tillage • Nitrous oxide emission from use of Nitrogen fertilizer	• Incorporating crop residue into the soil • Using appropriate level of tillage /no till • Planting wind breaks • Cover crops • Native perennial grasses to reduce dust
Soil	• Soil erosion	• Eliminating tillage • Managing irrigation to reduce runoff • Keeping plant covered (mulch)

IV. METHODS FOR SUSTAINABLE AGRICULTURE IN ADVERSE WEATHER CONDITION

Knowledge-based agro-ecosystem management holds the keys. Table II highlighted some natural resources, damage and remedy to maintain sustainable agricultural production.

Sustainable agricultural production practices involve a variety of approaches. Specific strategies must take into account topography, soil characteristics, climate, pests, local availability of inputs and individual grower's goal. This agreed with [15] that maximization of organic matter production keeping the soil covered, zero tillage and maintenance of biological diversity are key issues in sustainable production.

V. CONCLUSION/RECOMMENDATIONS

As the climate changes, agriculture needs to be transformed so that it becomes more profitable, sustainable and resilient. The smallholder farmers and producers who face the hard realities of the impact of climate change need a solution that works for them. The use of natural resources and the crops that adapt to adverse climate conditions should be encouraged. Only by creating policies that integrate sustainability into the Nigerian agricultural sector that the country can promote more sustainable agricultural systems in an adverse climatic condition.

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