



# Climate Change: Effects and Adaptive Measures in Africa

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## Authors' contributions

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## ABSTRACT

Climate change has constituted a global menace to standard of living in many countries of the world. The developing countries including the Africa continent are among the most susceptible to climate change impact. In order to ensure environmental sustainability, food security and socioeconomic growth in this region, strategic mitigation and adaptation to climate change impacts needs to be employed. This review paper highlights on climate change impact and adaptation in Africa.

Prolonged and intensified droughts has been recorded in Eastern Africa; unprecedented floods in Western Africa; depletion of rain forests in Equatorial Africa; and an increase in ocean acidity around Africa's southern coast. As a result of these, food, health, water and energy security have been threatened, therefore undermining Africa's ability to grow and develop.

Meanwhile, temporal migration pattern has been adopted in Sudan and Ethiopia as a way to adapt to recurrent drought; in adapting to floods, most western part of Africa have adopted building

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houses on stilts and cultivation of floating vegetable plots. Also, crops biotechnology developments have been applied to increase Agriculture production in many parts of Africa. However, the level of adaptation has not kept pace with the rate of climate change effects; it is important to develop sustainable ways through which the vulnerable in Africa will build climate change-resilient livelihoods. This will require substantial investment in: income diversification, disaster-risk management, empowerment of women and other marginalized social groups, provision of a reliable system of meteorological alerts, effective extension services and the establishment of independent networks of information exchange between and among communities across the region. Climate change will have significant impacts on communities and livelihood. It is important to assist the vulnerable group by boosting their adaptive capacity in response to climate change so as to safeguard sustainable development and food security improvement of their population.

*Keywords: Climate change; climate change effect; adaptation.*

## 1. INTRODUCTION

Climate change refers to changes in climate brought about by anthropogenic activities and natural variation that changes the originality of the global atmosphere observed over comparable period of time [1]. Climate change reality has become a germane topic of the 21<sup>st</sup> century and has attracted attention in the global corridor of developmental policies and global governance [2]. The on-going climate change and its associated global warming are expected to cause distinctive climate patterns in different climatic zones and will impact negatively on the ecosystem [3]. Climate change brings with it changes in weather patterns that can have serious repercussions on lives and properties; upsetting seasonal cycles, harming ecosystems and water supply, affecting agriculture and food production, causing floods, landslides, drought and famine as weather becomes fierce [4]. Recent research on Climate change has noted the impacts of climate change on agriculture and natural resources management in the developing countries [5]. The developing countries are more likely to be more vulnerable to climate change impacts; this is because of their warm baseline climate which encourages high reliance on rainfall for agricultural production and scarcity of information and resources for adaptation [6]. According to [7], millions of people who are directly and indirectly dependent on rainfed agriculture face a greater risk of poverty, hunger and malnutrition, because climate change will directly impact and alter their food security and livelihood status. Recent literature has documented prolonged and intensified droughts in eastern Africa [8]; unprecedented floods in western Africa [9]; depletion of rain forests in equatorial Africa [10]; and an increase in ocean acidity around Africa's southern coast [1].

Recent studies in African countries have highlighted populations' adaptation strategy with recurrent climate change impacts: temporal migration pattern has been adopted in Sudan and Ethiopia as a way to adapt to recurrent drought; in adapting to floods, most western part of Africa have adopted; building houses on stilts and cultivation of floating vegetable plots. Also, drought- and pest-resistant rice, drought-tolerant maize and insect-resistant millet, sorghum and cassava, among other crops [11] have been adopted as a way to increase Agricultural production in many parts of Africa. However, the level of adaptation has not kept pace with the rate of climate change effects. This could be attributed to scanty information available to affected population across the region on the impacts of climate change and sustainable adaptive measures. In order to buffer the adaptive capacity of these regions to these changes, a dedicated adaptation projects and information provision and dissemination platform will need to be encouraged. This adaptation projects will include: support to community-level adaptation actions that will enhance resilience to climate change in the short and long terms (this will require substantial investment in: water-wise irrigation systems, income diversification, disaster risk management, empowerment of women and other marginalized social groups, provision of a reliable system of meteorological alerts, effective extension services and the establishment of independent networks of information exchange between and among communities across the region) and promotion of integration of adaptation into policy and decision-making at the national and subnational levels. It is important therefore to assist the vulnerable group by ensuring their adaptation in response to climate change so as to safeguard sustainable development and food security

improvement of their population. This review paper therefore will emphasize on climate change impacts and adaptation strategies in Africa.

