



Review Article

Impacts of climate change on agriculture in Senegal: A systematic review

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ABSTRACT

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Climate change is a global environmental threat, affecting every sector of the economy with agriculture being the most affected as a result of its dependence on climate especially rainfall and temperature. The objective of this study is to examine the impacts of climate change on agriculture (crop production) and identify the farmers' adaptation strategies to the impacts of climate change in Senegal. This study employed systematic literature review. Searching of relevant documents were conducted between 26th December 2020 and 10th February, 2021. A comprehensive search of six databases were conducted. The databases searched were Scopus, African Journal Online (AJOL), ProQuest, Elsevier, Research gate, and Google scholar. The findings revealed that temperature is expected to increase by median value of 0.9°C (0.7°C-1.5°C) by 2035, by 2.10 (1.6°C-3.3°C) by 2065, and 4.0°C (2.6-5.9°C) by 2100 and rainfall could increase by 1% (uncertainty range of -4% to +8%) by 2035, 2% (-8% to +8%) by 2065, and 5% (-10% to +16%) by 2100. As a result of rising temperatures, local agricultural production will be less than 50kg per capita by 2050. This is expected to have an effect on crop imports as well as regional migration. The decrease in rainfall under RCP2.6, (Representative Concentration Pathway) combined with the effect of temperature, has a significant impact on the yield of sorghum, maize, and millet, with production decreasing by up to 20-50%. Farmers employed several adaptation strategies to adapt to the impacts of climate change; sowing improved variety, mixed cropping, income diversification, ownership of multiple farms, religious practices in form of prayer. The review recommends strengthening of climate related institutions, adoption of new innovations, implementation of new climate related policies, climate monitoring and forecasting, enhancing and strengthening community-based adaptation through sensitization and incentives.

1. Introduction

Global climate change is widely regarded as one of the most serious challenges confronting society today. Agriculture is vulnerable to climate change and a major source of the greenhouse gases (GHGs) that cause those changes (Beddington et al., 2012; Intergovernmental Panel on Climate Change [IPCC], 2007; National Research Council [NRC], 2010; Epule et al., 2014; Arbuckle et al. 2015; Epule et al. 2017; Tang 2019; Ahmed et al., 2020). Long-term shifts in annual averages and seasonal patterns of precipitation, temperature, and humidity, as well as more erratic and extreme weather events are expected in the future increasing the risk of floods, drought, and fire (Coulmou and Rahmstorf, 2012; Hatfield et al., 2011; Arbuckle et al., 2015). Predicted agricultural impacts include redistribution of

water availability and quality, increased soil erosion, and decreased crop productivity (Howden et al., 2007; McCarl, 2010; Arbuckle et al., 2015), all of which pose immediate and localised economic risks to farmers. The global average temperature increased by 0.85°C from 1880 to 2012 (IPCC, 2014). Thus, the increased global temperature contributes to the rise of sea level (Tang, 2019). Historical weather and climate observations indicates that the average temperature rises by about 0.90°C and average of 0.20°C per decade in Senegal (USAID, 2012). Similarly, rainfall decreased by 10-15 mm per decade, reducing the number of rainy days, increase in daily rainfall and the frequency of short dry spells and loss of shoreline from erosion of 1-2 m per year along shorelines of sand beaches, and 0.1-0.7 m per year along rocky coastline areas, aggravated by sea level

rise (USAID, 2012). As a result, it is obvious that climate change has already occurred in recent decades and, according to the most recent estimates, will continue to a greater extent during this century (Nastis et al., 2012).

Agriculture, in general, is the primary sector most affected by climate change (Mendelsohn and Dinar, 2009). The optimal crops to cultivate, as well as the optimal planting and harvesting times, are directly dependent on the weather conditions in each region. This implies that the impending climate change caused by increased greenhouse gas emissions will have a direct impact on agricultural production and productivity, and thus on farmers' income. Climate change poses a threat to agricultural production that extends beyond crop husbandry to include livestock and, indeed, the entire agricultural sector (Ayinde et al., 2011). Climate change results in the reduction of crop production and productivity (Arora 2019; Shi et al., 2020). Despite technological advances and the Green Revolution, weather and climate continue to be important factors in determining agricultural productivity in most parts of the world (Sarkar et al., 2020). According to Defrance et al. (2020) climate change is expected to cause reduction in sorghum, maize and millet yield by 20-50% by 2050 in Senegal.

