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Review

Gendered Gaps in the Adoption of Climate-Smart Agriculture in Africa and How to Overcome Them

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Abstract: In Africa, the agricultural sector contributes approximately 10–20% of the total anthropogenic greenhouse gas (GHG) emissions. It presents rapid growth as a result of rising food demand in Africa, which is being driven by population growth. Consequently, climate change can negatively affect crop yields and livestock production, thus threatening food security. This review highlights the existing gender gaps in African agriculture and discusses the drivers and barriers that maintain gender gaps in climate-smart agriculture (CSA) adoption in African countries. Moreover, the review offers a comprehensive roadmap for the essential measures required to facilitate the widespread uptake of CSA practices among female farmers. Several CSA practices were reported, such as agricultural practices, forest and cropland regeneration practices, water resources, and the use of weather and climate information services. The gender gap in the adoption of CSA practices was influenced by policy legislation, financial resources, social and cultural taboos, and technical determinants such as climate information access. To address this gender gap, scientific-outcome-based research should be used to address gender gaps among female small farmers. In conclusion, to overcome the gender gap in CSA adoption in Africa, this review recommends the use of a gender-responsive approach, the development of scientific research-driven measures, and the prioritization of gender equality in governments' agendas in the context of climate change uncertainty.

Keywords: gender inequality; climate change; smallholder farmer; food security; adaptation strategies

1. Background

Climate change refers to the phenomenon of escalating levels of greenhouse gas emissions, including nitrous oxide (N_2O), carbon dioxide (CO_2), and methane (CH_4), which lead to disruptive changes in the atmosphere [1]. These changes result in unpredictable variations in rainfall patterns, rising temperatures, and the occurrence of floods and droughts [2].

The impacts of climate change are anticipated to be profound, extensive, and irreversible in the future, with the African continent emerging as one of the most susceptible regions to its effects [3,4]. In the literature, several studies highlighted the vulnerability of African countries to climate change, which is essentially related to their high exposure to extreme climatic events such as drought and floods [5] and their low adaptive capacities [6–8].

Furthermore, the IPCC [3,4] projected that East Africa will experience warmer temperatures, a 5–20% increase in rainfall between December and February, and 5–10% less rainfall from June to August by 2050. Consequently, fishing activities in coastal areas and aquaculture systems and crop yields have been affected, particularly for maize cultivation [9,10]. In West, Central, Eastern, and Southern Africa, the most prominent climate factors posing substantial risks to rain-fed crop production systems and the livelihoods of subsistence farmers are long-term drought and high temperatures [11]. In addition, in North Africa, climate change is mainly manifested by temperature increases and a high rate of droughts [5]. Consequently, climate change negatively affects the yields of crop, livestock, and fishery production, thus threatening food and nutrition security [12].

Currently, climate-smart agriculture (CSA) has been recognized as a crucial strategy for addressing the challenges posed by climate change to agricultural systems [13,14]. According to the FAO [12,15], CSA is defined as "agriculture that sustainably increases productivity, resilience (adaptation), reduces/removes GHGs (mitigation), and enhances national food security and development goals." The FAO emphasizes the need for innovative financial mechanisms to implement CSA effectively. Its three pillars are adaptation, mitigation, and food security [14,16,17]. The World Bank also includes transitioning to low-carbon growth and reducing vulnerability in its definition of CSA [18]. Both definitions highlight increasing food production through various agricultural technologies and practices. The World Bank extends CSA to include a "governance framework" with essential tools, technologies (like energy efficiency and carbon capture), and institutions [18]. Moreover, CSA incorporates practices from environmental ecology, conservation, climate change, and agriculture, such as agronomy, agroforestry, livestock management, forestry, land use, water and soil management, and bioenergy [19]. These practices can also guide policy development for climate change initiatives, health, environment, and infrastructure [20].

Furthermore, climate-smart agriculture (CSA) empowers farmers, key institutions, and service providers by strengthening their ability to adapt and respond effectively to the long-term effects of climate change [21–23]. It equips them with the essential tools and strategies needed to manage the risks arising from increased climate variability. Through the adoption of CSA practices, stakeholders in the agricultural sector can proactively prepare for and overcome the challenges brought about by climate change while simultaneously fostering resilience and promoting sustainable agricultural development [11].

