IMPLICATIONS OF CLIMATE CHANGE ON SOIL FUNCTIONS: A CASE FOR ACHIEVING LOCAL COCONUT SUFFICIENCY FROM SUSTAINABLE AGRICULTURAL PRACTICES

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Abstract
Climate change is a major threat to agricultural food production globally and locally. It poses both direct and indirect effects on soil functions. Thus, agricultural management practices has evolved to adaptation strategies in order to mitigate the risks and threats from climate change. The study concludes with a recommendation the coconut farmers should explore the idea of soil biodiversity in a bid to mitigate the potential negative impact of climate related risk on the farming. The study proffers the need for adopting sustainable agricultural practices to boost local coconut production. This can contribute to the simultaneous realisation of two of the Sustainable Development Goals (SDGs) of the United Nations: SDG 2 on food security and sustainable agriculture and SDG 13 on action to combat climate change and its impacts. The study findings has implications for tackling climate change in Sub-Saharan Africa and in particular Nigeria in order to boost local agricultural production and coconut in particular without negative environmental consequences and an ability to cope with climate change related risks.

Keywords: Climate Change, Soil, Sustainable Development Goals (SDGs)

1.0 Introduction

Soil is the uppermost layer of the earth's crust vital to the well-functioning of plants and plays a key role to the realisation of the Sustainable Development Goals (SDGs) (Keesstra et al., 2016; Montanarella & Alva, 2015; Sposito, 2021). Montanarella and Alva (2015) identified soil functions as specifically relevant for three out of the 17 SDGs, namely: SDG 2 (End hunger, achieve food security and improved nutrition and promote sustainable agriculture), 13 (Take urgent action to combat climate change and its impacts), and 15 (Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification and halt and reverse land degradation and halt biodiversity loss). Soil refers to 'the biologically active and porous medium', composed of different mineralogy, organic matter, organisms, gas, and water (Sposito, 2021). Soil texture as 'the proportion of sand, silt and clay sized particles that make up the mineral fraction of the soil' (The Queensland Government, 2021). Soil systems have a multifarious benefits such as providing a habitat for organisms, biodiversity, biomass production, carbon sequestration, and a source of cultural and recreational space, etc. (Coyle et al., 2016; Hamidov et al., 2018; Montanarella, 2015; Tóth et al., 2013).

Climate change has become a subject of public discourse at the local and international scene (Bonfante et al., 2017; Hamidov et al., 2018). Countries such as the United States, Spain, Turkey, Israel, and Haiti have fallen under the scourge of climate change in recent times. This is a clear indication that no country bears immunity against 'extreme weather events', whether developed or developing. International organisations (e.g., UN, UNICEF), publics, state governments, NGOs and civil society organisations (e.g., Alexander von Humboldt Foundation) have made attempts at tackling this global menace. This includes the Paris Climate Accords and the Kyoto Protocol, among others. Recently, it was included as one of the 17 Sustainable Development Goals of the UN (specifically, the SDG 13). Also commonly referred to as global warming, issues such as greenhouse gas emissions (GHG) have increased atmospheric temperature over decades. This has led to atmospheric reactions such as extreme rainfall, thunderous storms, droughts, and coastal flooding (Hamidov et al., 2018). It has also been attributed as a cause of respiratory disorders (such as asthma); infectious diseases (e.g., water borne), and mental health, such as 'post-traumatic stress disorder' associated with natural disaster occurrence. This are but few examples from a myriad of other disturbing concerns which are the outcome of climate change.

The impact of climate change have not left the soil untouched. As stated in Hamidov et al. (2018), climate change impacts the soil directly and indirectly. The direct effects includes such as temperature, precipitation, and moisture regime changes. Indirect effects include those that are induced by adaptations such as irrigation, crop rotation changes, and tillage practices (Hamidov et al., 2018). The negative consequence of climate change poses a threat to soil functions from increased soil erosion, compaction, and eroding soil fertility (Lal et al., 2011). The effect has been a reduction in agricultural productivity and lowering food security globally (Hamidov et al., 2018; Lal et al., 2011). Climate and edaphic changes are prime determinants of agricultural productivity (Zhao et al., 2018). To achieve sustainable food production there is a need to mitigate the effects of soil erosion and nitrogen leaching from climate change and intense human activity (Qiao et al., 2018). The changes in soil properties have implications on soil functions such as the soil water retention, biomass transport, and plant growth (Ascough et al., 2019). The soil is a key resource in ensuring agricultural productivity, sustaining future generations and maintain sustainable food production.