The effects can vary across continents, countries and regions. Certain countries are more likely to suffer negative consequences than others, whereas other countries may benefit from climate change (EPA, 2016). As a result, climate change can have both positive and negative effects on the spatial level of agricultural production. However, studies indicate that the negative effects of climate change may outweigh the positive effects (IPCC, 2012; Sarkar et al., 2020). However, the effects of climate change on agricultural production vary by crop and region (Zhai and Zhuang, 2009; IPCC, 2014b). A growing body of evidence suggests that changing temperatures and precipitation levels caused by climate change can be detrimental to crop growth and yield in many regions and countries (Yesuf et al., 2008). Low-latitude and developing countries are expected to bear the brunt of the agricultural effects of global warming, owing to their disadvantaged geographic location, large agricultural share of their economy, and limited ability to adapt to climate change. Crop production in high latitude regions, on the other hand, can generally benefit from climate change (Sarkar et al., 2020).

In Senegal and other sub-Saharan African countries, high-level agricultural reliance on rainfall combined with observed crop vulnerability to maximum temperatures during the growing season reduced the yield output in most cases (Asseng et al., 2011; Serdeczny et al., 2017; Diouf et al., 2019). Furthermore, temperatures are expected to rise over the long term, leading to a decrease in yields and widespread infestation of weeds and pests (Diouf et al., 2019). In addition, rainfall variability is projected to result in major post-harvest losses. These effects will eventually lead to a sharp drop in crop production, which could influence the efficiency and sustainability of agricultural productivity and food security (Abid et al., 2015; Nelson et al., 2009; Rosenzweig, 2011). Recent studies by World Bank in 2013 indicates that these challenges are expected to negatively affect the economic growth and agricultural prosperity.

Adaptation to climate change received little attention in the early years of international climate change studies, with a greater emphasis on mitigation and impacts (Kates, 2000; Mertz

et al., 2009), but adaptation has recently been covered more extensively and has an important place in the IPCC's fourth assessment report (2007). In its Third Assessment Report, published in 2001 (IPCC, 2001b), the IPCC assessed the world's ability to cope with and adapt to the unavoidable effects of climate change. While this assessment is far from exhaustive, it concludes, predictably, that the effects of climate change are not evenly distributed. Therefore, the people who will be exposed to the worst of the effects are the ones least able to cope with the associated risks (Smit et al., 2001; Adger et al., 2003). "Most of the agricultural adaptation strategies suggested in the literature are not new, but have evolved from traditional practices and/or been promoted decades ago in response to major drought events" (Mortimore and Adams, 2001 cited in Douxchamps et al., 2016). These include soil conservation, high yielding varieties, drought resistant crops/animals, reforestation/afforestation, changes in planting dates, water harvesting, keeping few livestock, early or late planting, planting of perennials, embankment/dyke/dams, mixed farming, managing biodiversity, agroforestry, adaptation of animal traction, dietary changes, ownership of multiple farms, preservation and storage, income diversification, migration, and re-sowing among others (Raynaut, 1997; Watkiss et al., 2005; Mortimore and Adams, 2001; Douxchamps et al., 2016; Epule et al., 2017). The objective of this study was to examine the impacts of climate change on agriculture (crop production) and identify the farmers' adaptation strategies to the impacts of climate change in Senegal as well as provide a review of its impacts and adaptation options.

This review attempts to synthesise research on the effects of climate change on agriculture in Senegal. It is important to understand the past climate condition in order to adjust to the present and plan for the future. Therefore, this study provides useful information for policymakers in Senegal's agricultural sector to enable the formulation of sustainable policies in this sector and determine the best adaptation measures. The study also contributes to the understanding of the impact of climate change and adaptation and fills the existing gaps identified in the literature.

2. Materials and Methods

2.1. Location, position and size

Senegal is located at the westernmost point of mainland Africa, it borders with Mauritania to the North along the Senegal River, with Mali to the East and with Guinea-Conakry and Guinea-Bissau to the South (Fig. 1). The Gambia, which extends along and around the River Gambia, represents an enclave within Senegalese territory, creating a geographic separation between the Senegalese region of Casamance to the South and the rest of the country to the North (Fall et al., 2010).

The country has a total land area of 196,720km², with estimated population of 12.2 million people as of 2008 (USAID, 2015). Fifty-eight percent of the population is rural, and two-thirds of the rural population lives in poverty (USAID, 2015). Senegal is characterized by Sudano-Sahelian climate with two distinct seasons; dry season lasting from November-May and rainy season from June-October (Fall et al., 2010). The southern parts of the country records highest amount of rainfall than the semi-desert northern parts of the country, where rainy sea-

son lasts for only four months every year. Senegal has been affected by periodic droughts since 1970s. The country's territory is covered by, among other, savannah (44%), agricultural fields (27%), steppe (18%), forest (4%), surface water (2%) and mango (1%) (Fall et al., 2010).

