Gender-Specific Climate Change Adaptation Agricultural Practices in Selected African Countries: A Review

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Abstract

Climate change is a topical issue in all regions of the world. It has led to increased food insecurity, unemployment, and economic instability, among others, in developing regions of the world, especially Africa. The interaction between climate change mitigation and adaptation among different farmers' gender groups in various African countries has been overlooked in the scientific literature and other project reports. This paper assessed the impacts of climate change and identified the agricultural practices carried out by different farming gender groups to mitigate and adapt to climate change in selected African countries (Benin, Ethiopia, Morocco, Nigeria, Tanzania, and Togo). Published books, journals, articles, and reports were reviewed to provide in-depth knowledge on possible solutions to the effect of climate change on different categories of farmers. It is expected that the findings of this review will

make available to farmers the climate change adaptation practices in other African countries and guide government policy on climate change, consequently reducing the impact of climate change on agricultural productivity in Africa.

Keywords: Adaptation strategy, agriculture, climate change, gender, mitigation strategy

Introduction

In Africa, the agricultural sector has a significant impact on poverty alleviation and economic growth compared to other sectors (Abubakar, 2019). At the continental level, agriculture contributes about 30-45% of the economy (Blein et al., 2017). However, the sector is affected by climate change (CC) with the continent contributing 3.8% of greenhouse gas emissions (CDP, 2020). It is estimated that the impact of CC on the economy in Africa will reach 15% of the gross domestic product (GDP) of African countries by the year 2050 (AFDB, 2019). Therefore, it is important to provide information on the impact of climate change on the agriculture sector of selected African countries (Morocco, Togo, Nigeria, Tanzania, Ethiopia, and Benin) and their adaptation strategies.

Geographical description of the selected African countries

Morocco is the north-westernmost country in North Africa, located between the Atlantic Ocean (to the west), the Mediterranean Sea (to the northeast), the Saharan desert (to the south), and Europe (to the north). It has a strategic geographic position with large relief variability. It spans an area of 710,850 km^2 with an estimated population of 36,472,000 (APRM, 2024). Togo, Nigeria, and Benin are in West Africa, Tanzania is in East Africa, while Ethiopia is located in the North-Eastern part of Africa. Togo is bordered by Ghana to the west, Benin to the east, Burkina Faso to the north and the Gulf of Guinea to the south. It covers 56,600 km^2, making it one of the smallest countries in West Africa, with a population of 8,095,498 (INSEED, 2023), as well as one of the narrowest countries in the world with a width of less than 115 km (71 mi). Contrastingly, Nigeria is the biggest African country and lies on the Gulf of Guinea with borders with Benin (West), Niger (North), Chad (North-East across Lake Chad) and Cameroon (East). Nigeria covers 923,7770 km^2 and had a population of 221.2 million in January 2023. Benin republic has a bigger land area (114,763 km^2) and population (13,712,828) than Togo. Ethiopia is a slightly

bigger country (1,112,000 km²) with a larger population (26,527,060) than Tanzania whose land area and population are 945,087 km² and 66.46 million respectively.

Contributions of agriculture to the economic growth of African countries

Agriculture is the major contributor to the economic growth of most African countries. For instance, the agriculture sector of Morocco accounts for around 12% of GDP (gross domestic product) and employs 33% of the population (ETF, 2021).

Togo's economy is also largely based on agriculture, which accounted for 47.6% of the country's GDP in 2015 (BAD, 2016), and two out of every three of its inhabitants depend on crop and livestock farming for their livelihood. Togo's agricultural sector involves at least 70% of the active population, with 80% of them living in rural areas (AFDB, 2016). The major crops grown in Togo are corn, sorghum, rice, yams, manioc, peanuts, beans, and soy. Poultry farming is practiced by 80% of smallholder families. Togo's major exports are coffee, cocoa, and cotton.

Nigeria's agriculture sector is one of the most important sectors of the country's economy. The sector provides employment for up to 75% of the population and contributes approximately 40.2% of GDP, employs about 70% of the labour force, and provides over 80% of the country's food supply (FAO and ECOWAS Commission, 2018). The country has highly diversified agroecological conditions that allow the production of varied agricultural products including maize, cassava, guinea corn, yam, beans, millet and rice as major food crops.

Tanzania's agriculture sector contributes approximately 32% to the country's GDP (World Bank, 2016), mostly through food crop production. In Tanzania, the agricultural sector accounts for a third of export materials in the country (FAO, 2016). Moreover, the sector employs approximately 13 million people, the equivalent of 59% of the economically-active population (World Bank, 2016). In fact, Tanzania's agriculture sector is an important catalyst for economic growth, poverty alleviation, and food security.

Ethiopia's economy is highly dependent on agriculture. Agriculture accounts for about 50% of the GDP, 80% of exports, and an estimated 75% of the country's workforce (USAID, 2020). Agriculture is the backbone of the country's

economy. Crop production makes up about 60% of the sector's output whereas livestock accounts for 27% and other areas contribute 13% of the total agricultural value added (Welteji, 2018). Similarly, in the Republic of Benin, agriculture plays an essential role in the economy, contributing 35% of the nation's GDP and providing about 70% of employment (INSAE, 2020).