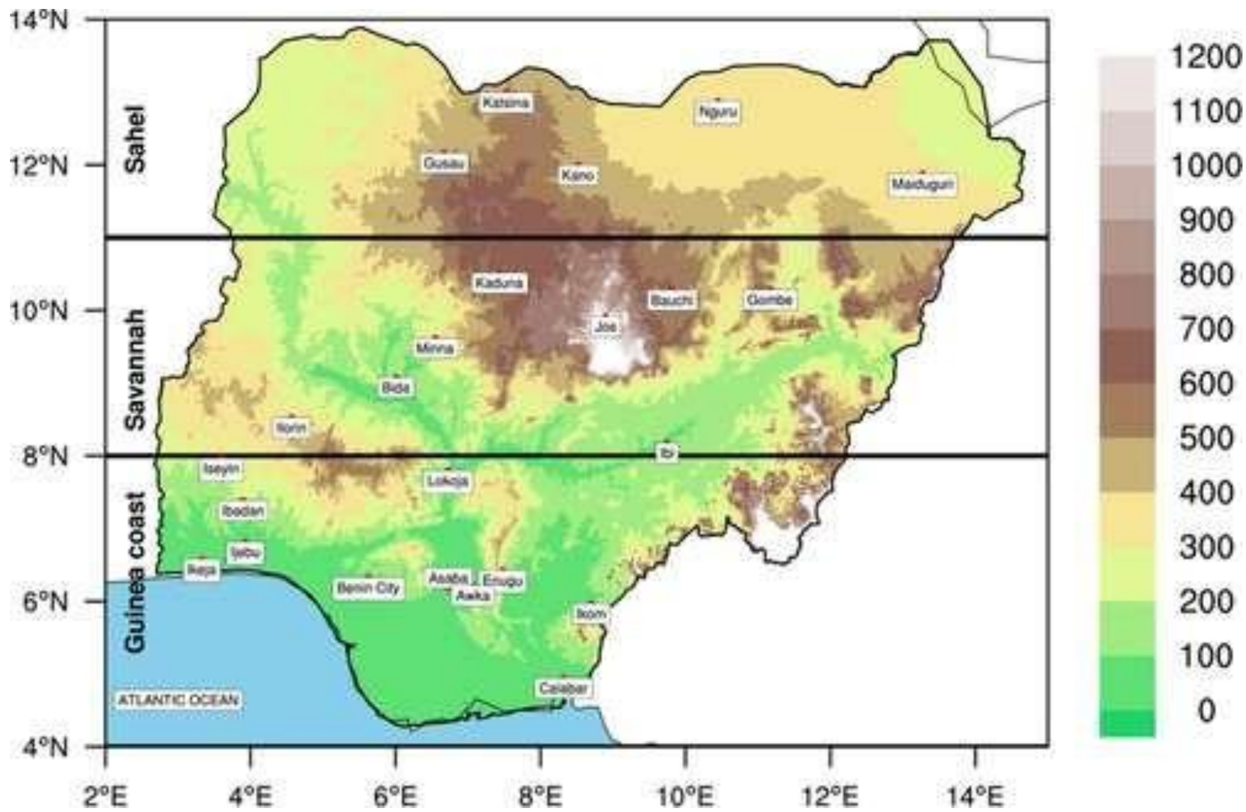

Figure 1: Three climatic zones in Nigeria
Source Data: Royal Meteorological Institute

The three climatic zones are mainly influenced by the West African monsoon (Gbode et al., 2019). The monsoon provides the climatic precipitation for agricultural produce in the country and other sectors of the economy (Gbode et al., 2019). At a continental level, the UNICEF estimate, shows that majority of high risk countries are in Sub Saharan Africa (SSA).

