Agriculture, which is the mainstay of the economies of many developing countries, is highly dependent on climatic conditions. This paper aimed at reviewing the climate change and its impacts on agricultural production with the specific objectives of reviewing the farmer's adaptation strategies and barriers to the climate change and the impacts of climate change on agricultural production and food security in Sub-Saharan Africa countries. Empirical evidence shows that most of the smallholder farmers in Sub-Saharan Africa have experienced the adaptation strategy of switching from planting high water-requirement to low water-requirement crops, planting diversified crops, changed planting dates to correspond to the change in the precipitation pattern and mixed cropping. The farmers’ ability to adapt to climate change has faced by access to information, extension services and access to credit. The effect of long-term mean climate change has significance impacts on global food production and affects all dimensions of food security in several ways ranging from direct effects on crop production to changes in markets, food prices and supply chain infrastructure which may require ongoing adaptation. Finally, effective institutions on climate change at the global level help to facilitate the policy implementations and to combat the impact of climate change.

Key words: Climate Change, Agriculture, Production, Sub-Saharan, Review

INTRODUCTION

Climate change is the worldwide environmental threat that seriously have emotional impact on agricultural productivity and which affects humankind in several ways, including its direct influence on food production (Enete and Amusa, 2016). According to IPCC (2014), the concept of climate change refers to the change of climate over time (long-run variability) because of human and non-human made activities while climate variability refers to the shorter-term variation or seasonal or multi seasonal of the climate. Climate change is predicted to have an effect on rains, increase the frequency of drought, and lift average temperatures, threatening the provision of water for agricultural production (IFAD, 2009).

Africa is one of the parts of the world that is the most vulnerable to the impacts of climate change (IPCC, 2014; Niang et al., 2014). Even though the climate change is worldwide problem, developing countries, like Sub Saharan African is the most adversely affected by climate change due to their dependence on agriculture as well as their poor financial, technical and institutional capacity to adapt (Singh & Purohit, 2014; Rose, 2015). The impacts of climate change such as rising global average temperature and changes in precipitation are deliberately clear with impacts already affecting ecosystems, biodiversity and human systems. In addition to climate change, land degradation and desertification are also expected to affect African countries (Hummel, 2015). This is because the livelihoods of millions of peoples who are poor and vulnerable are presently threatened by Climate change which altering the natural and physical resources they depend on generally and agricultural production particularly (Mesfin and Bekele, 2018).

Agriculture, which is the backbone of the economies of many developing countries, is highly depends on climatic conditions that are beyond the farmers’ control (Egbendewe et al., 2017; Mohammed et al., 2016).

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Agriculture is considered as the largest main economic activities in Africa by providing the employment for approximately 60 percent of the population, and more than 50 percent of GDP (Collier et al., 2008). In most of Sub-Saharan African countries, climate change would have negative effects on agricultural production which leads to lower farm incomes, increase of poverty, hunger and malnutrition, particularly in rural areas, with rain-fed agriculture as the main job (Abdulai, 2018; Lokonon and Mbaye, 2018; Di Falco, 2014; Ahmed et al., 2011).

Even though Africa is the country which mainly dependent on agriculture has been the lowest source of Greenhouse Gas emission owing due to the lack of industrial development (Gemeda & Sima, 2015), it is the most vulnerable to the impacts of global climate change (Hummel, 2015; Rose, 2015; Niang et al., 2014; Singh & Purohit, 2014; Bewket, 2012).

Fighting the impact of climate change on agricultural productivity through creation of adequate knowledge of farmer's awareness on adaptations, causes for the climate change and taking measures at universal level as well as at a national, regional and local level is important. In addition, policy options for effective institutions help for negotiation on climate change among all parties are important issues that may help to combat the impact of climate change.

The purpose of this paper is to review farmer's adaptation strategy, barriers to climate change and its impact on agricultural production and food security in sub-Saharan Africa.