The role of gender in the agricultural sectors of African countries

Men, women and youth farmers have varied degree of contributions to the growth of the agricultural sector in different African countries. For example, in Togo, the involvement of women in agriculture is 51.1%. Similarly, the contribution of women in Nigeria's agricultural sector is estimated at 60-79% of labour, particularly in food production and processing, and food marketing (FAO and ECOWAS Commission, 2018). In Tanzania, women make up roughly half of the workforce in the agricultural sector and produce more than 70% of the country's food (URT, 2014) and approximately 7.2 million youth make a living from agriculture. In Ethiopia, 47% of the rural labour force is made up of women. Indeed, Ethiopia's second Growth and Transformation Plan 2015/16 – 2019/20 places women farmers at the centre of the country's development process and its efforts to meet the Sustainable Development Goals. According to FAO (2019), Ethiopia has made significant progress in making its policies, strategies, and legal frameworks more responsive to its commitments to gender equality and women empowerment.

Beninese men are more involved in agriculture with larger farms than women, who cultivate small plots of land (Kinkingninhoun-Mêdagbé et al., 2010; Yegbemey et al., 2013; Yegbemey, Yegbemey & Yabi, 2017). Nevertheless, the contribution of Beninese women to agricultural activities is constantly increasing due to changes in production models such as organic farming and the expansion of cash crops (Alidou and Niehof, 2013). However, the involvement of Beninese youth (representing 60% of the population) in agriculture is low because of the view of the unattractive future (low earnings, expensive labour, low esteem for the profession) of the sector (Akrong and Kotu, 2022). In 2012, the Benin Ministry of Agriculture estimated that rural women made up 50-60% of the agricultural labour force.

Vulnerability of African countries to climate change and the impact on agriculture

Most African countries are vulnerable to climate change (CC). Morocco in particular is highly vulnerable to climate change because of its geographical location. Indeed, this country has a predominantly semi-arid climate, which is in a transition zone between the arid climate of North Africa and the rainy climate of central Europe. It is therefore potentially vulnerable to climate change because the environmental impacts are likely to be wide and varied. This vulnerability is growing, given the nature of its main economic sectors and their dependence on weakened natural and water resources (Singla et al., 2010; USAID, 2016; Choukri et al., 2020; Moroccan Ministry of Environment, 2020). Morocco's agricultural sectors are already highly impacted by CC. Moreover, the country's resources are under increasing pressure. Some regions are already threatened by water shortages (GIZ, 2021).

In the case of Nigeria, her agricultural sector is mainly dominated by two factors, namely rainfed and non-homogenous smallholder farming systems (Onyeneke, Okoli & Nwankwo, 2020). Hence, climate change through excessive rainfall, extreme temperatures, drought, frequent flooding, increased salinity of the water supply used for irrigation, windstorms, land and mudslides, deforestation, etc. has adversely affected her agricultural sector (Ajetomobi, Ajiboye & Hassan, 2011). These effects have led to poor land tenure, low productive capacity, and low adaptive capacity among smallholder farmers due to heavy reliance on natural resources, the high cost of commodities, and poverty in the country (Hitayezu, Mugaruka & Nduwayezu, 2014).

In Tanzania, the economic losses from CC impacts on agriculture are estimated at US$200 million every year (CIAT and World Bank, 2017). Approximately, 44 million hectares of Tanzania's land have the potential for crop production, however, 9.1 million hectares are classified as range land for agricultural (URT, 2016). The availability of pastures and water for livestock largely depends on seasonal rainfall, thus making the livestock sub-sector vulnerable to drought. In semi-arid areas, where over 90% of the traditional livestock are found, rainfall ranges between 400-600 mm per annual and even crops can be easily affected (URT, 2015). The Beninese agriculture sector is strongly dependent on climate, whose variability remains an important factor in

declining yields and loss of crop diversity (Cuni-Sanchez et al., 2012). This climatic constraint, associated with the probable exacerbation of climatic extremes such as droughts and floods, as predicted by the fourth report of the Intergovernmental Panel on Climate Change (IPCC, 2007), will severely impact the Beninese agricultural sector through crop yield reduction, causing a reduction of 4.4% of domestic agricultural output by 2025 (Hounnou et al., 2019). According to Awoye et al. (2017), these decreases in crop yields will be primarily due to an increase in temperature rather than a change in rainfall.

In view of the above, this review aims to contribute to the resilience of African farmers' to climate change. Specifically, it aims to assess the different CC adaptation agricultural practices used in the selected countries, in order to: (i) identify the best climate change adaptation practices in Africa, and (ii) identify gender-specific climate change adaptation practices.

Methodology

The information used in this review was gathered from published books, journals, articles, and reports. Various peer-reviewed articles were downloaded from scientific databases (Scopus and GoogleScholar) and examined to conduct this bibliography synthesis. The first step was to collate all documents on climate change and agriculture, followed by selecting various adaptations developed by farmers to address climate change in the six targeted countries. The adaptations that were mainly influenced by gender were identified through an in-depth study of these different works. Then, points of convergence and divergence between the adaptations developed by farmers in the selected countries were identified.

Results

Impacts of climate change on different gender groups

The occurrence of climate change (CC) events in any community is greatly influenced by human developmental activities. However, CC worsens poverty and inequalities, with women and men affected in different ways. Women are often more vulnerable due to differences in socio-cultural and economic roles and responsibilities. In every country, climate change has effects depending on geography and country history. Thus, the impact of

climate change in Africa is described below using five African countries as a case study.