However, ironically these high risk countries emit just approximately 9% of global CO2. This therefore calls for increased attention by policy makers more especially in the continent against this global scourge, more especially given the exponential growth of the population in the continent. A cursory look at the Notre Dame Global Adaptation Initiative Country Index (ND-GAIN), shows that Nigeria is not spared of the implications of climate related risk factors. According to the Index, Nigeria is placed in the 53rd position in terms of vulnerability and the 6th in terms of least ready country. A position which is abysmally low when compared to other countries. However, the country comparatively outperformed some of her neighbouring states such as Cameroon (59th most vulnerable country and 16th least ready country), Benin (10th most vulnerable country and 59th least ready country), and, Niger (is the most vulnerable country and the 57th least ready country). The Figure below shows the country’s performance in terms of ranking from 1995 to 2019.

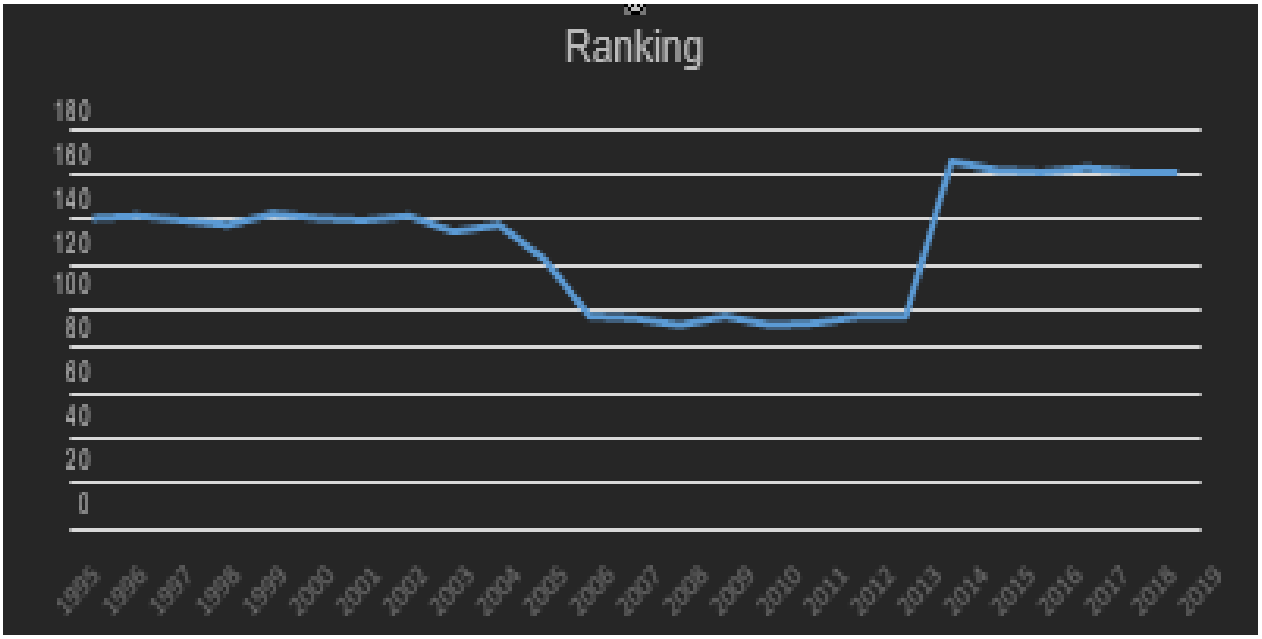

Figure 2: Nigeria ND-Gain Ranking from 1995-2019
Source Data: Notre Dame Global Adaptation Initiative (Graph plotted using Excel)

Studies have examined the effects of climate change on various soil functions and adaptations (Coyle et al., 2016; Ostle et al., 2009; Xiong et al., 2014). Ostle et al. (2009) for instance found that climate change related factors such as warming or drought decrease soil moisture and consequently reduce the carbon sequestration capacity in the UK. Agriculture has remained a crucial component of Nigeria's economy prior to the discovery of oil. It has remained a vital source for food production globally. More so, with the exponential growth of the country's population sustaining agricultural farm practices is crucial to feeding the nation. As at 2019 the country's population is estimated as at 195,874,740.

However, studies have shown that agricultural practices such as the cultivation of coffee, cotton, palm oil, soybean and wheat, may invariably lead to 'increase in soil erosion beyond the soil's ability to maintain itself'. To achieve coconut sufficiency in the Nigeria, it is therefore imperative to breed coconuts for tolerance/resistance in order to overcome the negative effects of biotic and climatic stress that hinder productivity (Suriya, 2016). This paper is an attempt at exploring implications of climate change on soil functions as a vital aspect of agriculture and the implications of this in achieving local coconut sufficiency from adopting sustainable farming and agricultural practices.