However, the Senegal's topography is comprised of low roll-

ing plains with foothills in the southeast; the highest point is 581 meters. Of Senegal's total land area, 43% is classified as agricultural; 13% of total land is considered arable (i.e., cultivable under rainfed conditions). Sixty-five percent of agricultural land is classified as pasture or grasslands. Seventy-five percent of arable land is in the central western region, known as the

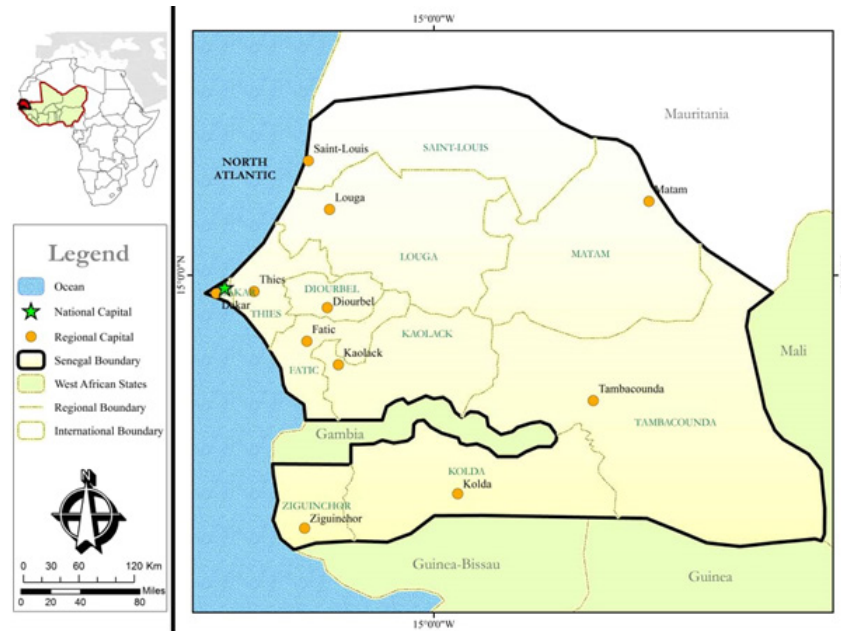


Fig. 1: The Study Area

Source: Department of Geography, University of Maiduguri, 2020

Peanut Basin, and the Casamance region south of The Gambia (World Bank, 2009; ADF, 2005; UNSD, 2009). Major crops grown in the country include groundnut, cotton, sorghum, millet, maize, cowpea and horticulture. The soil is generally low in fertility (USAID, 2015).

2.2.1. Systematic literature review

Systematic literature review is an overview and appraisal "of the state of knowledge on a given topic or research question, structured to rigorously summarize the existing understanding" (Ford et al., 2011). In the context of this paper the review focused on the linkages between climate change and agriculture. This type of literature review approach is an age-old tradition in medical sciences, but neglected in social sciences and environmental studies. However, systematic literature review approach "differs from traditional literature reviews in three main ways" (Ford et al., 2011). Systematic literature review approach involves eight steps; (i) identifying of the research question (ii) defining inclusion and exclusion criteria (iii) searching of relevant studies (iv) select studies for inclusion based on pre-defined criteria (v) extract data from included studies (vi) evaluate the risk of bias from included studies (vii) present results and assess the quality of the evidence (viii) find the best journal and publish the work (Liumbruno et al., 2013; Peters et al., 2015; Choi et al., 2019; Hersi et al., 2019; Muka et al., 2020).

2.2.2. Documents search criteria

Searching of relevant studies were conducted between 26th

December 2020 and 10th February, 2021. A comprehensive search of six databases were conducted. The databases searched were Scopus, African Journal Online (AJOL), ProQuest, Elsevier, Research gate, and Google scholar (Haby et al., 2016). The documents were obtained using search string "climate change impacts" OR "climate agriculture" OR "climate environment" OR "climate risk" OR "climate change adaptation" OR "adaptation risk" OR "smallholder adaptation" OR "adaptation impacts" OR "adaptive capacity" OR "adaptation Sahel" OR "adaptation ability" OR "agriculture vulnerability" OR "climate change Sahel" OR "Climate change Senegal". Keywords were searched in title and abstract, including where otherwise indicated in the supplementary files. Results were imported into excel spreadsheet and duplicates removed (Moher et al., 2009; Haby et al., 2016). The search was undertaken and evaluated by the author as per the eligibility criteria. The complete text of any potentially relevant document has been retrieved for further consideration. The author precluded on the inclusion side so there was some uncertainty as to its inclusion in place to ensure that no crucially significant articles were lost (Dolenc and Rotar-pavlič, 2019).