Tanzania

The adverse effects of CC in Tanzania have been documented in several government reports (ASDP 2019). The observed impacts include increased rainfall variability, reduced water volumes in water bodies such as rivers and lakes (Shayo, 2013), increased pest and disease incidence due to increased temperatures, saltwater intrusion, geographical shifts of ecosystems, and the replacement of perennial crops with annual crops owing to reduced crop cycles. Small-scale farmers are more likely to suffer the adverse effects, given their reduced adaptive capacity. Climate projections indicate an increase in temperatures of 1.4°C by the 2030s and 2.1°C by 2070. The West and Northwest will most likely experience faster warming (+1.9°C) relative to the coastal regions (+1.7°C). While historical rainfall trends have shown a decrease in precipitation, and climate models for future rainfall regime changes are rather uncertain, it is generally agreed that precipitation levels will increase throughout the country, with an uneven regional distribution (Collins et al., 2013). The largest increases (+7%) are most likely to occur in the North-West, the Centre, and the Northeast. Nevertheless, rainfall variability is expected to increase and reliability to reduce, as extreme events (droughts) are expected to be more frequent and severe. In the last 10 years, Dar es Salaam's economy and infrastructure have suffered from frequent and severe flooding, and the situation has gotten worse in the absence of major interventions such that the flood alone affected between 900,000 and 1.7 million people and 18% of the city population reported health impacts (Bird, 2019).

Ethiopia

The impacts of CC on agriculture in Ethiopia have threatened global food security. This country has climate variability and change and is frequently faced with climate-related hazards, commonly droughts and floods. The variability of rainfall and the increasing temperature are causes of frequent drought and famine, having a disastrous impact on the livelihood of the people. According to IFPRI (2009), higher temperatures eventually reduce yields of desirable crops while enhancing weed and pest proliferation.

Furthermore, changes in precipitation patterns increase the likelihood of short-run crop failures and long-run production declines (Nelson et al., 2009). According to Tesfamichael & Wossen (2016), female-headed households are more vulnerable to the impacts of climate change compared to male or male-headed households. On average in Ethiopia, household income in female-headed households decreased by 12.4% due to climate changes between 2010 and 2015, while it only decreased by 5.7% in male-headed households during the same period.

Morocco

The first signs of climate change are already being seen in Morocco. They are mainly revealed by an increase in the average temperature (0.16°C per decade and 1°C since the 1960s), an increase in the frequency and intensity of droughts, variability in the average precipitation, and a change in its spatial and temporal distribution (i.e., a decrease of 47% in spring precipitation), unusually devastating floods, a reduction in the duration of the mountain-top snowpack, and changes in the routes and times of passage of migratory birds. The national meteorological department is predicting an increase in average summer temperatures of 2°C to 6°C and a decrease of 20% in the average precipitation by the end of the century. These changes could have impacts, especially on natural resources, the various ecosystems, agricultural production (plants and animals), and the emergence and re-emergence of infectious diseases (Patz et al., 1996; Chakri, 2013; Maktit, 2009; USAID, 2016; GIZ, 2021).

Crop production is primarily rainfed (87%) and highly vulnerable to increased rainfall variability (particularly for barley and wheat). During dry years, yields of rainfed crops are reduced by 50-75%. Hotter, drier conditions increase crops' water requirements by up to 12%, increase demand for irrigation and further stress limited water resources. The average filling rate of dams rarely exceeds 70% and remains below this rate for 7 years out of 9. This leads to a decrease in water availability for irrigation, reducing the profitability of irrigated agriculture (Aoubouazza and Rajel, 2013; Maktit, 2014; USAID, 2016; Dunne, 2018).

Climate change is creating warmer temperatures, deeper droughts, and drier vegetation. These conditions lead to an increase in the extent,

intensity, and frequency of wildfires (Moore, 2021). Moreover, the oasis in Sous-Massa suffers from land degradation and biodiversity loss associated with higher temperatures and drier conditions (Khattabi and Bellaghmouch, 2009; Aoubouazza and Rajel, 2013; USAID, 2016). According to Nassif (2008), one of the effects of trends and changes in livestock management in Morocco due to climate change and the increased labour requirements of intensive animal husbandry is the increase in women's involvement in the livestock sector. The increase in labour demand is generally satisfied by female and children's unpaid labour within small-scale farms, which constitute the most common type of farm in Morocco. However, the contribution of women to livestock production remains neglected and undervalued. Thus, research addressing gender concerns in pastoral and agro-pastoral systems is rare in the country.

Togo

An assessment of the effects of climate change on crop yields in southern Togo using monthly precipitation and temperature for four weather stations collected from 1970 to 2014 shows that the increase in temperature had a significant effect on maize and bean yields (Koudahe et al., 2018). According to Gadédjisso-Tossou, Egbendewe-Mondzozo and Abbey (2016), irregular rain and a temperature increase of 1°C led to a net decrease in crop revenue of US$340.33/ha. An increase of 2°C will cause a decrease of 62.02% in revenue in 2050. Also, a decrease in rainfall of 2.5% in 2025 will lead to a 0.82% fall in the net revenue, while a 7.85% fall in the net revenue is expected with a 10% decrease in rainfall in 2050. Furthermore, CC has a negative impact on the dynamics of woody trees and forests in Togo. This results in abnormally increased mortality (21.2%) of trees, especially at the level of small-diameter individuals as well as all groups of pteridophytes (Abotsi et al., 2020; Adjonou, Bellefontaine & Kokou, 2009). Climate change also contributes to the decline of arboriculture, based on coffee and cocoa in the forest zone, two major export crops in Togo (Kola, Yabi & Pilabina, 2019). According to Gadedjisso-Tossou, Adjegan and Kablan (2021), rainfall and temperature variability have negative impacts on rainfed cereal crop production, especially in the north of Togo, where poverty is already predominant. Soviadan et al. (2019) reported that climate change has had a significant negative impact on cotton production, leading to an average decrease of 515 kg/ha of yield and an average income decrease of US $745 per farmer. Therefore, adaptation strategies for

sustainable agricultural production are needed. Small households and women are more vulnerable to climate change due to their low income and limited access to land and credit.