2.0 Literature Review

2.1 Conceptual Review

2.1.1 Soil Functions

Soil functions link the ‘physical, chemical, and biological’ processes in the soil system with purported outcomes and benefits to the society (Glæsner et al., 2014). The European Commission (2002) identifies seven major threats which cause soil degradation: soil erosion, decline in soil organic carbon, soil compaction, salinization, contamination, sealing and decline in soil biodiversity. Hamidov et al. (2018) opines two items listed above were not directly linked to agricultural soil management. Soil contamination and sealing were excluded as they are the direct result of industrial activities in the environment leading to pollution while the latter is the act of taking land out of production (European Commission, 2002). According to Hamidov et al. (2018) soil compaction has remained a global problem. It specifically affects root development and water retention capacity thus lowering crop yields (D'Or & Destain, 2016). The seven key functions of the soil are: food and biomass production; storing, filtering, transforming, and recycling water and nutrients; habitat and gene pool; SOC pool; providing raw materials; serving as physical and cultural environment for mankind; and storing the geological and archaeological heritage (European Commission, 2006).

Table 1: Soil functions and perceived link to with SGDs

Soil functions	Perceived link to SDG
Food and biomass production	Link to agriculture and biomass provision for food, fibre, energy: SDG 2
Storing, filtering, transforming, and recycling	Link to water quality, nutrients, flood control, microclimate, ecosystem resilience, detoxification: SDG 15
Habitat and gene pool	Link to biodiversity: SDG 15
Soil organic carbon pool	Link to climate change mitigation: SDG 13

Source Data: Montanarella and Alva (2015)

2.1.2 The Coconut Tree

The origin of coconut (Cocos nucifera L.) may be traced to Asia, however with no exact account found in the literature. The coconut is a monocotyledon plant which proliferates only via seeds. The coconut is a highly nutritional plant, and contains varied amounts of: Carbohydrates, Fat, Protein, Calcium, Phosphorus, Iron, Potassium, Vitamin A, C, B6, B12, Thiamine, Riboflavin, and Ash. The plant varieties range from the tall, dwarf and hybrids mainly found in Asia. The world’s major producers are Indonesia, Philippines, India, and Sri Lanka (Arunachalam, 2012). The caloric content of raw or cooked coconut is described and shown in the Figure below:

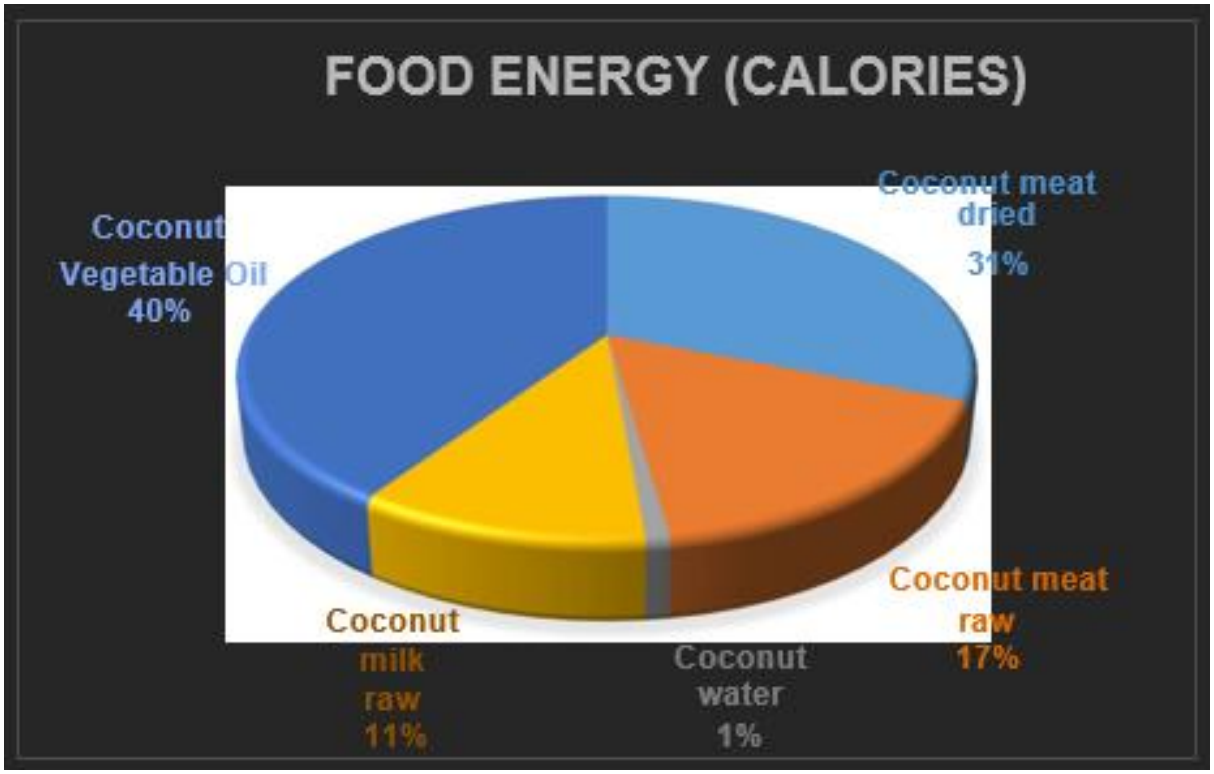

Figure 3: Nutritive value per 100g
Source: Infonet biovision (2021)

In addition, its other parts are also useful. These also include the hard shells which can be used for charcoal and when finely grated, can be used as fillers for objects made of plastic, such as buttons, containers and other objects. The fibres are also used in the upholstery industry, to make ropes, as mulching material or as a substitute for peat. The leaves and wood are used as building material and to make household objects (e.g. baskets, brooms) and tools. The Coconut tree is heavily water dependent, either from rainfall or ground water. However, it is resistant to water logging. The tree grows best at average temperatures of around 26-27degC. Therefore it grows at a length averaging between 750 m and 1300 m in favourable conditions. The growth is also stimulated by sufficient supply of chlorine in the soil and can withstand up to 1% salt in the soil (Infonet biovision, 2021).

2.1.3 Agricultural adaptation

Agricultural adaptation strategies, such as tillage and reconsolidation; plants and crop rotations; irrigation, manure and fertilization practices; and grazing management serve as major sources of temporal variability of soil properties and processes (Ascough et al., 2019). Studies have shown several benefits of agricultural adaptation strategies on improved crop production and sustainable environmental. Haddaway et al. (2015) in the U.K. found a positive mitigating effect of agricultural adaptation practices in mitigating climate change related risk factors. The use of such strategies can increase soil carbon sequestration process. And Westerberg (2011) argue that adaptation practices can optimise the phosphorus content with little environmental impact.

2.2 Strategies to mitigate impact of climate change

Authors have recommended that farmers implement varied forms adaptation for its related economic and climate related benefits. This is particularly useful in organic coconut cultivation which prevents monocropping (Infonet biovision, 2021).

> 'Existing plantations can be improved by sowing at least 1 bottom crop of plants that offer ground coverage. Legumes can be planted here as green fertilisers. In multi-level agroforestry systems, cacao, bananas, pineapples and many other crops can be used. Spices such as ginger and turmeric also thrive under palms. If animals are kept, fodder crops should be integrated in a crop rotation system underneath the coconut palms'.

Benefits of adaptations includes such as market price changes, improved technology and knowledge (Reidsma et al., 2015). The options that may be implemented to mitigate the climate change-related risk includes introducing irrigation in areas prone to drought, crop rotation, increasing fertilization on farmland, altering tillage practices, and cultivation of melting permafrost soils (Mandryk et al., 2017; Schönhart et al., 2016; Ventrella et al., 2012). More so, sustainable farming and agricultural practices can reduce the negative impacts of agriculture on the soil, which may consequently prevent soil erosion and degradation or potential desertification.

According to Infonet biovision (2021), the precarious diseases which affect coconut with regards to disease and pests may be attributed to the following:

1. Cultivation in a monoculture, or with too few different varieties.
2. Too little distance between species that grow to the same height; failure to trim agroforestry systems.
3. Degenerated or poor soil, lacking organic material.
4. Unsuitable sites (water-logging, too dry, soil not deep enough for roots).organic farming systems.

