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Review on the Potential Effect of Climate Change on Agricultural Production

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Abstract
Climate change presents a formidable challenge to global agricultural production, with significant implications for food security, rural livelihoods, and economic stability. This review explores the potential effects of climate change on agriculture, focusing on key climatic factors such as rising temperatures, altered precipitation patterns, increased frequency of extreme weather events, and elevated carbon dioxide (CO_2) levels. These changes directly impact crop yields, and also exacerbating plant disease. The review highlights the impacts of climate change, with developing countries, particularly those in sub-Saharan Africa, facing disproportionate risks due to limited adaptive capacity. In Nigeria, for instance, erratic rainfall, prolonged droughts, and desertification threaten staple crop production and increasing food insecurity and rural poverty. Policymakers must also implement supportive frameworks to facilitate the transition to climate-smart agriculture and ensure equitable access to

resources and technologies.This review underscores the urgent need for comprehensive research and policy action to address the complex challenges posed by climate change on agriculture, emphasizing the importance of integrating scientific knowledge, local practices, and innovative solutions to safeguard global food systems.

Introduction

Climate change poses one of the most significant threats to global agricultural production, with far-reaching implications for food security, livelihoods, and sustainable development. Rising temperatures, shifting precipitation patterns, and the increased frequency of extreme weather events are disrupting traditional farming systems and challenging the resilience of agricultural communities worldwide. Agriculture, which depends heavily on stable climatic conditions, is particularly vulnerable to these changes, making it imperative to understand and address the potential impacts of climate change on this vital sector (IPCC, 2022).

Smallholder farmers in developing countries, including those in sub-Saharan Africa, are especially at risk due to their limited adaptive capacity and reliance on rain-fed agriculture. Crop yields for staples such as maize, rice, and wheat are projected to decline in many regions due to increased temperatures and unpredictable rainfall patterns (Lobell & Field, 2007). Additionally, elevated atmospheric CO_2 levels, while potentially enhancing photosynthesis in some crops, may negatively impact the nutritional quality of food, further exacerbating global malnutrition (Myers *et al.,* 2014).

Climate change is caused by many factors but before discussing these, it is necessary to understand the meaning of Climate Change and its implications for different sectors of the economy. Climate change refers to any change in climate over time, whether attributable to natural variability or as a result of human activity (Comoé *et al.,* 2014; Zwiers *et al.,* 2014). Climate Change is defined as a variation that is ascribed directly or indirectly to human action that changes the structure of the global atmosphere and that is in addition to natural weather inconsistency perceived over comparable period

(Mustapha *et al.,* 2012; Ogbo *et al.,* 2013). This variation will adversely affect the human and agricultural sectors if proper measures are not put in place to reduce the impact.

Causes of Climate Change

The occurrence of Climate Change has intensified in recent years due to human activities. Human actions such as gas flaring, agriculture, deforestation, transportation, electricity production, dumping of waste, and construction of residential buildings have contributed to the rise in greenhouse gas emission into the air, thus causing a rise in temperature in the global climate - global warming (Parry *et al.,* 2007; Bello *et al.,* 2012a; Audu, 2013). These condition have threaten the livelihood of small-scale farmers and poses a challenges to agricultural production.

Gas Flaring

Gas flaring is among human activities that contribute to global warming and Nigeria flared up to 46%, 42%, 40%, 32%, 33% and utilized 54%, 58%, 60% 68%, 67% of gas from oil refineries in 2003, 2004, 2005, 2006, and 2007 respectively (Audu, 2013). It is estimated that Nigeria is the second-largest gas flaring country in the world, accounting for about 15 BCM after Russia which flares up to 40 BCM as shown in (Figure 1.1). These two countries account for about 40% of the total gas flared globally while other countries account for the remaining 60% (Elvidge *et al.,* 2009).