Climate-smart agriculture (CSA) offers the agricultural sector in Africa a powerful tool to combat climate change and enhance resilience through adaptation. CSA strategies could contribute significantly to social equity and local economies, especially in the southern countries [24–27]. A lot of interest has been shown in CSA in recent years, and a number of actors, such as governments, farmers, civil society organizations (CSOs), international organizations, the private sector, and the research community, have initiated different interventions in CSA [28]. However, CSA adoption by African women smallholder farmers remains low, despite the fact that they are the majority and are more exposed to the effects of climate change [29]. This gender gap is influenced by several interrelated factors. Sociocultural barriers such as traditional gender roles and lower educational levels for women limit their participation in agricultural activities and access to training [30,31]. Economically, women face greater challenges in accessing credit, financial services, and land ownership, which are crucial for investing in CSA technologies [32]. Institutional factors, including male-targeted extension services and a lack of gender-sensitive agricultural policies, further exacerbate this gap [33]. Additionally, women's limited access to agricultural technology hampers their ability to implement CSA practices effectively [34]. Addressing these issues through inclusive education, resource access, and policy frameworks is essential for bridging the gender gap in CSA adoption.

In this narrative review, we assume that climate-smart practices are used in African countries and that their impact has been noted by smallholder farmers. However, CSA gender integration remains weak; it varies from one country to another. The objectives were to (1) highlight the existing gender gaps in African agriculture; (2) discuss the drivers and barriers that maintain gender gaps in CSA adoption in African countries; and (3) provide a holistic guide for the actions needed to scale up CSA adoption among female farmers.

2. Literature Search Method

To obtain publications concerning gender gaps in the adoption of climate-smart agriculture (CSA) in Africa, a systematic search was conducted across various databases, including Web of Science and Scopus. In the identification phase, multiple keywords, synonyms, related terms, and variations were combined using the Boolean operators "OR" and/or "AND": ("Climate-Smart agriculture" OR CSA OR (("Climate-chang*" OR "global-warmin*") AND Agriculture)) AND Africa AND ("Gender gap*" OR "gender inequalit*" OR "gender disparit*" OR "gender imbalance" OR "gender-based disparit*")).

All located citations were input into Endnote ×5 software (Thomson ISI ResearchSoft, Philadelphia, PA, USA). Duplicate articles were subsequently removed, retaining only the pertinent ones. The reference sections of the remaining articles were examined to identify additional related studies from alternative platforms such as Google Scholar. For inclusion in this review, no restrictions were imposed on the publication sources, and articles or technical reports were required to be published in English.

3. Gender Gaps in Agriculture Production in Africa

African women play a great role in agriculture production, and their contributions in ensuring family food security have been documented [35,36]. They account for up to 52% of the total population in the sector and approximately 50% of agricultural labor on farms in Sub-Saharan Africa (SSA). It has been observed that women have a higher workforce rate than men by approximately 64% [37]. According to Palacios-Lopez et al. [38], the contribution of women's workload in six African countries to crop production averaged 40%, while it is slightly higher in Malawi, Tanzania, and Uganda and significantly lower in Nigeria (37%), Ethiopia (29%), and Niger (24%). Women also help with agricultural activities such as land preparation, harvesting, planting, and weeding. Despite their high contributions and roles in agricultural production, studies have shown that women have lower agricultural productivity than men.

There is a visible gender gap in agricultural production that is not related to population size but rather to agricultural productivity. In Kenya, Ethiopia, Malawi, and Nigeria, for example, the productivity gaps between men and women ranged from 8 to 11, 28, and 30 percent, respectively [39]. The productivity gap with similar land sizes in similar settings can be as high as 66% in Niger, 44.3% in Ethiopia, and 20.18% in Mali [40,41].

This gender gap in agricultural production can be attributed to a number of factors; women have less access to inputs and technologies for agricultural production [42], less access to agro-climatic information [43], less access to finances, and as a result, a lack of cash income to hire labor and access fertilizer and other inputs [44]. Also, women tend to have less control over land resources in the community or household, in addition to challenges in mobilizing the labor needed to help their farms thrive and reductions in the production of high-value crops [41,45]. Cultural norms that prevent them from reaching their full potential include a lack of participation in decision-making processes in households and farmer groups such as cooperatives, a lack of involvement in community groups, and a lack of adoption of new technology [46,47].