The depth and temporal pattern of root growth varies with widely in different soil types (Ascough et al., 2019). The variation in pattern is such that occurs between and within species of a plant. The pattern of root growth is a function of the soil properties such as density, temperature, water retention capacity, salinity, and nutrient deficiencies, which change with depth in heterogeneous layered soils. Therefore alternating or use of varied roots would definitely depend on the soil structure and macroporosity.

The temporal pattern and depth of the root growth determines the distribution of water and nutrient uptake from the soil. This, in turn, influences water, chemical, and heat movement in the soil.

1. However, irrigation and the use of heavy machinery may increase the risk of soil compaction in the area. Thus, an appropriate use of agricultural machinery (e.g., low pressure and wide tires) is one effective measure against compaction (Prager et al., 2011).
2. Adaptation of crop varieties/hybrids and improved organic fertilizer use and management have been proposed to offset such climate change challenges when irrigation water is available (Dono et al., 2016), which may result in increased crop and biomass production due to the extended growing season, the CO2 fertilization, and the effect of milder winters on irrigated autumn–spring hay crops.

3. Qiao et al. (2018) found evidence of spatial changes in the wheat-cultivated area primarily caused by nitrogen leaching from fertilization.

Studies have reported the decline in soil biodiversity as a key future threat (McBratney et al., 2014). As stated by Hamidov et al. (2018) the impact of biodiversity on soil fauna and microorganisms are relatively unexplored.

3.0 Survey

The researchers engaged in a field survey of local agricultural farmers in Anambra State. To ensure uniformity of responses, a structured questionnaires was administered. The distribution and retrieval of the questionnaires was conducted with the assistance of farmers' cooperative societies. This is particularly useful to reduce incidence of non-response bias. The graphs below summarise the responses to the questions asked.