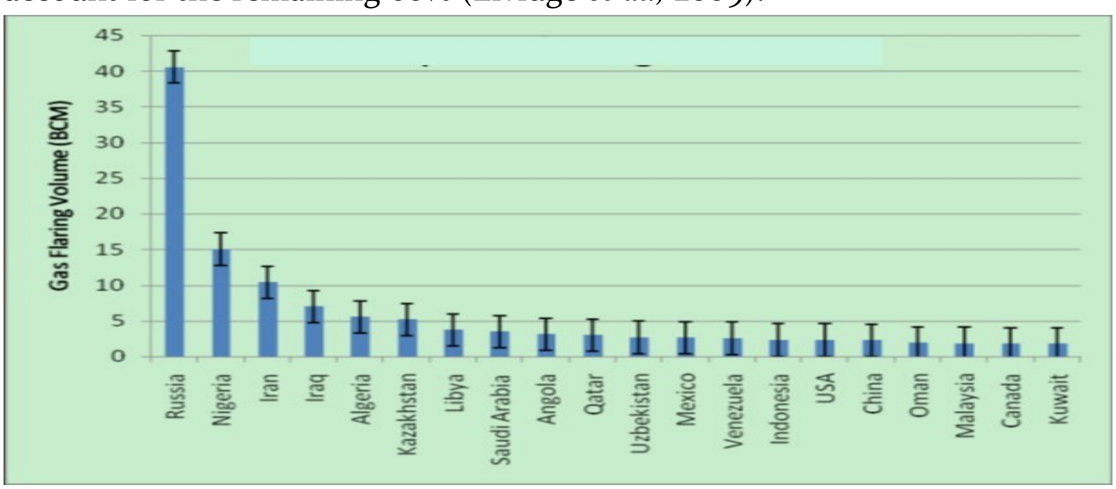


Figure 1.1 Gas flaring estimates in billions of cubic meters (BCM) for the top 20 countries in 2008 (Elvidge *et al.*, 2009).

Electricity Production

Electricity generation and heat is the largest contributor to greenhouse gases (GHGs) in the atmosphere: about 27% globally, 31% in EU and 34% in Australia (Figures 1.2, 1.3 and 1.4). The burning of fossil fuels such as coal, oil, and gas, discharge GHGs into the atmosphere (Ifeanyi and Obi *et al.,* 2012; Audu, 2013). This discharge of GHGs such as carbon dioxide (CO_2) and methane (CH_4) into the atmosphere is the key cause of CC because their accumulation in the atmosphere leads to warming of the Earth's surface (Efe, 2010; Odjugo, 2010). In Nigeria for instance, flaring of gases has increased the temperature and made many areas in the Niger Delta region uninhabitable (Ogbo and Onyedinma, 2012).