This is not to say that women are inefficient but rather that female and male farmers do not face the same production conditions, production choices, outputs, incomes, perceptions, and adoption of new techniques that can help improve their productivity [48].

Rural women in particular rely on ecosystem services because they are more involved in agricultural production and natural resource management [49]. This gender gap in agricultural production reflects a number of constraints.

These factors contribute to a 45% productivity gap due to labor mobilization challenges, where 8–18% of workers lack cash for new technology, 25–45% do not use pesticides or fertilizer (they rely on organic fertilizer), and 13% do not use insecticides [39]. Women may be less likely to plant high-value crops due to several factors, such as the lack of access to climate smart technologies and extension services [50–52]. In the same way, due to a lack of collateral for a bank, women have fewer opportunities to obtain credit, and they are more involved in domestic activities such as childcare, food preparation, and water fetching [40]. Furthermore, over 56% of the agricultural productivity gap in Mali is influenced by female-specific structural disadvantages, such as education level, age, and the use of fertilizers. The remaining 44% is due to an endowment effect (resource allocation) [41]. In developing countries, women have the potential to enhance farm yields by 20–30% if they are granted equal access to productive resources when compared with men. This, in turn, could result in a 2.5–4% boost in total agricultural output, consequently reducing the global hunger rate by 12–17% [53]. Consequently, closing the gender gap in agriculture would result in significant benefits for both the agricultural sector and society through an increase in production and income [42,54].

4. Gender Gaps in CSA Adoption

As mentioned above, CSA adoption was aimed at increasing productivity and incomes, building resilience and adaptation to climate-related extreme weather events, and achieving mitigation through greenhouse gas emission reduction [12]. Moreover, it has the potential to play a significant role in reducing the gender gap. Khatri-Chhetri et al. [55] showed that CSA technologies such as green manure and zero tillage can reduce women's workload (rice transplanting, weeding, irrigation, harvesting, and threshing) in agriculture. In another study, Andrieu et al. [56] showed that CSA adoption can support diversification and improve incomes for women in Mali through the cultivation of improved varieties and the use of intercropping systems that involve cultivating two or more crops in a field simultaneously (e.g., sorghum and cowpea). While the adoption of CSA practices can result in significant benefits, their widespread implementation in African countries has been progressing slowly and, notably, in a gender-dependent manner. In northern Benin, male smallholder farmers are adopting CSA technologies related to soil and water conservation practices and livestock management systems more extensively than their female counterparts. The adoption rates for technologies related to animal health services were 66.2% for men compared with 44.9% for women, and for organic fertilizer, the rates were 59.6% for men and 46.3% for women [57]. In Kenya, access to climate information services can positively affect decisions to adopt CSA technologies and strategies such as irrigation, agroforestry, soil conservation, changing animal breeds, and supplementary feeds [58,59]. The results reported that men tend to have notably greater access to early warning systems and advisory services related to adaptation through channels such as extension officers, print media, television, and local leaders. However, women have better access to weather forecasts through radio broadcasts and participation in social groups. Moreover, climate information services meet the needs of female farmers at a rate of 38% compared with 30% for male farmers [59]. In both Malawi and Tanzania, male farmers exhibited a higher tendency to utilize improved maize seeds on their farms when compared with their female counterparts, with adoption rates of 61% versus 45.1% and 44.8% versus 35.1%, respectively. In contrast, female farmers in both countries were more reliant on local maize varieties [60]. In Tanzania, the implementation of CSA practices was influenced by the farmers' genders. For example, the adoption of improved crop varieties, composting, chemical fertilizers, and agroforestry exhibited different patterns among males and females, with adoption rates of 73.8% versus 26.2%, 72.2% versus 27.8%, 56.7% versus 43.3%, and 73.9% versus 26.1%, respectively [61]. In North African countries, the impact of CSA practices on smallholder farmers while using gender as a variable is poorly documented when compared with other African nations [19]. However, gender inequality represented by complete male dominance was reported in southern Algeria in pastoral communities breeding camels [62], cattle [63], and goats [64], with effects also found on the schooling of children, especially girls [65].

Furthermore, a study conducted in Senegal by Bonilla-Findji et al. [66] reported that CSA technique adoption was higher among male farmers (159, 96%) than among female farmers (110, 70%). The study found higher acceptance rates for agroforestry and reduced tillage practices (70%), medium adoption levels for manure (40%) and organic matter plus micro-doses of artificial fertilizers (about 23%), and low acceptance rates (15%) for micro-doses (NPK plus urea) and drought-tolerant varieties.