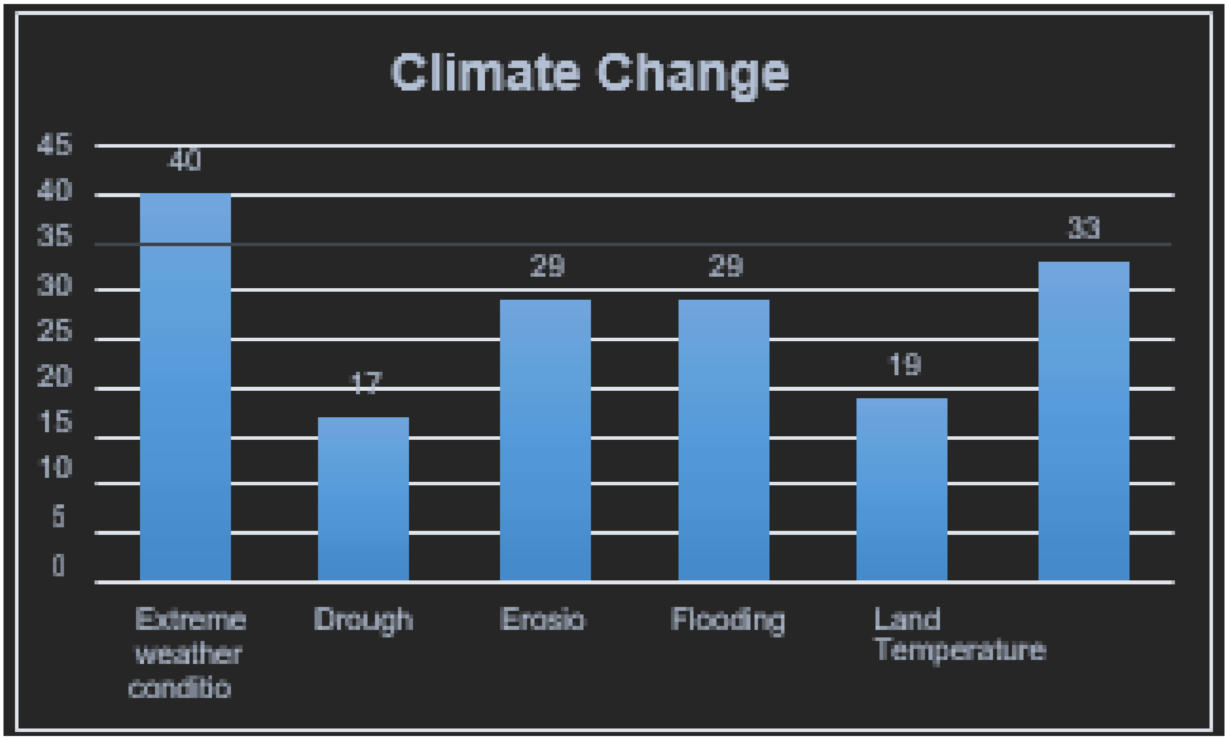

Figure 4: Climate change risk as perceived by local farmers

Source: Field Survey (2021)

The respondents were asked to indicate the extent of awareness of government intervention, the researchers engaged in a field survey of local agricultural farmers in Anambra State. To ensure uniformity of responses, a structured questionnaires was administered. The distribution and retrieval of the questionnaires was conducted with the assistance of farmers' cooperative societies.

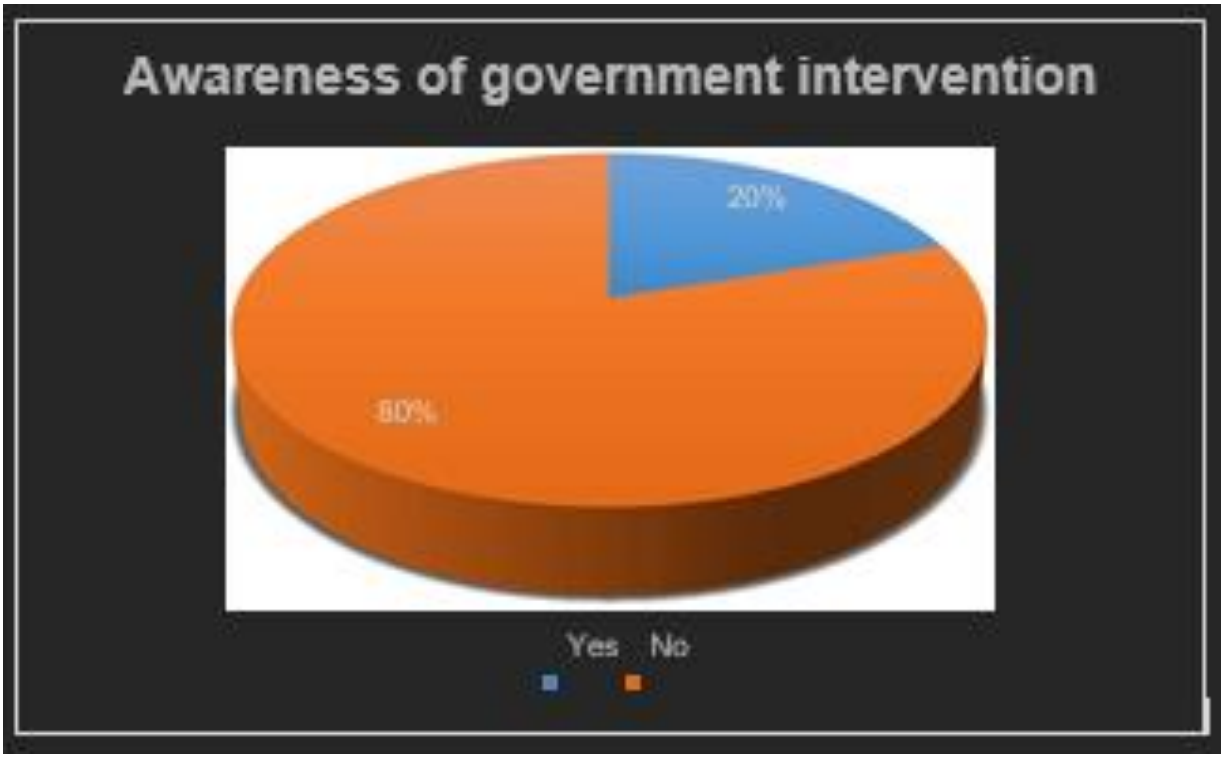

Figure 5: Awareness of government support towards climate change
Source: Field Survey (2021)