MATERIALS AND METHODS

The sources of information for this review are mainly secondary. As much as possible, the paper reviews the recent published articles about the climate change on agricultural production, its impact on food security of households, the farmers' adaptation strategy and barriers in sub-Saharan Africa. Furthermore, it considered only studies published in English during the most recent decade in Sub-Saharan Africa. Publications were identified by keyword searches with Google Scholar. In addition to this, government and non-government agencies produced reports on the issues in Sub-Saharan Africa were used.

CLIMATE CHANGE

Causes and Measures to Reduce its Effects

Harris and Roach (2016) defined the global climate change as the changes in global climate, such as global temperature, precipitation, storm frequency and intensity, and changes in carbon and water cycles, that resulted from the increased concentrations of greenhouse gases in the atmosphere. It is a worldwide challenge that need an international collective action to curb its negative effects (Schenck, 2008). The impacts of climate change is becoming visible in all fields but with highly related to agriculture and human health (FAO, 2016). Although other factors also contributing for climate change, it is confidently concluded in (IPCC, 2014) that the emissions of greenhouse gases is mostly due to anthropogenic factors resulted from human activities.

Global warming which is an increase in average global temperature resulted from emissions from human activities is one of the peculiar manifestations of climate change (Harris and Roach, 2016). According to the latest report of the World Meteorological Organization (WMO) report of 2017, it has been confirmed that the year 2016 was the warmest year of record with a remarkable 1.1 °C above the pre-industrial period1.

Greenhouse gases increase the global warming by absorbing infrared radiation resulted in trapping heat to make the planet warmer (EPA, 2017). It was also indicated in the same document that the most important GHGs that directly emitted by anthropogenic process are carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), along with several other fluorine-containing halogenated substances. Compared to the pre-industrial era, concentrations of CO₂, CH₄ and N₂O have increased by 44%, 162% and 21%, respectively in the globe (NOAA/ESRL, 2017).

If a business continued as usual without significant intervention to reduce the greenhouse gas emission, the global average temperature will increase ranging 2.5°C and 7.8 °C by 2100, relative to pre-industrial levels as forecasted by IPCC (2014). It is understandable that business as usual costs more than intervening to mitigate the impacts of climate change. In fact, international communities have already recognized the threat of climate change and started tackling the hurdle by designing different climate change strategies and policies. One of the powerful international policies is the Kyoto protocol of 1997 (UN, 1998). This protocol is an international treaty ratified by 165 nations aiming to reduce GHG emissions in developed nations. There have been also several other national and regional policies and strategies to combat GHG emissions in developing nations like European Unions and US. To implement policies and strategies to reduce GHG emissions, numerous policy options have been proposed internationally. However, there is no a single best option as each of them has their own advantages and limitations.

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1 Pre-industrial period is the period from 1850-1900 in most literatures. However, Hawkins et al. (2017) systematically defined with justification the period from 1720-1800.
RESULTS AND DISCUSSION

Farmer’s Adaptation Strategy and Barriers to Climate Change

The results of the several studies carried out in Sub-Saharan African on issues related to farmers’ adaptation strategy and barriers to climate change were discussed here under.

- Adaptation Strategy to Climate Change in Sub-Saharan African

The farmers in Sub-Saharan Africa where arable farming is predominant have experienced increased pests and crop diseases, increased crop water requirements, leading to crop failures, reduced crop production. The climate change and climate variability have led to decreased livestock weight and an increase in livestock death. These imply loss of farm income and livelihood for the majority of the rural population. Hence, it creates a general deterioration in welfare of the farmers (Sofoluwe et al., 2011; Mengistu, 2009). Because of these reasons, farmers have adopted adaptation measures or coping mechanisms to dampen the adverse effects of climate change in Sub-Saharan Africa.

Switching from planting high water-requirement to low water-requirement crops were the leading adaptation strategy that pointed out by different studies (Gandure et al., 2012; Yesuf et al., 2008; Deressa et al., 2008). Planting diversified crops, changed planting dates to correspond to the change in the precipitation pattern, planting tree crops, mixed cropping and off-farm income generating activities were also observed by different studies in SSA. (Gandure et al., 2012; Mengistu, 2009; Deressa et al., 2008).