In Ghana, adoption of CSA strategies was analyzed in farmers with a basic education level. The reported findings indicate that CSA practices were adopted less by males compared with females for several practices, including crop rotation (11% vs. 20%), crop diversification (7% vs. 21%), changing planting dates (14% vs. 25%), and intercropping (13% vs. 25%, respectively) [48]. Duffy et al. [67] reported that CSA practices such as conservation tillage can increase the frequency of weeding, an activity often performed by women in Africa south of the Sahara.

In the literature, CSA adoption is thwarted by existing gender gaps not only in agriculture [42] but also in other fields such as education [68], salary and income inequality [69,70], political participation [71,72], and sports [73]. Consequently, it is essential to get out of this vicious circle. For enhancing agricultural productivity under an uncertain climate change context, it is necessary to implement CSA. However, to achieve this, it is necessary to eliminate the existing gender gap in agriculture.

Based on the data given above, a gender-responsive approach to CSA identifies and addresses the various constraints faced by various vulnerable groups, targets their specific needs and interests, and ensures that women and men can benefit equally and the outcomes are sustainable [74]. Moreover, to determine the most appropriate climate-smart agriculture practices and technologies for a given area, it is necessary to examine its specific socioeconomic and institutional context, current agro-ecological conditions, projected climate change scenarios, and potential future impacts (Table 1).

Table 1. Case studies on the gender gap in the adoption of CSA practices.

Location	CSA Practices	Gender Gap	Reference
Benin	✓ Soil and water conservation practices ✓ Livestock management systems	✓ Animal health services were 66.2% for men vs. 44.9% for women. ✓ Organic fertilizer was 59.6% for men and 46.3% for women.	[57]
Kenya	✓ Climate information services (CIS) ✓ Adoption of CSA technologies such as irrigation, agroforestry, soil conservation, changing animal breeds, and supplementary feeds	✓ Men tend to have notably greater access to early warning systems and advisory services, related to adaptation through channels such as extension officers, print media, television, and local leaders. ✓ Women have better access to weather forecasts through radio broadcasts and participation in social groups. ✓ 38% of female farmers reported that CIS adequately met their needs. ✓ 30% for male farmers reported that CIS adequately met their needs. ✓ 16.03% of male farmers were reported to adopt agroforestry and 8.33% of female farmers.	[59]

Table 1. *Cont.*

Location	CSA Practices	Gender Gap	Reference
Malawi	✓ Improved maize seed on farms	✓ Improved maize seed adopted by 61% if male farmers and 45.1% of female farmers. ✓ Local maize seed adopted by 44.1% of male farmers and 57.6% of female farmers.	[60]
Tanzania	✓ Improved maize seed on farms	✓ Improved maize seed adopted by 44.8% of male farmers and 35.1% of female farmers. ✓ Local maize seed adopted by 55.4% of male farmers and 64.9% of female farmers.	[60]
Tanzania	✓ Improved crop varieties ✓ Composting ✓ Chemical fertilizers ✓ Agroforestry ✓ Early planting	✓ Male and female adoption rates of CSA practices were 73.8% vs. 26.2%, 72.2% vs. 27.8%, 56.7% vs. 43.3%, 73.9% vs. 26.1%, and 62.5% vs. 37.5%, respectively.	[61]
Senegal	✓ Agroforestry and reduced tillage ✓ Manure ✓ Microdose (NPK plus urea) ✓ Drought-tolerant varieties	✓ Male and female adoption rates of CSA practices were 74% vs. 64%, 40% vs. 21%, 14% vs. 3%, and 14% vs. 2%, respectively.	[66]
Ghana	✓ Crop rotation ✓ Crop diversification ✓ Changing planting dates ✓ Intercropping	✓ CSA practices were adopted less by males compared with females (11% vs. 20%, 7% vs. 21%, 14% vs. 25%, and 13% vs. 25%, respectively).	[48]
Nigeria	✓ Crop rotation ✓ Green manure ✓ Organic or compost use ✓ Minimum tillage	✓ Male farmers adopted CSA practices more than female farmers (23.0%, 21.0%, 39.0%, and 45.0%, respectively).	[75]
Mali	✓ Crop association ✓ Improved seed varieties ✓ Composting ✓ Organic manure ✓ Crop rotation	✓ Male and female adoption rates of CSA practices were 47% vs. 47%, 16% vs. 11.32%, 69% vs. 60%, 56.49% vs. 25%, 56.49% vs. 40%, and 55% vs. 42%, respectively.	[76]
Uganda	✓ Agroforestry ✓ Zai or planting pit ✓ Efficient use of fertilizer ✓ No or minimum tillage ✓ Improved varieties	✓ Male and female adoption rates of CSA practices were 93% vs. 90%, 17% vs. 11%, 50% vs. 34%, 48% vs. 21%, and 56% vs. 22%, respectively.	[77]
Zimbabwe	✓ Drought-tolerant maize cultivation (improved variety of maize) ✓ Conservation agriculture	✓ The adoption rate of the practice depends on wealth assets (63.7%), location (22.0%), land size (16.8%), and farmer's age (13.5%).	[78]
Ethiopia	✓ Conservation (bundle) tillage ✓ Improved crop variety ✓ Crop diversification	✓ Male-headed households had 2.5% higher rate of adoption, while female-headed ones had no record. ✓ Educated farmers adopted them 7.3% more often. ✓ Experienced and aged farmers had 10% adoption rate. When age increased, farmers shifted from small bundles to large bundles.	[79]