## 2. CAUSES OF CLIMATE CHANGE

Climate changes as a result of natural processes (bio-geographical) and several activities of human (e.g. burning of fossil fuel and deforestation) that releases greenhouse gases or reduce the ability of the greenhouse gases to be removed from the atmosphere [12]. The natural processes are volcanic eruption which increases carbon dioxide in the atmosphere; changes in the intensity of energy emitted by the Sun; and variations in Earth's position relative to the Sun, both in its orbit and in the inclination of its spin axis [12]. Human activities such as industrialization, gas flaring, burning of fossil fuel, urbanization and agriculture emit large amount of greenhouse gases (GHG) [13]; methane (CH<sub>4</sub>), carbon (IV) oxide (CO<sub>2</sub>), chlorofluorocarbons (CFCs) and nitrous oxide (N<sub>2</sub>O) [14] among others into the atmosphere that destroys the ozone layer. Similarly, deforestation activities, alterations in land use, water pollution and agricultural practices among others reduce the amount of carbons absorbed from the atmosphere [15]. Studies of long-termed climate change have however discovered a connection between the concentrations of carbon dioxide which is one of the most important GHGs in the atmosphere and mean global temperature [14,12]. Carbondioxide is one of the most important gases responsible for the greenhouse effect [12]. These GHGs are able to alter the energy balance of the earth by being able to absorb long wave radiation emitted from the earth's surface [12]. The net results of this process and the re-emission of long wave back to the earth's surface increases the quantity of heat energy in the earth's climatic system [12]. Humans are however the major inducer and sufferers of climate change [16]. In fact, Climate Change refers to influences on climate resulting from human practices [12]. This is because increases in the concentration of greenhouse gases in the atmosphere resulting largely from burning of fossil fuels, deforestation and human population increase, have led to an observed and projected warming of the earth, known as the enhanced greenhouse effect [12]. This is why many scientists regard human-caused (anthropogenic) global climate change to be the most important environmental issue of our times [17,12].

## 3. CLIMATE CHANGE: GLOBAL AND AFRICAN EXPERIENCE

### 3.1 Global Trend

It is evident through continuous scientific research that an unambiguous warming of the climate system is taking place [18,12,19,20,21]. These warming can be attributed to the impacts of rising GHG emissions caused by human action which are majorly burning of fossil fuel and land use change associated with Agriculture and Forestry [19,12]. As a result of these; during the period between 1906-2005 global average air temperatures increased by 0.74°C [12]. Sea surface temperatures on the global scale have also been on the rise since 1950 and the ocean has absorbed great intensity of heat energy which is added to the climate system [22]. Sea level rise has been on the increase as a result of temperature increase and associated thermal expansion which account for up to 57% of the average sea level rise of 1.8 mm per year between 1961 and 2003; melting of glacial and polar ice sheets contributed a further of 28% to this increase [12]. Oceans which are a great carbon sinker absorb approximately 25% of human produced CO<sub>2</sub> causing ocean acidification [23]. Freshwater hydrology including rivers and lakes has been significantly affected by the continued changing patterns and seasonality of snow melt [12]. Up till present, there is a decline in average sea alkalinity from 8.2 to 8.1 [24], which is equivalent to a 30% increase in acidity. Impacts of climate change are expected to be different considering different regions [25], northern latitude are expected to witness higher temperature increase over land masses [26].