2.2.3. Inclusion and Exclusion criteria

The inclusion and exclusion criteria narrow down to full length research papers, relevant documents found useful and the keywords selected had to be included in the article's title or abstract, the articles had to refer to the adaptation and climate change (Dolenc and Rotar-pavlič, 2019). The review was

based on peer reviewed literature on climate change adaptation published between 2000 and 2020 (Berrang-Ford et al., 2011). And articles must report conceptual issues on adaptation, policy analysis, impact assessment, consultation, review and these studies focus on vulnerability, development, agriculture, development policy, adaptation financing, adaptation planning and impact studies (Lwasa, 2015). Papers not in English, beyond the search duration and apart from articles and reviews have been removed. This query extracted 230 articles. Thereafter all recovered documents were checked on the basis of title and abstract to evaluate the appropriateness or validity for final assessment and inclusion for review (Berrang-Ford et al., 2011; Ford et al., 2011; Berrang-Ford et al., 2015; Dolenc and Rotar-pavlič, 2019).

2.2.4. Data Analysis

Data were analysed using thematic analysis approach (in qualitative research, thematic analysis is used to examine themes within a topic by identifying, analysing, and reporting patterns (themes) within the research topic) to enable capture important issues related to the study objectives. The developed themes were categorized into various associations or sub-themes for further analysis. Therefore, only documents that passed the inclusion criteria were analysed descriptively.

3. Results and Discussion

3.1.1. Overview of agriculture in Senegal

About one-third of the labour force in Senegal engaged in agricultural activities (USDA, 2007). Most farmers rely on rain-fed crops, although there are slightly more than 1,000km² of land under irrigation, out of a total slightly less than 200,000km² of land in the country. This sector remains the major source of export earnings (CIA, 2013; Zamudio and Terton, 2016). However, available surface water bodies and runoff water have the potential to significantly improve agricultural production (Worldwide Extension Study, 2010; FAO, 2015). Agriculture is basically subsistence. The major crops grown includes; groundnut, millet, maize, sorghum, cowpea, rice, cotton and cassava (Poulsen, 2015).

Senegal faces a number of constraints to crops production. Initially, the significant proportion of the landmass of Senegal is found in the Sahel region part of the country and is therefore arid (with 300-350 mm of rain per year) and remarkably susceptible drought (Wuehler and Wane, 2011). The region of Casamance south of Gambia is experiencing more of rain (1000-1500 mm per year), and indeed a valuable crop production area; although the region is poorly developed in terms of infrastructure and transport development (Wuehler and Wane, 2011). However, "Soil quality throughout Senegal is generally poor, serving as an additional barrier to agricultural production. And lastly, climate change trends have placed a strain on farmers: mean annual rainfall has been decreasing by 10-15mm per decade, and mean annual temperature has increased by 0.9°C since 1960, now hovering around 28°C (82°F)" (The World Bank, 2015; Poulsen, 2015).

3.1.2. Agricultural production

An account of production of various agricultural commod-

ities is presented in (Table 1). Cereals production particularly rice is cultivated on 210,000 ha and 462,000MT of yield is expected assuming good weather, strong prices, subsidies and inputs that encourage farmers to increase rice field area (USDA, 2018). Other cereals include maize produced under 189,973 ha of arable land and produced 324,703 tonnes, while sorghum occupied 188,380 ha and produced about 161,645 tonnes. Millet account for 857,973 ha and produced about 612, 563 tonnes. Whereas legumes such as groundnut are cultivated on 880,000 ha and produced about 719,000 tonnes (Global Yield Gap Atlas, 2018).