Table 1. *Cont.*

Location	CSA Practices	Gender Gap	Reference
Mozambique, Malawi, South Africa, and Zambia	✓ Land, water, and soil conservation technologies	✓ Adopters were significantly older than non-adopters, while 70% of adopters had access to agricultural extension, where 60% of non-adopters had no agricultural extension service. ✓ Adopters were shown to have slightly more years of formal education. ✓ Pieces of land owned or used by each smallholder farmer were also found to be significantly different between adopters and non-adopters. ✓ Lack of access to information led to non-adoption among 59% of married men. ✓ CSA is more likely to be adopted in households where women are empowered to some degree.	[80–82]

5. Determinants of Gender Gaps in CSA Adoption

The determinants of gender gaps in CSA adoption are multifaceted and involve a combination of socioeconomic, cultural, institutional, and environmental factors. The literature highlights several determinants that explain the gender differential in the likelihood of CSA adoption and significant heterogeneity across countries [83]. In this review, we have grouped these determinants into three families.

5.1. Level of Access to Productive Resources

Among the challenges for the gender gap in CSA adoption, land ownership is a major divide, with women owning and managing fewer, smaller, and less valuable plots than men. In Zimbabwe, prior to and shortly after independence, the percentage of women who owned land was strikingly low, standing at less than 5%. However, encouragingly, there has been progress in recent years, with the figures rising to a range of 12–27% for both small- and large-scale farms [84]. The same results were also recorded in Uganda, where 69% of men and 57% of women were reported as landowners with existing ownership documents. However, the proportion of those having any documents showing land rights in their own names fell to 52 percent for men and just 18 percent for women [85]. In Maghreb countries, although there have been advancements in terms of legal frameworks and policies that grant men and women equal rights to access to land ownership, there persist numerous tangible gender-based differentiations and obstacles that impede women's actual ability to access land and engage in agricultural pursuits [86]. Similarly, within Nigeria's six states, Ologeh et al. [87] observed a prevailing pattern where land ownership is predominantly held by men (48%) in the northern regions. This dynamic is accompanied by a substantial employment of female laborers. Conversely, the majority of female farm proprietors (42%) are concentrated in southern Nigeria. In the context of limited access to land ownership or, in certain cases, the lack of official land titles, women encounter significant challenges in obtaining credit. This severely restricts their capacity to fund innovative climate-smart agricultural practices [88,89].

In Malawi, Murray et al. [90] highlighted that female smallholders often face limited access to basic agricultural tools, transport, rural energy, and labor-saving technologies, hindering their engagement in CSA. Moreover, Chibowa et al. [91] explored gender differentiation in CSA technology adoption and adaptive capacity, such as zero tillage and mulching, among smallholder farmers in Malawi. Their findings showed that over 70% of male farmers adopted CSA technologies, while less than 30% of female farmers did. The main constraints leading to low adoption among female farmers were high input demand, the cost of inputs, labor requirements, and a lack of credit opportunities and income.