Nigeria

Climate change has an extensive influence on small-scale farmers in Nigeria, most especially those that do not have non-agricultural activities and hence solely depend on agriculture as their means of income and source of livelihood (Durodola, 2019). This is because Nigerian agriculture depends highly on rainfall, temperature, and relative humidity, as the main drivers of crop growth and yield. Thus, the climate is a major contributor to food production, availability, and agriculture-based income (Adejuwon, 2004). The increase in water temperature, and acidification of the ocean, among other factors, also affect fish stocks and threaten the livelihood of small-scale fish farmers (Lekwot, Uchenna & Alfred, 2012). Studies have shown that women are more vulnerable to climate change-induced food insecurity in Nigeria due to a lack of access to resources such as land, credit, income, and technical assistance (e.g., extension services). According to Anugwa et al. (2020), 79.2% of Nigerian men and 90.0% of Nigerian women were classified as food insecure within their households due to climate change's impact on agricultural productivity.

Benin

Benin's agricultural sector, which is mainly climate-dependent, is strongly impacted by climate change. Beninese women are more vulnerable to climate change than men mainly due to their limited access to land and education (Dossou-cadja and Akimabera, 2020). Indeed, men often have more fertile and more secure land for income generation, while women have access to less fertile and more precarious land for household subsistence. In addition, Beninese women have limited knowledge about the impacts of climate change, mainly due to their restricted access to climate information (Teka et al., 2013). According to Beninese farmers, CC has adverse effects on their agricultural activities, their health, and their living environment (Vissoh et al., 2012). Hounnou et al. (2019) demonstrated that CC will lead to a decrease in economic growth and household welfare by 2035 and 2045 respectively, if no adaptation strategies are adopted by Beninese farmers. Sonneveld et al.

(2012) demonstrated that by 2030, reduced rainfall and increased climate variability in Benin will lead to a decline in the yield of major food crops such as maize and yam. Jalloh et al. (2013) reported that under CC, maize productivity will be reduced by around 5 to 25% by 2050. Similarly, regarding cotton, the main cash crop supporting the Beninese economy, Akponikpe et al. (2019) found a significant decrease in crop yields of up to 20% by 2050 in central Benin. This situation is even more alarming because a great majority of cotton producers have a wrong perception of the impacts of climate change on agricultural production decisions (Mounirou and Lokonon, 2018).

In addition, CC and its positive impact on the proliferation of invasive alien species have created a destructive spiral that threatens food security in many countries, including Benin. For example, the fall armyworm, *Spodoptera frugiperda*, which is native to the Americas, has now become a new invasive species in West Africa, where outbreaks were first recorded in early 2016 (Goergen et al., 2016). In Benin, annual maize yield losses due to *S. frugiperda* have been estimated at between 295.6 and 735.8 thousand tons with an economic loss of between 86.6 and 215.6 million dollars (Day et al., 2017). Another invasive pest native to Central America, the larger grain borer (*Prostephanus truncates* Horn), induces significant maize post-harvest losses in Benin. It has also be noted that the proliferation of an invasive exotic plant species, the Siam weed (*Chromolaena odorata* L.), native to South America poses a serious threat to Beninese agricultural systems (Dandjlessa et al., 2021). The same applies to an invasive fruit fly pest from Asia, *Batrocera invadens* Drew Tsuruta & White, introduced in West Africa in 2004, which causes significant damage to fruit crops (Goergen et al., 2011). The main method used by farmers to control the populations of these invasive species is chemical control. Therefore, an indirect impact of climate change is the overuse of synthetic chemical insecticides with their negative impact on human health and the environment.

Land degradation exacerbated by climate change is very serious in Benin with 62% of degraded agricultural land (Dosso, Idrissou & Moussa, 2021). Sustainable land management is therefore a priority in Benin for resilience to CC. In addition, CC has a social impact, with the exacerbation of conflicts between farmers and herders causing many deaths in recent years. The scarcity of water sources and pasture due to drought has not spared certain regions of Benin.

Discussion

Climate change adaptation strategies

From the above report, it is clear that small households and women are more exposed to climate change impacts. Therefore, the development of adaptation strategies to climate change can substantially reduce the adverse effects of climate change on food production, improve the livelihood of smallholder farmers and reduce the problem of food insecurity in Africa. For this purpose, several strategies have been reported across the continent at national and international levels. The participation of the continent in different Conferences of the Parties (COP) and the development of national climate change strategies and action plans are major actions reported. However, the local population across each country has developed specific strategies to face the effects of climate change. These strategies are summarized below for the targeted countries.