Table 1. Major crops grown in Senegal

	Area harvested (ha)	Yield (t/ha)	Production (t)
Groundnut	880,000	0.8	719,000
Millet	857,973	0.7	612,563
Rice	225,324	3.9	885,284
Maize	189,973	1.7	314,703
Sorghum	188,380	0.9	161,645

Source: GYGA (2018)

3.1.3. Climate change vulnerability and impacts on agriculture

The Sahel region (Senegal included) is vulnerable to the impacts of climate change and variability (USAID, 2015). Recently, inconsistent rainfall patterns and rising sea levels that increase soil erosion rates and salinization in agricultural soils are evidence of climate change in Senegal (Table 2). Rainfall variability at different seasons, both in inter-annual and multi-decadal levels is one of the main determinants to crop production in the main agricultural regions of the country. This rainfall variability affects crop production and food security. Historically, climate change in Senegal has been connected to long-standing drought in the 1970s and 1980s (Mortimore and Adams, 2001; Reynolds et al., 2007). Rainfall in Senegal is highly variable with inter-annual and inter-decadal timescales. So also establishing rainfall trends on a longer timescale is very difficult. The 1960s period were the wettest period compared to 1980s which were regarded as the drier period in Senegal, Sahel and West Africa (McSweeney et al., 2010)

Table 2. Recent Climate trends in Senegal

Mean annual rainfall	10-15mm per decade	Between 1960-2006 in the southern regions (during the wet season of June-September)
Mean annual temperature	0.9°C (or an average rate of 0.20°C per decade)	Since 1960
Hot nights per year	27 days (an additional 7.3% of nights)	Between 1960-2003

Source: Siwa (2014)

Senegal is characterized by Sudano-Sahelian climate with two distinct seasons, that lasts from November to May and is influenced by the harmattan and trade winds, and a wet season that occurs from June to October in the south and from July to September in the north, as the Inter-Tropical Convergence

Zone moves northward (Ministry of Environment and Nature Protection, 2010; Noblet, 2013; Zamudio and Terton, 2016). The climate in West Africa, including Senegal, is characterized by high inter-annual and inter-decadal variability, land process and direct response to radiative forcing (Christensen et al., 2013; Daron, 2014). Rainfall varies along the latitudinal gradient that decreases to create four major rainfall zones from the country's southern to the northern regions: the Guinean and Sudano zones in the south, the central Sudano-Sahelian zone, and the Sahelian zone in the north with a desert climate (MENP, 2010). Mean annual rainfall varies from 1,547 millimetres in the southern city of Ziguinchor to 330 millimetres in Podor, the northernmost town in Senegal (Coulthard, 2001; MENP, 2010; Zamudio and Terton, 2016).

3.1.4. Projections of future climate in Senegal

Temperature projections in West African Sub-region, of which Senegal is part of; is projected to continue rising throughout the 21st century (Zamudio and Terton, 2016; Ouedraogo et al., 2018). Climate models' projections suggests that temperature in West Africa is expected to increase by median value of 0.9°C (0.7°C-1.5°C) by 2035, by 2.10 (1.6°C-3.3°C) by 2065, and 4.0°C (2.6-5.9°C) by 2100 (Christensen et al., 2013; Zamudio and Terton, 2016). Other projections suggest increase in temperature of 0.9°C per year which is above global average. Temperatures are also expected to continue rising with higher increase in the interior than coastal areas (Tall et al., 2017). The rising temperatures is at the range of 1.0-1.4°C by the mid of 21st century (2040-2059) (USAID, 2015). The projected increase in the mean annual temperature by 1.1-3.1°C by 2060s and 1.7-4.9°C by 2090s. The range of projections by 2090 is 1.0-2.5°C. Further annual projections indicate increase in the number of hotter days by 22-46% of the days in 2060s and 29-67% of the days in 2090s. Hotter nights are projected to occur on 27-51% by 2060s and 37-70% of nights by the 2090s. However, all projections indicate decreases in the frequency of days and nights that are considered 'cold' in current climate (McSweeney et al., 2010).

Projection of average annual rainfall over the country from different models in the ensemble project a wide range of precipitation changes for Senegal (Table 3), but tend to decrease, especially during the wet season July, August and September. The projected changes in rainfall ranges from -38 to +21% by 2090s, with ensemble mean between +7 and -18% (McSweeney et al., 2010). Similarly, the predicted changes for the months of July, August and September ranges from -41 to +48% by the 2090s and -3 and -18% ensemble means. According to Alioune and Moctar (2018), rainfall projections show contradictory results, with increases and decreases in rainfall during the monsoon season (JJAS). As a result, rainfall under RCP4.5 and RCP8.5 scenarios is highly variable. Similarly, project decline in rainfall over the Sahel and its associated impacts on the local incomes (Hein et al., 2009). Whereas Serdeczny et al. (2017) projected increase in rainfall in Senegal.

Simulation models of precipitation changes in West Africa and Sahel are associated with uncertainties. Some models showing increasing trends while others showing decreasing trends of rainfall for the 21st century (Daron, 2014). However, this uncertainty range is reflected in the most recent analysis

released by the Intergovernmental Panel on Climate Change (IPCC), which suggests that mean annual precipitation levels in West Africa could increase by 1% (uncertainty range of -4% to +8%) by 2035, 2% (-8% to +8%) by 2065, and 5% (-10% to +16%) by 2100.