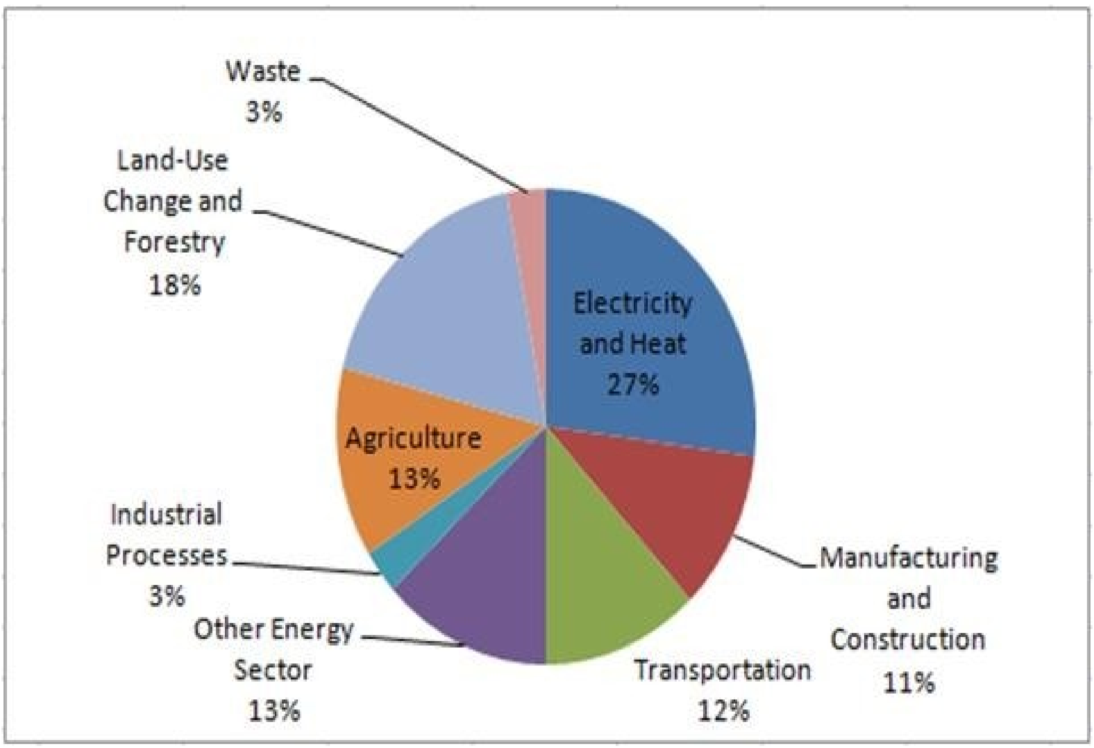
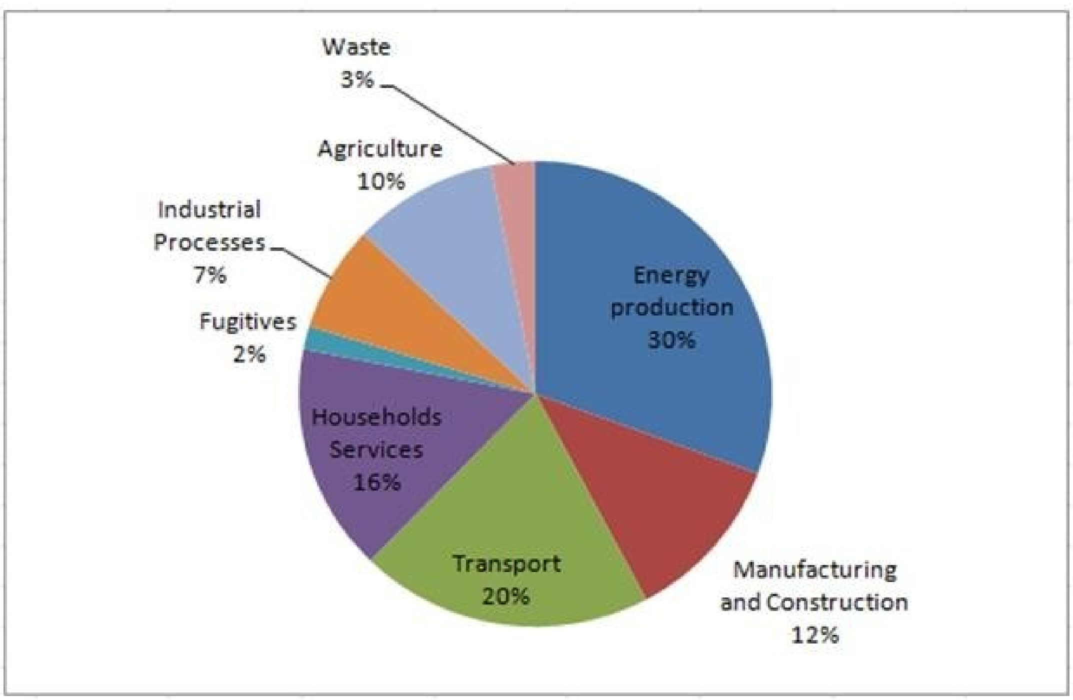


Figure 1.2 Contribution of different factors to global GHG emission in 2014 (Yarnal, 2014)

Agriculture

Agriculture and other energy sector are ranked third-largest producers of GHGs, accounting for 13% of the global GHGs emission (Figure 1.2). In the