Tanzania

The CC events that frequently occur in Tanzania include flooding, extreme cold, intense drought, storms, heat waves, rising sea level, melting glaciers, and warming oceans. These directly harm animals and people, destroy the places they live, and wreak havoc on people's livelihoods and communities. As climate change worsens, dangerous weather events are becoming more frequent or severe as well. The above climate change events have caused several effects, including the destruction of houses, poor academic performance by students, the death of domestic animals, a lack of feed for livestock, , and the failure of family developmental activities. Table 1 shows some of the events that occurred annually in various years.

Other effects that occurred during these events include the dynamics of insect pest populations, disease severity, and strong winds. Also, non-harmful earthquakes occurred in the last 2-3 years. The survival, recovery and adaptation mechanisms of various climate change events in Tanzania are highlighted in Table 2.

Table 1: Key climate change events in Tanzania with respective years of occurrence and effects

No.	Event	Year(s) of Occurrence	Effects caused
1.	Floods	2010-2021	Destruction of houses, infrastructure, and crops. Kids failed to attend schools which caused poor performance academically. Poor water quality due to the destruction of water infrastructure.
2.	Severe drought	2015	Death of domestic animals (cattle, goats, sheep, chickens, and ducks. No farming at all, which led to food insecurity and hunger in 2016. Respiratory problems due to heavy dust.
3.	Extreme cold	2021	Horticultural crops yielded nothing.
4.	Soil erosion	2010-2021	Accumulation of soils to one angle, loss of soil fertility, and weed dispersal.

Source: Binagwa (2021).

Table 2: Survival and recovery mechanisms in Tanzania with respective adaptation strategies

Strategy	Mechanisms	Adopted Method
Survival strategy	Established trenches across the houses that prevent water from entering community houses.	Continuous practices season after season.
	Placed sandbags around the houses to prevent water from entering the houses.	Continuous practices season after season.
	Moved to churches or schools during flooding.	Continuous practices season after season.
	Pastoralists established the traditional method of conserving dry pastures/feeds for livestockduring the devastating event.	Continuous practices season after season.

Strategy	Mechanisms	Adopted Method
Recovery strategy	Use of stored cleaned drinking water from their respective water tanks. This helped them to escape from disease outbreaks.	Continuous practices season after season.
	Digging ditches and directing them to the nearby river.	Continuous practices season after season.
	Relocating livestock to neighbouring villages that are not affected/severely affected by flood.	Implemented by neighbouring villages.

Source: Binagwa (2021).

More survival and recovery mechanisms include changing the farming principles by cultivating smaller land for easier management, planting short/early maturing crops, storing foods, establishing small irrigated systems for horticultural crops, and buying pasture/feeds from neighbouring villages. These mechanisms were widely adopted and practised by other neighbours which made them sustainable and reduced flood effects year after year.

Ethiopia

According to the literature, the country has been implementing different legal and policy reforms to overcome the impact of climate change in the agricultural sector generally and specifically on women. In Table 3, the adaptive and mitigation techniques/practices implemented in Ethiopia are summarized and presented with their effects on agriculture and women.

Table 3: Adaptive and mitigation techniques/practices implemented in Ethiopia

No.	Adaptation technique	Adaptation impact	Gender-related	References
1	Homestead gardening	Homestead gardens help to grow vegetables all year round, which helps to overcome dry seasons and ensure food security.	Since these farms are small scale and within the yard of the households, women can easily benefit from this. It does not require a large amount of labour. Women can also generate income by selling vegetables.	FAO (2015)
2	Good agronomy practices such as climate-smart agriculture	Implementedthrough soil and waterconservation measures, agroforestry, farmer-managed natural regeneration (FMNR), area closures, and dissemination of improved varieties	Climate-smart agriculture practices that include integrating tree species that provide fuelwood, fodder, shade, and fruit are highly valuable for women.	CIAT/BFS/ USAID (2017) FAO (2017)
3	Soil fertility conservation practices	Helps to use farmlands productively by reaping high yields and being able to do so in the future as well	Increased women's incomes, labour involvement,household food security, as well as risks for land and crop dispossession by men when farming becomes lucrative.	Baudron et al. (2009)
4	Use of irrigation	Prevents waiting for rainfall to practice agriculture and promotes producing crops more than once a year	Small-scale irrigation significantly increases women-headed households' income from crop and vegetable production. In addition, it gives women access to more diversified food, health, and education services.	Smur et al. (2020)
5	Flood management	Through flood management technologies, farmers can get information and data that enable	One of the techniques used in flood management is the preparation of water reservoirs and this especially	CGIAR (2015)

No.	Adaptation technique	Adaptation impact	Gender-related	References
		them make informed decisions about cropping schedules, water use, and disaster risk management.	helps women because it increases their access to water near their homes.	
6	Early warning systems	Play an important role to tackle the impact of climate change on agriculture by enabling early warning of possible harvest shortfalls, which in turn increases crop production and ensures agricultural sustainability.	Plays an important role in reducing the risk of disasters by providing women with the time they need to prepare and respond safely and helps to understand, effectively respond, and shape the dynamic situation on the ground.	https://www.fao.org/climate-change/our-work/areas-of-work/climate-risk-management/earlywarning/en/
7	Hazard mapping and monitoring technology	Hazard mapping by using technologies such as remote sensing which is low-cost but effective is very essential to tackle the problems of climate change in agriculture. It helps by predicting areas prone to floods and other hazards and developing farming systems that enable the production of enough food and fodder.	Since women and children are the primary victims of natural disasters such as floods and related effects such as food insecurity and disease, the implementation of such technologies that predict is very useful for them.	Gumma et al. (2022)
8	Livestock disease prevention and control	Implementation of this adaptive technology helps to have higher production of livestock and avoids future control costs.	This adaptive technology greatly benefits women farmers who depend on livestock production and helps them to ensure food security by depending on the results.	Clements & Ditommaso (2011)