Table 3. Projections of future climate in Senegal

Mean annual rainfall	Expected to increase by 1.1-3.1°C by 2060 and 1.7-4.9°C by 2090.	Projected rates of warming faster in the interior than in those areas closer to the coast
Mean annual rainfall	Projection in annual rainfall are inconsistent	Various model in the ensemble predicts a wide range of improvements in the country's average annual rainfall, from -40 per cent to +48 per cent by 2090s, but more models indicate decreases. Although it is difficult to draw robust conclusions regarding changes in precipitation, extreme rainfall events are likely to produce higher proportion of precipitation
Extreme	Cold nights are projected to decrease	All projections indicate substantial increases in the frequency of days and nights that are considered 'hot' in current climate, with such increases occurring more rapidly in the south and east of the country. All projections indicate decreases in the frequency of days and nights considered 'cold' in current climate.

Source: Siwa (2014)

The increase in precipitation could be greater in the period of December to February compared to June to August (Christensen et al., 2013; Zamudio and Terton, 2016). Changes in rainfall in the far future (2071-2100) raise some concerns. The RACMO22T model predicts a significant increase in rainfall for both scenarios, particularly for the RCP8.5 scenario (up to 15%) (Alioune and Moctar, 2018).

Various models such as MAX PLANCK (ECHAM) project drier conditions while MIROC (UNIV of TOKYO) projections shows a wetter future at the south of the country. Both models project warmer future in Senegal with slight variations while MAX PLANCK model predicts losses in crop production particularly rice and groundnut (Siwa, 2014).

3.1.5. What are the adaptation options for Senegal?

The adaptation options in Senegal are likely the same as of other countries in Sahel with slight difference is specialization and local experience. These adaptation options include climate monitoring, climate forecasting, soil conservation, improved varieties, drought tolerant crops, agroforestry, adoption of animal traction, destocking (reducing the number of livestock), planting perennials, mixed cropping, ownership of multiple farmers, preservation and storage, income diversification, field fencing (reduce wind erosion), religious practices (group prayers), adjustment in sowing dates, fertilizer management, migration, changes in tillage, selling of assets, sales of livestock for grains, remittances and reduction of fallows among others

(Mbow et al., 2008; Mertz et al., 2009; Epule et al., 2017; Day-amba et al., 2018; Ayebe-Karlsson et al., 2019; Ahmed et al., 2020; Ahmed, 2020).

3.1.6. Public Policies on Climate change

There is no universally accepted definition of policy. Thus, it can mean different thing to different people, whereas the reality is in the partisan beholder's subjective view. For others, policy is usually a course of action adopted for the sake of expediency; a course of action adopted and followed in conjunction with social and economic goals to be accomplished by government, private sector organizations, group or individuals (Ochola et al., 2010).

Two existing policies mainly form national development planning in Senegal: the Government Emerging Senegal Plan (PSE) adopted in 2012, and the National Strategy for Economic and Social Development 2013-2017 (SNDES). The need to respond to the impacts of climate change is to some degree recognized in each of these documents (Zamudio and Terton, 2016). Other policies include; Sustainable Development Strategy for Fishing and Aquaculture (2001), Orientation Law on Agriculture, Forestry, and Pastoralism (2004), Strategic Plan for Sustainable Tourism Development in Senegal (2014–2018), National Strategy for Equity and Equality of Genders (2005–2015), The Genesis of Intensive Agriculture in Senegal 1971/2 and National Development Plan for the Health Sector (2009–2018) (Table 4).

In its commitment to reduce the impacts of climate change Senegal ratified several international treaties and conventions toward reducing the impacts of climate change. These include; the signed of Paris agreement on 22nd April 2016 and ratified the agreement of 21st September 2016. Similarly, the country ratified Kyoto protocol on 20th July 2001 which came into force on 16th February 2005. In its commitment Senegal submitted the first National Communication to the United Nations Framework Convention on Climate Change on 1st December 1997, submitted second communication on 16th September 2010 and submitted the third communication on 8th January 2016. However, on 14th October 1995 Senegal signed the United Nations Convention to Combat Desertification and ratified the convention on 26th July 1995. Others include; Environmental code (Law, 2001), Ministerial Decree 1220, establishing the National Climate Change Committee 2011, Air Pollution Norm 2003, The National Implementation Strategy on (NIS) on Climate Change, 1999, The National Programme to Combat Desertification and Forest Code 1998 among others.