EU agriculture is the 5^{th} largest producer accounting for up to 10% (Figure 1.3). It is also the 4^{th} largest producer of GHGs in Australia contributing up to 14% (Figure 1.4). According to Bellarby *et al.* (2008), the agricultural sector causes 17–32% of global human-induced GHGs emissions. However, this percentage rises to more than 30% if the indirect sources of carbon emission are included, the use of fossil fuel in carrying out farm operations, manufacture of agrochemicals, and conversion of another available land to agricultural production (Foereid *et al.*, 2008). This makes the agricultural sector the second-highest contributor of greenhouse gases after fossil fuel use (US-EPA, 2006). Agriculture is also the principal producer of both methane and nitrous oxide, which make up about 22% of worldwide GHG emissions (Baumert *et al.,* 2005). According to Breysse *et al.* (2013), agriculture is the least contributor of greenhouse gases, having only about 8%. The generation of CO_2 in agriculture is mostly from microbial decomposition, bush burning, livestock manure, and the use of nitrogen fertilizer (Bouwman *et al.,* 2002; Change, 2006; Steinfeld *et al.*, 2006). Agricultural expansion to feed the growing population has increased land use and led to the conversion of forests to other uses, thereby reducing the amount of GHGs sequestered by the forests (Foereid *et al.*, 2008).



Commercial and Residential areas

Waste is also among the least contributor to global GHGs with 3% (Figure 1.2). Also, in the EU and Australia waste is the least producer of GHGs accounting for about 3% each (Figure 1.3; Figure 1.4). Breysse *et al,* (2013) stated that businesses and homes in the cities contribute heavily to the emission of GHGs producing about 11% of the gas emitted in the USA by burning fuel, waste disposal, and the use of certain products that contain GHGs. As the world's population increases, so the need for food, livestock, and energy also increases (Ifeanyi-Obi *et al.,* 2012). African urban population is predicted to rise by 760 million in the year 2030 (Douglas *et al.,* 2008). Iwejingi (2013) stated that the annual increase of 3.2% in the Nigerian population will lead to deforestation, the building of residential homes, other structures, indiscriminate dumping of wastes, which will add to the emission of methane, cause an increase in GHG emissions, and disruption of agricultural production.

Effect of Climate Change on Agriculture

Nigeria's agricultural sector, which employs over 70% of the population and contributes significantly to the country's GDP, is highly vulnerable to the impacts of climate change. As a predominantly agrarian economy, Nigeria relies heavily on rain-fed agriculture, making it particularly susceptible to changing climatic conditions. Rising temperatures, erratic rainfall patterns, and increasing frequency of extreme weather events are already posing significant challenges to agricultural productivity, food security, and rural livelihoods. Climate change has change the productivity capacity and sustainability of agriculture in several sub Saharan region (IPCC, 2022). According to Ani et al. (2022) one of the major reason why climate change remains a global challenge is the danger pose to agricultural production. Studies revealed that Nigeria has witness a steady shift from the usual agricultural production pattern over the decades (Ikem, 2018). Due to high erratic rainfall patterns and rising temperatures make farmers' production choices a uncertain to grow their crops.

Ayinde et al (2011) study indicated that increase of any climate change agents such as temperature reduces agricultural productivity in Nigeria. Study of Ajetomobi et al. (2015) annual rainfall and extreme temperature threaten the productivity of more than half of staple food crops in Nigeria. Such effects have adveserly affected Nigerians agricultural production system including the supply chain. Several literatures revelead that extreme temperature and rainfall has negetative effects on crop yields and incddences of diseases. Nigeria agricultural sector is experiencing drastic decline in crop yield, increase of disease incidence, detoriation of soil fertility and health as well as threaten livestock production due to effects of climate change (Nzeh et al., 2016).

Effect of Climate Change on Crop Yield

Climate change affects agricultural productivity both directly and indirectly, the direct effect is mostly caused by variation of physical parameters such as temperature, precipitation variation on agricultural produce. While the latter decline productive through changes in pests, diseases, vectors, and invasive pollinators that can play a major role in yield reduction (IPCC, 2014a). Climate change poses a negative effect on the production of cereals crops around the word (FAO, 2015). The effect of climate change manifested on crop production in many countries around the globe (Porter *et al.,* 2014). Such as the high price spike of cereal crops yields (Lobell and Costa, 2011).

Climate change effect on agricultural crop yield depends on several parameters; includes atmospheric temperature, precipitation, CO_2, solar intensity, etc. temperature variation can result in geographical yield productivity of agricultural produce. According to Svobodova *et al.,* 2014 increase in temperature in the Mediterranean basin resultedthe in the high manifestation of tropical species. Literatures reveleade that an increase temperature increase decreseases rice yield by 3.2% in slightly warmers conditions, 8.2% in greater warmers conditions, and 8.4% in extreme warmers conditions (Agba *et al.,* 2017). The study of Agboola & Ojeleye (2007) revealed that small-scale farmers have experience crop yield reduction due to rainfall, relative humidity and increase in temperature.