No.	Adaptation technique	Adaptation impact	Gender-related	References
9	Use of cover crop (planting trees or fruits)	Cover crop planting (trees or fruits) improves the soil structure and thus facilitates water retention by soils, protects against wind and water forces that contribute to erosion.	Beneficial to women in two ways. First, they can use the cover trees for wood in their households which they otherwise may have to collect from far places. Second, they can use the fruits for household consumption and for income generation.	Delgado et al. (2011)
10	Diversification of income	Income diversification helps in ensuring food security as households can access food other than from their farms.	Women especially can benefit from these adaptations because they can prepare household items and /or "ballerina" to increase their income	Adem et al. (2018)
11	Use of drought-tolerant varieties	The crops will have better performance andincreased yields even in severe conditions.	Helps women to overcome food security problems at the household level.	

Morocco

Morocco's National Committee for CC was established in 2007 and oversees all climate-related activities (USAID, 2016). The country hosted the 7th Conference of the Parties (COP7) in 2001 and COP 22 in 2016 and was one of the first countries to develop a climate change strategy and action plan, with its National Plan Against Global Warming (PNRC), presented to the 15th COP in Copenhagen in 2009. It has ratified several international climate agreements (e.g., Kyoto Protocol, NAMA) and is actively involved in the UNFCC Process (Moroccan Ministry of Environment, 2020; GIZ, 2021). The PNRC engages the country and identifies government actions to fight global warming. It focuses on investing in renewable energy and energy efficiency (USAID, 2016), and provides for the reduction of greenhouse gases through energy diversification and the development of clean energies, as well as the implementation of mitigation and adaptation measures to CC, which mainly fall under a Water Strategy and the "*Plan Maroc Vert*" (Green Morocco Plan) for agriculture, launched in 2009. This plan is based on a triple-win scenario: it aims to adapt the country to the reality of climate change, mitigate its impact on populations and the environment, all while creating opportunities such as helping farmers adopt climate-smart techniques and increasing their productivity and improving the distribution channels for their goods (World Bank, 2016).

The mitigation measures within the PNRC aim to reduce greenhouse gas emissions (estimated at 94,290 t-eq CO2 in 2018) by more than 53 million t-eq CO2 / year by 2030. To do so, Morocco expects to generate 52% of its electricity needs from renewable energy by 2030 and is stimulating local manufacturing with a target of sourcing 35% of the second phase of the NOOR concentrated solar plant from local producers. Morocco has also lifted all subsidies on diesel, gasoline, and heavy fuel oil to encourage more efficient use of energy and free up resources to invest in the transition to a green economy (World Bank, 2016, 2021). Within the agriculture and forest sectors, the main mitigation measures undertaken by the country are (Wang et al., 2023; Maktit, 2014; Moroccan Ministry of Environment, 2020):

- Improving the yield of agricultural land through targeted land use and diversification of agricultural activities.

- Reclamation of methane emissions from solid waste, through the rehabilitation of uncontrolled landfills and the implementation of recovery systems in controlled ones.
- Reclamation of greenhouse gases from wastewater treatment plants.
- Reforestation (50,000 hectares per year) and planting (promoting arboricultural and pastoral plantations to improve the agricultural landscape, and conservation and organic agriculture to strengthen mitigation of climate change).
- Protection against forest fires through the implementation of the 2003 Master Plan for the prevention and fight against fires.

Adaptation to CC is integrated into several Moroccan strategies, policies, action plans, and programmes (e.g., National Water Strategy and Plan; National Plan for the Protection against Floods; Green Morocco Plan (focusing on the Agriculture Sector); National Action Programme to fight desertification: National Strategy for the Planning and Development of Oases; Halieutis Plan (focusing on fishery), etc.). Moreover, Morocco has developed a National Adaptation Plan (NAP) up to 2030, to better coordinate its actions and maximize its impact in the field of adaptation. Furthermore, adaptation has had significant budgetary implications in Morocco. Over the period 2005-2010, Morocco devoted 64% of all climate-related spending in the country to adaptation, which represents 9% of overall investment expenditures. In addition, Morocco expects to dedicate at least 15% of its overall investment budget to adaptation to climate change (GIZ, 2021). Adaptation measures undertaken within the agriculture and water sectors are (Maktit, 2009; Moroccan Ministry of Environment, 2020):

- Conversion to localized irrigation systems.
- Improvement of piped water supply systems.
- Sensitization and supervision of farmers for water-saving techniques.
- Construction of 59 large dams over the 2008- 2030 period and 1,000 small and medium dams by 2030 to prevent droughts and floods.
- Implementation of rainwater harvesting and storage projects.
- Exploiting non-conventional water resources, such as desalination of

seawater, demineralization of brackish water (mm^3), and reuse of treated wastewater (300 mm^3/year).

- Preservation and protection of water resources through the protection of groundwater resources and the quality of water resources.
- Protection against natural floods, droughts, and erosion hazards through the improvement of hydrometeorological forecasting and flood-proofing works.
- Modernization of information systems.
- Improvement of the early warning system against extreme weather events (floods, heat, cold waves, etc.) through strengthening the monitoring network (at the ground and high altitude levels).