Difficulties in accessing information regarding the adoption of CSA is also seen as a significant barrier which disproportionately affects female farmers [81,92,93]. Improving men's, women's, boys', and girls' access to extension and climate-related services is a critical component of the transition to gender-responsive climate-smart agriculture. According to the study, only 5% of the extension services were directed to female farmers during the analysis of gender-responsive CSA practices implemented in 97 countries [53], and the extension services were biased toward rich farmers rather than poor farmers [94]. According to the Nationally Determined Contribution (NDC) review, only 43 countries (22%) addressed gender in relation to agricultural adaptation or mitigation actions in 2021, and only 23 of the 48 NDC reviews submitted by African countries included a reference to gender in relation to agriculture [95].

5.2. Socio-Cultural Factors

In the literature, Antwi and Antwi-Agyei [48] showed that married male smallholder farmers used CSA interventions on their farms more than single and divorced male farmers, implying that women play a role in CSA adoption. It is well proven that women are more vulnerable to the effects of climate change than men, making them more likely to adopt new technologies [96]. Married women appeared to be able to make independent decisions about adoption, despite numerous obstacles such as a lack of land ownership or other productive assets [83,97,98]. Furthermore, research has also indicated that women's involvement in decision making positively influences CSA adoption in countries like Malawi, emphasizing the socio-cultural drivers of women's participation in decision-making settings [99]. Moreover, the gender gap in CSA adoption is due to discrimination-related social norms, culture, and other factors that discriminate against women and prevent them from participating in economic activities [60]. In Kenya, women face more significant constraints compared with men due to traditional customs and taboos in accessing agricultural equipment, input, public support, financial resources, markets, and transportation [100]. Migration from regions where temperatures are increasing and periods of drought are prolonged may also contribute to the outbreak of conflict, which can slow down the adoption of CSA [101]. In Benin, Obossou et al. [57] reported that 11% of women and 24.3% of men rely on media, including television, radio, and cell phones, to learn about CSA technologies. The low rate of media use could be attributed to the limited coverage of CSA-related information tailored to specific socio-cultural contexts.

In African countries, Njoh and Akiwumi [102] reported a significant correlation between the three most important religions (indigenous African, Islam, and Christianity) and the percentage of school-aged girls in school, female adult literacy rates, share of non-agricultural employment, and representation in government. These can negatively affect women's empowerment, which might affect CSA adoption. In the same way, the patriarchal system and cultural practices of African traditional religions and Christianity can impacts women's access to land ownership in the Gwanda district of Zimbabwe [103].

5.3. Technical Capacities

Climate change adaptation and risk management strategy are reported to have demonstrated a significant role in reducing women's labor burden in agriculture as well as improving their access to agricultural resources and decision-making processes [104]. Women can lessen their labor burden in agriculture by implementing CSA practices and technologies, such as direct-seeded rice, zero tillage machines, laser leveling, and green naming. Crop harvesters, weeders, solar pump irrigation, and post-harvest management practices are examples of CSA technologies. However, 'women's participation in CSA is hindered by a lack of knowledge, training, and opportunities, limited resources, and household chores [104].

Encouraging education and training opportunities for women in agriculture, with a specific emphasis on CSA techniques, is an effective approach for employing scientifically driven adaptation strategies and prioritizing climate. This was recommended as a measure to enhance the uptake of CSA practices in Africa [19]. It can be achieved through partnerships with agricultural universities, vocational training institutes, and extension services.

Training should cover topics such as sustainable farming practices, water conservation, agroforestry, soil management, and climate-resilient crop selection.

Research conducted by Tesfaye et al. [105] on "Gender empowerment and parity in East Africa: evidence from CSA in Ethiopia and Kenya" emphasized the importance of training for female farmers. The study highlighted education and training as a means of enhancing the bargaining power of women to improve their role in decision making. In Ghana, it was reported that CSA adoption was driven by the educational level of female farmers [48]. Since CSA serves the purpose of enhancing food security and promoting gender empowerment and equality, giving women access to education and training will be a good strategy for strengthening the capacity of African women in CSA. In this manner, the positive contribution of CSA will guide policy and decision makers to scale up these practices with a better-targeted approach that recognizes and adequately addresses the implementation of CSA practices in a manner where both men and women can share equal benefits [105].