Further studies reveals that some crop plants are expected to experience negative effects of climate change due to the vulnerability rate and the level of interaction with disease triangle; environment, plant, host, and pathogen (Pautasso *et al.,* 2012). Furthermore, due to high temperature in sub-Saharan Africa the region is experiencing early appearances of invasive pest and diseases such as the deslocustscust and stem rust diseases in Africa (Cressman, 2013).

Plant Disease

Plant disease is one of the most important factors affecting global agricultural production rate at an unprecedented time and climate change further intensifying the situation (Sahar A. Z 2019). Disease and pest infestation causes yield reduction of about 16% globall (Ficke *et al.,* 2018). Developing countries may likely experience yield reduction of certain crop of about 10% by 2055, that are attributed to several climate change parameters (Gachene *et al.,* 2015). These losses directly affect food security of the region. "Plant disease is a result of an infectious biotic (living component of an ecosystem) agent or a non-infectious, or abiotic (non-living, physical and or chemical component) factors" (Hassan S. *et al.,* 2015).

Effect of Climate Change on Plant Disease

Diseases of crop is one of the most significant components affecting agricultural production. Plant diseases occur as a result of interaction between a susceptible host, a virulent pathogen, and favorable environmental conditions in which climate is a major contributing factor directly or indirectly (Yanez-Lopez R. *et al.,* 2012). Furthermore, climate variability significantly affects plant development and increases rate of diseases infestation on crops (Kang *et al.,* 2010). Causing an estimated loss of about 10% globally (Nazir, *et al.,* 2018). Rising in atmospheric temperature and CO_2, the Ozone are the driving agent responsible for altering the development of pathogen, and declining crop yield (Chakraborty S. *et al.,* 2002 & Mina & Sinha, 2008). Climate change parameters have direct and indirect negetative effect of resistability on plant host and the pathogen

(Coakley S. *et al.,* 1999). According to (Calzadilla *et al.,* 2013 and Teixeira *et al.,* 2013) extreme temperature have negative impact on crop during flowering stage and shorten the growing lifespan of the crop. Carbon dioxide (CO_2) elevation in agricultural activities affect crop productivity directly or indirectly in several ways; high CO_2 atmospheric concentration affect plant nitrogen absorption, which further stagenet crop growth, and increases the rate of transpiration (Jongen M. and Jones B.M 1998). Sub-Sahara Africa regions have shown an increase in temperature and precipitation pattern of about 2% increase in West Africa and 7% increase in East Africa, but a 4% decrease in southern Africa.climate change plays a significant role in the parameters variation. Furthermore, sub Saharan Africa is likely to face the emergency of invasive plant diseases that can excabate the issue of food insecurity (FAO, 2015).

Conclusion

Climate change presents a profound and multifaceted challenge to agricultural production globally, with particularly severe implications for food security, rural livelihoods, and economic stability in vulnerable regions. The review highlights that key climatic factors such as rising temperatures, erratic rainfall patterns, extreme weather events, and elevated CO_2 concentrations are already impacting crop productivity. These changes exacerbate soil degradation, water scarcity, and pest dynamics, leading to reduced yields, lower nutritional quality of crops, and increased susceptibility to disease in plants.

In regions heavily reliant on rain-fed agriculture, such as sub-Saharan Africa, including Nigeria, the adverse effects are particularly pronounced. Smallholder farmers, who lack the resources and infrastructure to adapt effectively, face increased poverty, food insecurity, and displacement. The socio-economic consequences extend beyond agriculture, affecting local economies and exacerbating conflicts over diminishing resources. Policy interventions, such as investments in research, extension services, and climate-smart agriculture, are essential to support farmers in adapting to changing climatic conditions.

In conclusion, addressing the potential effects of climate change on agriculture requires a holistic and coordinated approach that integrates scientific innovation, policy support, and community engagement.

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