Where most countries are water stressed, the farmers have developed water conservation methods such as water harvesting, waste water re-use in agriculture and crop irrigation (Gandure et al., 2012; Mengistu, 2009). Farmers in West Africa, where most countries experience short intensive rainy season plant short duration crops, practice upland farming and soil conservation methods (Sofoluwe et al., 2011). Some farmers, especially in southern and some parts of East Africa have switched from arable to livestock farming (Mengistu, 2009; Deressa et al., 2008).

To adapt to climate change in sub-Sahara Africa, livestock or pastoral farmers have dug more boreholes in drier regions, switched to off-farm income generating activities and have reduced the number of livestock, by slaughtering and/or selling them during extended drought periods and restocking after the drought (Gandure et al., 2012; Deressa et al., 2008). Some other livestock farmers have switched to livestock that can withstand water stress and hot temperatures (Nzeadibe et al., 2011).

- Barriers to Climate Change Adaptations in Sub-Saharan African

Farmers’ ability to adapt to climate change has challenged by numerous barriers. Institutional factors that influence adoption of new technologies are access to information via extension services and access to credit (Deressa et al., 2008). According to the study’s results, extension education is an important factor that motivates increased intensity of the use of specific soil and water conservation practices (Deressa et al., 2008). Among several of the sources of knowledge, agricultural extension is that the most vital for analyzing the adoption selections of reconciling measures.

Different studies pointed out that access to credit is another important barrier to adoption of agricultural technologies. It increases financial resources of farmers and their ability to meet transaction costs associated with various adaptation options they might want to adopt (ACCCA, 2010).

Impact of climate change on agriculture and food security

The several studies carried out in sub-Saharan African on issues related to influence of climate change show that the long-term mean climate change have significant impacts on global food production and greater risks to food security due to different situations are discussed below.

Impact of climate change on agricultural production

Study by Gornall et al. (2010) pointed out the effect of long-term mean climate change as to have significance impacts on global food production and may require ongoing adaptation; greater risks to food security and extreme weather events. Historically, low precipitation events have been attributed many of the largest falls in crop productivity (Kumar et al., 2004; Sivakumar et al., 2005). However, even small changes in mean annual rainfall has an impact on productivity (Gornall et al., 2010). Another study shows that climate response function indicated that, West Africa suffers the greatest losses amounting between 36% and 44% of the losses for the entire continent, which means this damage; represent losses between 42% and 60% of agricultural GDP in this region (Mendelsohn et al., 2000). Hoffmann (2013) found out that crop yields show a strong correlation with temperature change and with the duration of heat or cold waves and differ based on plant maturity stages during extreme weather events. The result of Gornall et al. (2010) also shows that the change in temperature, rainfall and severe weather events are expected to reduce crop yield in many regions of the developing world, particularly sub-Saharan Africa and parts of Asia. High-temperature sensitivity thresholds for important crops such as maize, wheat and sorghum have been observed with large yield reductions once the threshold is exceeded and maize, which is one of the most
common crops in sub-Saharan Africa, has been found to have a particularly high sensitivity to temperatures above 30 °C within the growing season (Luo, 2011). Different study shows that crop production is the most significantly influenced by Climate variability year to year, even in high yield and high-technology agricultural areas (Kang et al., 2009).

Moreover, different studies show that climate extremes will alter the ecology of plant pathogens, and higher soil temperatures can promote fungal growth that kills seedlings (Patz et al., 2008). Similarly, the effect of CO2 fertilization remains uncertain but important. Depending on crop variety and region, assuming positive CO2 fertilization may even reverse the direction of impacts. However, major crops in West Africa are C4 crops, such as maize, millet and sorghum, which benefits less from higher CO2 concentration, so that the positive effect may be overestimated (Roudier et al., 2011). In general, the overall effect of climate change on yields of major cereal crops in the sub-Saharan African region is very likely to be negative, with strong regional variation (Niang et al., 2014).