3.1.7. Adaptation Projects and Programs

A lot of climate change adaptation programmes were implemented in Senegal. Some of these projects are ongoing and or recently completed (Zamudio and Terton, 2016). These adaptation programmes are either at regional or national level and usually funded by international donor agencies to adapt to the impacts of climate change.

The adaptation projects cut across various sector of the economy with more emphasis on agriculture, climate information and water resources. However, an emphasis on adaptation in these sectors is not surprising given that they were identified as priority areas for action in Senegal's NAPA and second national

communication (Zamudio and Terton, 2016). The focus of the large number of these projects identified is on the agricultural sector, reflecting its importance to local livelihoods and the national economy; Capacitating African Smallholders with Climate Advisories and Insurance Development, Climate Change Adaptation and Sustainable Water Management in Senegal, Climate for Development in Africa, Decentralising Climate Funds in Mali and Senegal, Disaster Risk Management and Climate Change Adaptation, Global Climate Change Alliance Regional Programme for West Africa and R4 Rural Resilience Initiative (Table 5)(Zamudio and Terton, 2016).

Climate change policy and legislation are part of a complex structure and holistic approach to the national development. However, after the 1996 institutional reforms in Senegal, policy making have been highly decentralized, with local and regional governments sharing responsibilities with national government on a number of issues including climate change. The international community also plays a leading role in this process, with international organizations and foreign countries working closely with governments and/or civil society on climate issues. As a result, climate change is linked to the promotion of sustainable development, both socially and economically defined and in a wide range of policy areas, related to poverty reduction and the promotion of the United Nations Millennium Development Goals (MDGs) (Nachmany et al., 2015). The National Plan of Action for the Environment (1997) provides a framework for linking various sectoral policies with forest conservation and natural resource and coastal zone management, the Initial National Communication (1997) presents information on key sector vulnerabilities, possible adaptation strategies, and the policy and institutional context for responding to climate change, the National Adaptation Programme of Action (NAPA) (2006) incorporates participatory methods in the implementation and monitoring of projects, community ownership of solutions, capacity building, poverty alleviation, strategies for improving and diversifying livelihoods for vulnerable groups, and consideration of gender issues (USAID, 2012).

Conclusion and Recommendation

Climate is constantly changing with varying impacts from region to region and from country to country. The Sahel region, including Senegal, is vulnerable to the effects of climate change and variability. Rising temperature over West Africa (Senegal), shifting rainfall patterns and frequent occurrence of extreme weather events affects agricultural production and will continue if meaningful and viable adaptation measures are not put in place. These would have a direct impact on crop yield and productivity, causing water stress to the plants, decline in soil fertility, shortage of water for irrigation and the prevalence of pest and disease.

About one-third of the labour force in Senegal is engaged in agricultural activities. This sector remains the major source of export earnings. The major crops grown includes; groundnut, millet, maize, sorghum, cowpea, rice, cotton and cassava which are still in subsistence. Senegal faces a number of constraints to crops production. For instance, soil quality throughout Senegal is generally poor, serving as a barrier to agricultural production. More so, climate change trends have placed a strain on farmers. That is, the mean annual rainfall has been decreasing by 10-

Table 4. Summary of Public Policies on Climate change

Policy	Objectives	Outcome	References
Water Resource Management Action Plan (2008-2015)	To improve integrated water resource management in line with national goal of poverty reduction and sustainable development	The action plan is expected to improve knowledge and capacities in managing water resource, creating legal and political reform related to water resource management and guidance on the use of water	Zamudio and Terton (2016)
The Local Development Reform Support Programme (PARDL)	Contribute to the creation of conditions conducive to inclusive, robust and sustained economic growth through increased decentralization, improved multi-sector governance and the promotion of local entrepreneurship	Decentralization is strengthened to enhance community development	African Development Bank (2016)
The national Strategy for Economic and Social Development (2013-2017)	To integrate holistic approach in achieving economic growth and social development and emphasizing to address the impacts of climate change, while achieving the development objectives	The policy is expected to take into consideration the public finance recovery, the development of domestic savings and sustainable improvement in the long term.	Green Growth Knowledge Platform (2012).
The National Climate Change Adaptation Programme (NC-CAP), 2001	To identify the sectors most at risk for the impacts of climate change, formulate participatory implementation strategies and raised funds for the implementation of the scheme.	The policy is coined to ensure sustainable climate change adaptation in the four vulnerable sectors; agricultural production, coastal zones, water resources and tourism and fishing.	Seck et al. (2005)
The Biodiversity Conservation Strategies and Action Plan, 1999	To conserve biodiversity in high density sites and the integration of conservation of biodiversity in programmes and activities related to production.	The policy is expected to build upon and reinforce other policies of national interest in the management of natural resources, poverty alleviation and social development.	Seck et al. (2005)
The National Environmental Action Plan, (PNAE) 1997	To ensure that environmental considerations are taken into account in all social and economic planning.	This policy is expected to harmonize other policies from different sector of the economy that are related to the enhancing and sustainable management of natural resources and planning	Seck et al. (2005)
Forest Development Master Plan (PDFF) 1981 updated in 1993 Forest Action Plan	To stimulate participatory approach in natural resources management and decentralize forest management structure	The policy is mandated to combat desertification, reduce or minimize the negative impacts of biodiversity loss and soil degradation and overall to improve the livelihood of the Senegalese.	Wade (2004), Diaw (2006), FAO, (2006)