### 3.2 Climate Change Trend in Africa

The high dependence on rain fed agriculture and high reliance on agricultural production for socio-economic development in Africa exposes it to climate change impacts [27]. From the climatic parameters that have been observed for sometimes now shows variation and fluctuation in different region across Africa. On the general note, surveys on temperatures across Africa have indicated an increasing warming trend since the 1960s [28]. Although these inclination shows consistency across the globe, however, these changes are not always uniform [28]. For instance, warming rates over a decade is 0.29°C in the African tropical forests [28] and 0.1 to 0.3°C in South Africa [29]. Between 1961 and

2000, there was a proliferation in the number of warm stretch over southern and western Africa, and a reduction in the frequency of extremely cold days [30]. In eastern Africa, observation from weather stations located close to the coast and major inland lakes shows decrease in the trend of temperature measured over some period of time [31]. In South Africa and Ethiopia, minimum temperatures have been noticed to increase faster than the minimum temperature or average temperature [29]. Generally, for Africa, identification of southward shifts of 120 km of the June -August rainfall in the period 1961–1990 compared to the 1931–1960 period [32]. This is related to the drying of the Sahel [33]. However, rainfall is characterized by spatial and temporal variability [32]. In West Africa, reports of continued observation has shown decline in annual rainfall in all climatic zones with major decline of up to 40% observed in drier Sahel parts of Africa [34,35,36]. In the tropical rain-forest zone, reduction in average annual precipitation of around 3% in North Congo, 4% in West Africa, and 2% in South Congo for the period 1960 to 1998 have been noted [28]. In Guinea coast of West Africa rainfall increases of about 10% in the last 30 years have been observed [37]. In Southern Africa, there is increased rainfall, but, also inter-annual variability and anomalies also increases in the post 1970 - period leading to more intense and widespread droughts [38,39,40]. In Angola, Namibia, Mozambique, Malawi, Zambia there is significant increase in heavy rainfall and weather extremes [41,42,30]. In South-East Africa Zimbabwe, Botswana, Transvaal, rainfall decrease of up to 15 percent [32]. In recent decades, Eastern Africa has been experiencing intensified dipole rainfall, that is, increased rainfall over northern sector, with reduced rainfall in the southern sector [43], rainfall increase between September and November (warm period) leading to spread of malaria vector [44, 45]. Climate variability and changes have a great influence on livelihood in Africa due to its direct impacts on agricultural productivity [46]. It is however important to develop a strategy to cope with the current impacts of climate change and to devise a means to mitigate potential influence of variability. In coping with potential influence of variability, climate regime changes (e.g., El Nino-Southern Oscillation (ENSO) events) in Africa needs to be properly understood and requires further research [33]. The influence of ENSO decadal variations has been observed in South-West Africa, which is also influence in part North Atlantic Oscillation (NAO) [37]. The way these

mechanism influences weather patterns have been linked to cause severe droughts, which is influenced by regional atmospheric-oceanic anomalies before the 1970s but to ENSO in more recent decades [40].

#### **4. EFFECTS OF CLIMATE CHANGE: AFRICA CONTINENT OUTLOOK**

The effects of climate change are diverse and severe. Many elements of human society and the environment are sensitive to climate variability and change. Putting reference to sub-Saharan Africa, interest has emerged on climate sensitivity factors and possible impacts of climate change on such sensitive factors which includes agriculture, sustainable development and economic growth [47]. Effect of climate change on such factors include changes in soil moisture, changes in soil quality, crop adaptation [48], timing/length of growing seasons, yield of crops and animals, changes in atmospheric temperatures, disease, desertification and pest problems on crops and livestock [49], weed insurgence, flooding, unprecedented droughts, sea level rises [50] and many more. The specific effects of climate change as modified from [48] include:

##### **4.1 Frequent Environmental Disasters and Health Issues**

Climate change induced disasters such as droughts, floods, severe weather and sea-level rise and wild fires are likely to increase in intensity and frequency with the consequent increases in vector-borne diseases, infrastructure damage, the degradation of natural resources upon which livelihoods depend on, food insecurity as well as loss of life and property [51]. Evidence of inter-annual lake-level fluctuations and lake-level volatility, for example, has been observed since the 1960s, probably owing to periods of intense droughts followed by increases in rainfall and extreme rainfall events in late 1997 (e.g., in Lakes Tanganyika [52], Victoria [53] and Turkana [52]). After the 1997 floods, Lake Victoria rose by about 1.7 m by 1998 [53], Lake Tanganyika by about 2.1 m [52], and Lake Malawi by about 1.8 m [52], and very high river-flows were recorded in the Congo River at Kinshasha [53]. Large scale atmosphere-ocean interactions in the Indian Ocean have been attributed to the heavy rainfall and massive flood [54]. Large numbers of people, mostly in the coastal and urban areas

are currently at risk of floods [55], where coastal erosion, lack of efficient drainage facility in urban areas among others are already influencing the destruction of infrastructure, housing and tourism facilities (e.g., in the residential region of Akpakpa in Benin [56]. Climate change has wide-ranging consequences on human health. This is because the health of communities depends on sufficient food, safe drinking water, comfortable homes, good social conditions, and a suitable environmental and social setting for controlling infectious diseases. The effect of climate change in Africa has influenced health stresses to many communities. Recent assessments shows that estimated 700,000 to 2.7 million people die of malaria each year and 75% of those are African children [57]. Incidences of malaria, including the recent resurgence in the highlands of East Africa, however, involve a range of multiple causal factors, including poor drug-treatment implementation, drug resistance, land-use change, and various socio-demographic factors including poverty [58,57,59,60]. Other diseases are also important to consider with respect to climate variability and change, as links between variations in climate and other diseases, such as cholera and meningitis, have also been observed [61]. About 162 million people in Africa live in areas with a risk of meningitis [61].

#### **4.2 Declining Agricultural Productivity**

As temperature increases and rainfall pattern becomes more unpredictable, crop yields are expected to drop significantly [62]. Also extreme weather events such as thunderstorms, heavy winds and floods devastate farmlands and can lead to crop failure [63]. Pests and diseases migrate in response to climate changes and variations and are potential crop destroyer [13]. Climate change is expected to greatly influence agricultural productivity in Africa [15]. The expected influence would include (1) Occasional changes in rainfall and temperature, which impact on agro-climatic conditions directly and indirectly affecting agricultural productivity [13] (2) alteration in planting seasons which will directly affect planting and harvesting calendars [64] (3) fluctuation in water availability [65] (4) increase pest, weed and disease incidences [66] (5) alteration in evapotranspiration, photosynthesis and biomass production [12] (6) alteration in agricultural land in quantity (spatial) and quality (fertility) [67]. West African countries and other African countries have been facing these consequences of climate change [68], this is reflected in their losses of agricultural produce,

which is estimated up to 4% of GDP [19]. Northern and Southern Africa, however, are expected to have losses of 0.4 to 1.3% [69]. Southern Africa would be likely to experience notable reductions in maize production under possible increased ENSO conditions [66]. These impact as broadly classified by [70] to include Biophysical impacts (increase weed and pest infestation, fluctuation in soil nutrient and water availability, ocean acidification and change in salinity and temperature, incidence of flood and erosion of agricultural land, extreme weather conditions for crop and livestock among others) and socio-economic impacts (reduction in yield from agricultural produce, reduction of agricultural contribution to national development, effects on livelihood and food security, conflicts as a result of land argument and water resources use, migration and civil unrest [71]. Fisheries are another important source of revenue, employment and proteins [72]. The sector has contributed immensely to economic development of Africa [72]. Part of the impact that may arise in this sector include changes in freshwater flows and a greater intrusion of salt water into lagoons, will affect important inland water and aquaculture fish potentials [73], also changes in estuaries, coral reef bleaching and ocean acidification are other major effects that will limit the benefit of fisheries resources to meet food security challenges [74].