Livestock production in Sub-Saharan Africa is additionally susceptible to global climate change. Livestock is an important source of food (such as meat and milk and other dairy products), animal products (such as leather), income, or insurance against crop failure (Seo and Mendelsohn 2007). The pastoral systems of the drylands sub-Saharan Africa are highly dependent on natural resources, including pasture, fodder, forest products and water, all of which are directly affected by climate variability (Djoudi et al., 2011). Livestock is vulnerable to drought, particularly where it depends on local biomass production (Masike and Ulrich 2008), with a strong correlation between drought and animal death (Thornton et al., 2009). Available soil could also be reduced by human influences, together with moves toward exaggerated biofuel cultivation, veterinary fencing, increasing competition for land and land degradation (Morton 2012; Sallu et al., 2010).

**Impact of climate change on food security**

FAO, defined food security as a situation which "exists when all people at all times have physical or economic access to sufficient safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO 2008a). From this definition, food security consists of four key dimensions: food availability (production, distribution, trade and exchange), food accessibility (affordability, allocation and preference), food utilization (nutritional and societal values and safety) and food stability (FAO 2008a).

In Sub-Saharan Africa climate variability and extreme weather, events such as droughts, excessive rains and floods are the main threats affecting agricultural productivity and hence rural household food security. A failure of the time of year is directly joined to agricultural failure reducing food convenience at social unit level additionally as limiting rural employment potentialities (Haile, 2005).

Climate change and extreme weather events affect all dimensions of food security in several ways ranging from direct effects on crop production to changes in markets, food prices and supply chain infrastructure (FAO, 2008a; Gregory et al., 2005). Specifically, climate change will reduce food availability, because it will negatively affect the basic elements of food production such as soil, water and biodiversity. Access to food be affected by climate change events in terms of direct impacts on agricultural zones affecting incomes, employment opportunities, macro economy and GDP that shape livelihoods in many ways, including forms of social protection (Boko et al., 2007).

In addition, physical, economic, and social access to food will be severely compromise by climate change and variability because as agricultural production declines, food prices rise, and purchasing power decreases (von Braun, 2008). In many developing countries, between 10 and 40% of cereal consumption will have to be covered by imports. Many of those countries, however, lack the foreign exchange to finance food imports, thus putting them at risk of increased food insecurity (Shah et al., 2008). Currently, the SSA region’s net cereal imports amount to approximately 7 million tons, but the impact of climate change may result in a net import of roughly 143 million tons of cereal by 2080 (Shah et al., 2008). Food stability is viewed in relations to stability of crop yields and food supplies that will be negatively affected by variable weather conditions and influenced by the temporal availability of, and access to, food (FAO, 2008a).

Recent studies recommend that whereas the globe food provide does not seem to be seriously vulnerable by the projected international changes in climate, food insecurity in Africa can worsen and the population at the risk of hunger will increase in terms of both percentage and absolute numbers during the coming century. Finally, climate change poses threats to food utilization through its impacts on human, including the spread of diseases such as malaria, HIV/AIDS, and undermines livelihood capability and food security at various scales (Boko et al., 2007).

According to the IPCC (2007) report, the causal contribution of climate to food insecurity in Africa is still not fully understood, particularly the role of other multiple stresses that enhance the impacts of droughts and floods and possible future climate change.
CONCLUSION

Agriculture, which is the mainstay of the economies of many developing countries, is highly dependent on climate change which is the worldwide environmental threats that seriously have emotional impact on agricultural productivity and it affects humankind in numerous ways, including its direct influence on food production. However, most of the farmers in sub-Sahara Africa were aware of the impact of climate change especially changes in temperature and precipitation, their ability to ongoing adaptation to climate change has challenged by numerous barriers. Finally, effective institutions for negotiation on climate change at the global level help to facilitate the policy implementations and hence to combat the impact of climate change. All parties (both developed and developing countries) can play a role but with common and differentiated responsibilities for each.

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