15mm per decade, and mean annual temperature has increased by 0.9°C since 1960, now hovering around 28°C (82°F) which significantly affects agricultural productivity. Temperature is expected to increase by median value of 0.9°C (0.7°C-1.5°C) by 2035, by 2.10 (1.6°C-3.3°C) by 2065, and 4.0°C (2.6-5.9°C) by 2100 and rainfall could increase by 1% (uncertainty range of -4% to +8%) by 2035, 2% (-8% to +8%) by 2065, and 5% (-10% to +16%) by 2100. As a result of rising temperatures, local agricultural production will be less than 50kg per capita by 2050. This is expected to have an effect on crop imports as well as regional migration. The decrease in rainfall under RCP2.6, (Representative Concentration Pathway) combined with the effect of temperature, has a significant impact on the

yield of sorghum, maize, and millet, with production decreasing by up to 20-50%. Therefore, the study recommends that farmers should employ several adaptation strategies to adapt to the impacts of climate change; sowing improved seed variety, mixed cropping, income diversification, ownership of multiple farms, religious practices in form of prayer.

The study therefore, recommends strengthening the capacity of climate related institutions technically and financially and the need for technology adoption in climate change adaptation. This study recommends further research on climate change in relation to the institutional capacity to reach out to the farmers and disseminate new adaptation innovations, design and implement holistic programs and policies, increase investment

Table 5. Summary of climate change adaptation projects in Senegal

Name of the project	Objectives	Funder(s) and budgets	Sector	Duration
Capacitating African Smallholders with Climate Advisories and Insurance Development	To strengthen smallholder farmers' use of climate information as they engage in seasonal agricultural decision making.	CCAIFS	Agriculture, climate information, insurance	2019
Climate change adaptation and sustainable water management in Senegal	To enhance resilience of agricultural systems and reduce the impacts of climate change on water sector	LDCF, International fund for agricultural development	Agriculture, watershed management, freshwater supply; government	2012-2016
Climate for development in Africa	To strengthen the climate resilience of Africa and improve climate information	European Union, Finland, Nordic Development Fund, Sweden, UK Aid, United States Agency for International Development (USAID)	Climate information	2012-2015
Decentralising Climate Funds in Mali and Senegal	To support more effective climate adaptation planning and improve community's resilience to climate change	DFID through the Building Resilience and Adaptation to Climate Extremes and Disasters program	Disaster risk management, government	2015-2017
Disaster Risk Management and Climate Change Adaptation	To mainstream climate change adaptation and disaster risk management in Senegal	World Bank through Global Facility for Disaster Reduction and Recovery	Disaster risk management; climate information; government	2012-2015
Global Climate Change Alliance Regional Programme for West Africa	To strengthen the capacity of national and regional stakeholders to mainstream climate change in development policies and strategies, and to implement measures to adapt to climate change and increase the resilience of the population	European Union through the Global Climate Change Alliance	Climate information; government	2011– 2015
R4 Rural Resilience Initiative	To enable vulnerable rural households to increase their food and income security in the face of increasing climate risks.	USAID, Norwegian Ministry of Foreign Affairs, Swiss Agency for Development	Agriculture; insurance	2011–2017 (estimated)

Source: Adapted and modified from Zamudio and Terton (2016).

in agricultural productivity, agroforestry, integrated systems agriculture, forest rehabilitation, rehabilitation of degraded pasture, strengthen and decentralize the national extension programs, facilitate climate data forecasting, collection and dissemination, channel substantial support, incentives toward community-based adaptation strategies.

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