#### **4.3 Insecurity and Conflicts**

Climate change may pose threat to the security situation in a country through increasing water scarcity [75]; decreasing food security [76]; increasing climate-induced migration [77] and increase of poverty [78]. Conflicts and dispute have recently been recorded regarding land and associated agricultural activities in the Greater Horn of Africa (Somalia, Ethiopia and Sudan) and the Great Lakes region (Burundi, Rwanda and the Democratic Republic of Congo) [76]. The causes of such conflicts can be attributed to climate change and also to land scarcity for agricultural purposes [79], habitat loss [1], over-harvesting [80], the spread of alien species [80], and activities such as hunting and deforestation [12], which threaten to undermine the integrity of the Africa's rich but fragile ecosystems [81]. Land distribution and land scarcity for agriculture have promoted conflict in Niger Delta in Nigeria [82], Darfur and Sudan among others [79]; this land scarcity is often worsened by environmental degradation as the case of Niger Delta in Nigeria [83].

## **5. EFFECTS OF CLIMATE CHANGE ON HUMAN SETTLEMENT**

Desert encroachment has become a great threat to human settlement in Africa [12]. The northern part of Nigeria is fast becoming un-habitable due to desertification [84]. The trees in some parts of the Northern Nigeria are scanty and completely inadequate to support living conditions [84]. In many parts of Africa, farmers and pastoralists also have to contend with other extreme natural resource challenges and constraints such as poor soil fertility, pests, crop diseases, and a lack of access to inputs and improved seeds [12]. These challenges are usually aggravated by periods of prolonged droughts and/or floods and are often particularly severe during El Nino events [70]. Desertification has penetrated into half of the sub-humid and semi-arids parts of the southern region which are at moderate to high risk [70]. In West Africa, rainfall has drastically reduced and has resulted in a loss of grassland and acacia, the loss of flora/fauna, and shifting sand dunes in the Sahel [85] and consequent shift in human settlement [77]. Droughts also have long contributed to human migration [86]; cultural separation and population dislocation [86]. The rising sea level and gully erosion are equally claiming several kilometers in the coastal areas in Africa. The increase in sea-level rise has contributed to increase flooding [87], particularly on the coasts of eastern Africa [12], causing high implications for health [88]. Coastal erosion has however destroyed infrastructures, housing and tourism facilities [89].

## **6. ADAPTIVE STRATEGIES TO CLIMATE IN AFRICA**

Adaptation to climate change refers to adjustments in practices, processes or structures in response to projected or actual changes in climate, with the goal of maintaining the capacity to deal with current and future changes [12]. There are ranges of adaption practice in operation in Africa, the technique of adaptation practice that is commonly employed as documented can be categorized as (1) Diversification of sources of household income through; participation in income stabilization programs [90]; introduction of social protection initiatives [91]; development of innovative risk financing instruments and insurance schemes to reduce climate-related risk [12]; (2) building response capacity through conservation of genetic resources [11] and implementation of co-