Togo

Climate change adaptation strategies depend on the level of awareness of each local population about CC. In Togo, recent reports show that more than 6 out of 10 Togolese (63%) are aware that recent climate variability has led to a decrease in crop yields in the last decade. Farmers (72%) are more aware than other citizens (60%) (Adetou and Ahlin, 2019). However, according to the same authors, only 41% of farmers have enough information about CC. Another survey carried out on a purposely selected sample of 216 farmers of both sexes in the savanna region (north of the country where drought is often severe) shows that 98.10% of respondents were aware of the degradation of their soils while 99.50% felt the effects of CC, which are manifested as long droughts, delayed rainy seasons, heavy rains, and high temperatures (Abalo-Esso et al., 2021).

The above-mentioned effects of CC are a real threat to food security, in addition to the low level of lending and weak technical support to farmers in Togo. To face these effects of CC, farmers adopt several approaches. The most common approaches are the selection and use of resistant and high-yielding varieties, crops and livestock integration, use of mineral and organic manure, use of soil and water conservation practices, and adjustment of sowing time (Ali, 2021; Sanou et al., 2018). Also, crop rotation and association, establishment of grass strips and stone bunds, reforestation to protect and restore plots, diversification of agricultural production, and use of extra-agricultural

activities (Kola et al., 2019) are the most adopted farming practices for CC. According to Waibena, Okey and Kao (2019), in the maritime region where the major crop is maize, 55.6% of farmers adopt improved and sustainable farming practices including assessing soil fertility variables, use of tractors, technical support of Association pour la Gestion Intégrée et Durable de l'Environnement (AGIDE), technical advice from extension agents, and training in integrated soil fertility management (ISFM). Waibena et al. (2019) noted that gender is significant at 5% and has a positive impact on the adoption of sustainable practices. It was further reported that the adoption of sustainable farming practices provides an additional income of 27,250.73 FCFA (46.98 US$) per hectare (Waibena et al., 2019).

According to Ali, Awade and Abdoulaye (2020), among soybean farmers in Togo, only 40.37% of the women have adapted to CC compared to 59.62% of the men. Moreover, being a member of a farmer-based organization (FBO), having access to credit and extension services, and agricultural training for women are the main factors that increase the likelihood of adaptation. The authors further indicate that gender-differentiated impact shows that women would earn more than men from adaptation but lose 0.268% of the soybean revenue compared to men if they do not take any adaptation actions. According to Ali (2021), households' minimum consumption needs, gender, land, and access to credit and extension services are the main determinants of the choice of the number of adopted strategies. Ali et al. (2020) reported that reviewing the financial policy in terms of affordability, access to extension services, and supporting FBOs will increase technology adoption and farming revenue. Soil and water conservation techniques and sustainable irrigation are additional sustainable practices to improve farmers' welfare under climate change, especially when combined with subsidy and credit policy (Pilo, Gerber & Wünscher, 2021; Adji, Egbendewe & Lokonon, 2022).

Nigeria

The development of adaptation strategies to climate change can substantially reduce its adverse effects on food production, improve the livelihoods of smallholder farmers and reduce the problem of food insecurity in Nigeria. Nigerian smallholder farmers have employed the following climate change adaptation strategies: varying farming land sizes, use of soil conservation techniques, varying crop planting and harvesting dates, mulching,

increased percentage of sales crops, livestock rearing by crop farmers, mixed cropping and mono-cropping, and use of agrochemicals e.g., pesticides, herbicides, and fertilizers (Ojo and Baiyegunhi, 2020).

Gender is an important factor affecting the adoption of CC strategies in Nigeria. Reports have shown that female farmers mostly prefer to adopt natural resource adaptation/management practices while male farmers are always willing to try new CC adaptation practices and are mostly the ones that have adopted the new practices (Ojo and Baiyegunhi, 2020). This observation agrees with the study of Owombo, Idumah & Afolayan (2015), who reported that young farmers are interested in adopting new CC adaptation strategies because they are aware of recent innovations in agriculture and are keen to try new practices or technologies that will improve agricultural productivity. However, older farmers are reluctant to try and adopt new agricultural methods possibly due toilliteracy levels and lack of information.

Benin

To contribute to the resilience of populations to CC, in 2022, Benin republic, through the Ministry of Living Environment and Sustainable Development and the Directorate General of Environment and Climate (DGEC), elaborated a national plan for adaptation to CC, considering the most vulnerable sectors, including agriculture (PNA, 2022). This plan facilitates the integration of CC adaptation into all national planning documents. Faced with the impact of CC, Beninese farmers are developing various adaptation strategies (Vissoh et al., 2012; Yegbemey et al., 2013; Loko et al., 2013; Dossou-Aminon et al., 2016; Yegbemey et al., 2017; Fadina and Barjolle, 2018; Soglo and Nonvide, 2019; Adjahossou et al., 2021; Gbemavo et al., 2022). These coping strategies developed by farmers vary according to the crop. For example, Beninese yam farmers use mulching as a drought adaptation strategy (Loko et al., 2013), whereas this practice is not used by sorghum (Dossou-Aminon et al., 2016) or rice farmers (Gbemavo et al., 2022). Likewise, there appears to be a gender difference in the adoption of adaptation and mitigation measures (Teka et al., 2013). Indeed, Yegbemey (2020) suggested that the gender bias in land allocation and inheritance systems existing in Benin infers that men are more likely to develop coping strategies than women. Table 4 summarizes the coping strategies developed by Beninese farmers and the influence of gender on these strategies.