Table 2: Frequency distribution of questionnaire responses

S/No	Item	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
1	Introduction of new species and crop rotation	77	14	7	19	50
2	Altering the intensity of tillage practices	59	37	8	11	52
3	Implementing the use of irrigation and drainage systems	77	22	10	12	46
4	Organic manure and fertilizer optimization	102	3	12	14	36
5	Change of arable land to grassland	63	43	4	10	47

Source: Field Survey (2021)

The main inhibiting factors as identified by the respondents are shown in the Figure below. The respondents identified lack of access to finance as the main reason for non- implementation of modern farming techniques. This is correlated with absence of climate change initiatives, as most modern technologies are capital intensive requiring huge capital outlays. At the bottom is land unavailability, as most lands lie fallow in the rural communities with individuals lacking funds for cultivating such expanse land mass and therefore resorting to subsistence farming as a means of livelihood and not for large commercial endeavours.

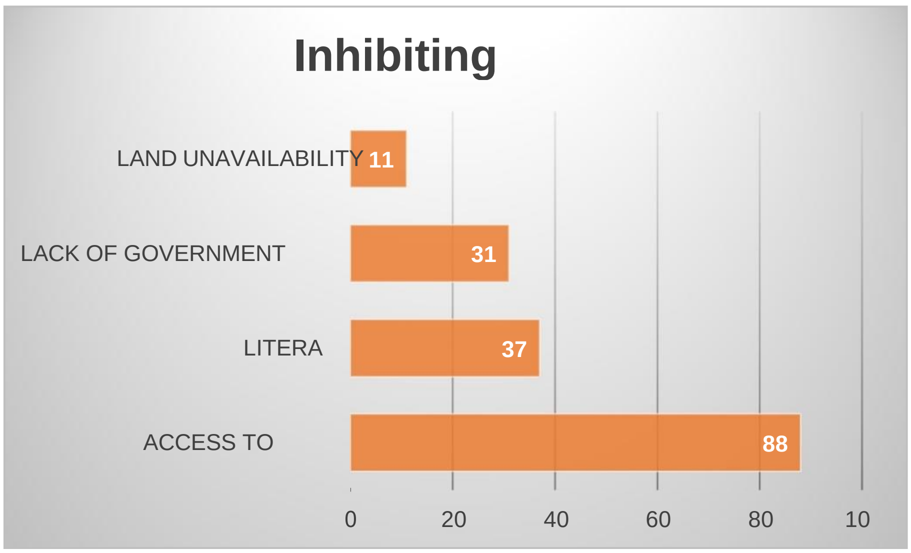

Figure 6: Inhibiting factors towards climate change adaptation
Source: Field Survey (2021)

4.0 Conclusion and Recommendations

The rate of climate change poses a significant threat to Sub-Saharan Africa. This threat if left unchecked may lead to lower crop yield and food scarcity in the region. In addition, the global volatility in oil prices from variable oil price movements and most economies adapting to renewable and sustainable energy options. May dampen the economic growth, while hindering the growth of future generations. Based on this, the study concludes that in this era there is a need to adapt and advance sustainable agricultural practices. These practices can promote food production in the country, both for local consumption and export. The country should strive to maintain a sustained diversification agenda by growing other non-oil sectors of which the agriculture is a key. However, sole focus should not be only increasing food production and soil systems; but rather, adopt a holistic approach geared towards the overall ecosystem (Hamidov et al., 2018). In addition, as suggested by Bonfante et al. (2017), the use of 'bioenergy crops' for their potential in reducing greenhouse emissions is highly recommended. These crops have also a potential to rejuvenate previously docile lands for re- cultivation. However, further research on usage and particular combinations for such intercropping should be embarked upon to avoid perennial losses. This therefore calls for renewed government intervention in agricultural research funding in order to meet up with countries in Asia, Europe, etc. that have implemented the use of artificial intelligence (AI) in agricultural practices.

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Appendix

University of Notre Dame Global Adaptation Initiative Country Index (1995-2019)

Year	Ranking
1995	141
1996	142
1997	140
1998	138
1999	143
2000	141
2001	140
2002	142
2003	135
2004	138
2005	123
2006	98
2007	97
2008	94
2009	98
2010	94
2011	95
2012	98
2013	98
2014	166
2015	162
2016	161
2017	163
2018	161
2019	161