management systems [11]; (3) Managing climate risk through disaster risk reduction and management [12]. In human settlement, where there is problems associated with drought and flood, migration of human population has always been an adaptive measure response to these threats. Recent evidence have however shown that migration of people are primarily influenced by climate stressors which most often causes unfavorable living condition [92], these stressors include changes in land and water regimes [93], changes in the frequency and intensity of droughts [93], flooding [92], water shortages [12], desertification [34], worsening soil conditions [67], disease and pest outbreaks on crops and livestock [94]. Also, migration occurs when inhabitant considers labour operation in a nearby location so as to seek for livelihood means this most often is seasonal in nature [95]. In some part of Africa (Nigeria, Ghana, South-Africa and Egypt among others), biotechnology research has yielded tremendous benefits leading to production of pest resistance and drought tolerant rice [11], insect and pest resistance maize [11], pest resistance tomato [11], insect and disease resistance cassava [11], Also, adaptation strategy has been found to include altering of the timing or location of cropping activities [96]; improved water management through use of technologies to harvest water [93], conservation of soil moisture (for example, through crop residue retention) and use/transport water more effectively [93]; altering inputs such as crop varieties and species to those with more appropriate thermal time and vernalization [96]; diversifying livelihood strategy to include income from other farming and non-farming activities [95]; improving the effectiveness of pest [97], disease and weed management practices through wider use of integrated pest and pathogen management, development and the use of varieties and species resistant to pests and diseases [97]; maintaining or improving quarantine capabilities [97] and monitoring programs [97]; using climate forecasting tools to reduce production risk [97]. Managing livestock also has attracted adaptive measures that include: modification of the time of grazing [98]; altering forage and animal species/breeds [98]; altering the integration within mixed livestock and crop systems including the use of adapted forage crops [71]; ensuring adequate water supplies and the using of supplementary feeds and concentrates [71]. Adaptation in fish production includes erecting cover/shades over ponds especially in dry weather [99], building ponds close to water sources [99], digging bore

holes/wells to supply water during dry seasons [100], building embankments to prevent flood water [100], adjustment in the time of stocking [100], stocking of quick maturing fish species [100], stocking fish species that are more favoured by climate change [100]. Other strategies that have been employed to reduce the shock of climate stress in Africa include: Government intervention driven programmes that offer subsidy to farmers in relation to farm input and also policy driven initiatives to enlighten the farmers on resilience strategies through extension workers [64], provision of storage facilities for farm produce to help in the establishment of national grain reserve [91], insurance provision to farmers to cushion the effects of damage from climate change impacts [101], climate forecasting tools to reduce production risk [101].

## **7. GOVERNMENTAL INTERVENTION AND ACTION FRAMEWORK TO CLIMATE ADAPTATION IN AFRICA**

In African countries, assessments of vulnerability to the impacts of climate change have been evaluated. Identified priority actions that need to be taken to reduce these vulnerabilities have been established. These actions are exemplified in programs of many organizations in Africa. Among these organization are the African Union (including the New Partnership for Africa's Development, NEPAD), intergovernmental organizations, pan-African ministerial bodies and trans-boundary efforts to manage water resources [102]. One of the action plans by these organizations includes the Climate for Development in Africa Initiative [102] and the Green Wall for the Sahara and Sahel Initiative [102].

## **8. CONCLUSION AND RECOMMENDATION**

African population has always battled with the vagaries of weather and climate. These struggles, however, are increasingly waged alongside a range of other stresses, such as disease, conflict, reduced agricultural productivity and land struggles, these have significantly impacted communities and livelihoods in the region. It is clear that climate change and variability, and associated disaster risks increased, and will seriously hamper future development. Boosting adaptive capacity and resilience of highly vulnerable population to

climate change impact will help to improve the African populations' livelihoods. In boosting adaptive capacity therefore, there is need to: 1) encourage institutional involvement and research focus on climate change in various region of Africa, 2) encouragement of young scientist will be necessary so as to foster youth involvement in research in the fields of climate-change impacts, vulnerability and adaptation; 3) great need for a well-established program of research and technology development in climate prediction, which could assess the risks and impacts of climate change on ecosystems; 4) research on the links between agriculture, land use, and carbon sequestration and agricultural use in biofuels also needs to be expanded; 5) detailed local-level analyses of the role of multiple interacting factors, including development activities and climate risk-reduction in the African context should be conducted; 6) there is also an urgent need to begin a dialogue and research effort on the heightened vulnerabilities associated with diseases and periods of climate stress and climate change. In order to boost the adaptive capacity of the venerable population in Africa, it is pertinent to render assistance by ensuring their adaptation in response to climate change so as to safeguard sustainable development and food security improvement of their population.

## **COMPETING INTERESTS**

Authors have declared that no competing interests exist.

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