Table 4: Gender-responsive Climate Change Adaptation Strategies Developed by Beninese Farmers

Adaptation strategies	Adaptation impacts	Connection with gender	References
Adjustment of the agricultural calendar	Sowing is delayed limiting seed losses due to pockets of drought.	Men practice early sowing more than women and adopt farming calendar adjustments. In addition, older farmers are more likely to change sowing timecompared with younger farmers.	Alle et al., 2013; Yegbemey et al., 2013; Soglo and Nonvide, 2019; Adjahossou et al., 2021
Agroforestry	Trees serve as cover for crops, contributing to better soil water retention and reduced soil erosion.	Male farmers cultivate more in theagroforestry system compared to females.	Adjahossou et al., 2021
Adoption of shorter-cycle varieties	Farmers are adopting shorter-cycle varieties due to the shortening of the rainy season.	Both men and women are likely to adopt shorter-cycle varieties	Alle et al., 2013; Dah-gbeto, and Villamor, 2016; Soglo and Nonvide, 2019
Use of varietal diversity	The different varietal performances allow farmers to cultivate varieties that are tolerant or resistant to various biotic and abiotic stresses.	Gender influences farmers' decision to use cultivars resistant to the existing varietal diversity. Female farmers are more sensitive to the use of varietal diversity.	Loko et al., 2013 ; Gbaguidi et al., 2015
Adoption of new crops	New cash crops are being adopted at the expense of drought-sensitive cereals.	Young farmers prefer to abandon cerealcrops, which are very sensitive to climatic hazards, for cash crops	Alle et al., 2013
Use of improved varieties	Improved varieties have scientifically proven performance.	Both men and women are likely to use improved varieties as a coping strategy	Dah-gbeto, and Villamor, 2016
Adoption of crop rotations and associations	Successively growing different crops on a plot or rotating crops can reduce risk aversion due to climate change	Women have a higher probabilityof adopting crop rotations and associations	Degla et al., 2016
Crops and livestock diversification	Allow farmers to have various products at harvest and to minimize losses due to climate change	Men mainly adopt crop and livestock diversification strategies because they have more resources	Fadina and Barjolle, 2018; Yegbemey et al., 2013; Yegbemey et al., 2014

Adaptation strategies	Adaptation impacts	Connection with gender	References
Ploughing practice	The soil is ploughed to increase its physical fertility	Men are more likely to adopt ploughing practice because they have more resources (ploughs, tractors, etc.) than women.	Alle et al., 2013 ; Obossou et al., 2022
Use of irrigation	Irrigation provides water to the plant at any time and therefore favours off-season cultivation.	Men tend to adopt irrigation practices more because they have more resources and are landowners.	Soglo and Nonvide, 2019
Use of chemical fertilizers and pesticides	Fertilizers and pesticides are used more because of the impoverishment of the land due to its permanent cultivation and the proliferation of pests	Men are more likely to use chemical fertilizers and pesticides to cope withdeclining yields	Dah-gbeto, and Villamor, 2016
Diversification of income-generating activities	Farmers diversify their sources of income to earn additional funds or stabilize their incomes	More women choose diversification ofincome-generating activities as adaptation to climate change	Alle et al., 2013; Dah-gbeto, and Villamor, 2016; Fadina and Barjolle, 2018
Crop-livestock integration	Livestock dung fertilizes the soil and livestock is fed with crop residues.	Female and young farmers are more technically efficient in crop-small-ruminant production	Asante et al., 2019
Land use strategies	Change in land use between different crops for better resilience	The transfer from one production site to another requires the availability of land. Therefore, men are more likely to use this coping strategy.	Gbaguidi et al., 2015
Making large mounds	Maintaining humidity, and water retention, and prevents the seeds from drying out in the mound.	The construction of large mounds requires physical effort; this practice of adaptation to drought is mainly used by men.	Loko et al., 2013 Gbaguidi et al., 2015
Climate-smart agriculture technologies	Improved crop production and livestock management systems enable resilience to climate change.	Men adopt more climate-smart agriculture technologies than women.	Obossou et al., 2023

Conclusion

This review reports that climate change is a serious phenomenon that affects farmers' livelihoods in Africa. Increasing temperatures, land degradation, droughts, and floods were mainly reported across the targeted countries. Numerous adaptation strategies are currently employed to ameliorate the effect of climate change in African countries. However, to achieve effective CC adaptation strategies, proper coordination actions need to be taken. Information provided in this review shows that all the study countries have consistent programmes and actions regarding resilience and adaptation to climate change (ratification of several conventions related to climate change resilience strategies, and national programmes focused on adaptation to climate change, etc.). In addition, the majority of the countries use temperature control measures such as mulching and irrigation as CC coping strategies. Furthermore, men, women and youth employ different CC adaptation strategies based on their literacy level and exposure to information. However, gender-responsive programmes, at national or regional level, are lacking in all the studied countries. Therefore, programmes are needed, aimed at building a pipeline of connected, inter-generational climate responsive scientists, such as the One Planet Fellowship, who could help identify the best approach to climate change in various African countries. Furthermore, technology transfer from the developed world is also essential for better climate change adaptation.

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