In Zambia, women trained in aquaculture are using climate-resilient techniques to raise fish for home consumption and the market, allowing them to invest in their children's education and other domestic expenses. In Mali, women's associations were trained in a process for parboiling rice using a fuel-efficient and labor-reducing technology (GEM parboiler, AfricaRice, Abidjan, Côte d'Ivoire), which increased production and profits, improved the quality of the results, decreased wood fuel use, and reduced the time women spent boiling the rice [106]. Access to finance to support these productive activities can be explored in different formats, including Village Savings and Loan Associations (VSLAs), which increase access to finance as well as other resources [107,108], mobile money [109], and small-scale climate insurance [110].

Strengthening the technical capacity of women in CSA requires strategies that will ensure the supply of adequate information to aid them during decision making [111]. Across different gender groups, information creation and acquisition are key in decision making [92]. Currently, smallholder farmers in Sub-Saharan Africa have taken a step forward on this by relying on available knowledge sources that they trust in making climate decisions which help them adapt to climate impacts. These women primarily rely on the application of adaptation measures [111,112] and the use of indigenous knowledge and local knowledge for weather and climate forecasting to accomplish this [113,114].

Furthermore, education and training are critical for overcoming challenges in adopting climate-smart agriculture (CSA) technologies, as demonstrated by successful initiatives worldwide. For instance, Farmer Field Schools in Kenya, community-based training in India, revamped extension services in Uganda, and participatory methods in Vietnam have all significantly increased the adoption of CSA practices, leading to enhanced agricultural productivity and climate resilience [115–118]. Effective execution of these programs should incorporate gender-sensitive approaches, leverage local knowledge, utilize ICTs, provide continuous learning opportunities, and promote participatory and experiential learning to ensure broader and more sustainable impacts [30,119–121].

Few studies carried out in Africa have shown that technological interventions can be explored to enhance access to scientific climate information, which can encourage female farmers in CSA strategies. The studies strongly agree with regional analyses of how farmers and communities might adjust to the changing climate using indigenous knowledge and local knowledge [113,114,122]. This obviously shows the hunger of African women for climate information and technology. Women who are already less economically empowered than men are less likely to be able to afford costly new CSA technologies. Ultimately, rural women need appropriate CSA technologies that can transform their contexts and realities where necessary, helping them to become more resilient. Therefore, it is pertinent to strengthen the technical capacity of women by supporting their use of agricultural technology that is gender-responsive, such as drought-tolerant seeds, precision farming equipment, and renewable energy sources [123].

6. How to Improve Women' Adoption of CSA

Governments need to develop and implement policies that will promote equal access to resources, land rights, and decision-making opportunities for both men and women. This will strengthen women's participation in farmer organizations, cooperatives, and agricultural planning processes [78]. Khoza et al. [92] reported preexisting gender inequalities at the household level, which may be perpetuated by gender-blind CSA implementation. Consequently, improvement in CSA adoption by women farmers would require gender-sensitive policies to ensure that issues of gender inequality are addressed to achieve gender parity [97]. This requires a holistic assessment of CSA that will consider implementation strategies and resilience capital which is not just limited to the technological benefits of CSA.

Government administration has made steps to promote equal access to resources through policies, which are promising and must be followed through on the ground. Namely, the Kenyan Constitution of 2010 provides that women have equal rights to own property, outlaws gender discrimination for land and property, and grants everyone the right to inherit and access land [124]. Ghana's constitution also outlaws gender-based discrimination. In South Africa, women have the right to own land, either alone or with their spouses. This may be observed based on constitutions everywhere on the African continent, suggesting rules and rights for women in terms of ownership, violence, and discrimination. However, this is challenging, and practically, it has been observed that, in general, women are forbidden from inheriting and owning land. Ethiopia's Climate-Resilient Green Economy Strategy has successfully integrated CSA into national policies. These initiatives include providing financial incentives, enhancing extension services, and promoting sustainable land and water management practices, resulting in increased adoption of CSA practices and improved climate resilience [125].

It is essential to examine policies associated with CSA, both directly and indirectly, to understand their impacts on various genders. This examination should encompass a range of factors, including land tenure systems, laws related to marriage and property inheritance, technology development, and economic empowerment [75,97,126].

Financial support and inclusion are also other points that could facilitate CSA adoption. Giving opportunities to women which are equal to their male counterparts enhances CSA implementation [74]. In Nigeria, Oyawole et al. [75] reported that males receive significantly more support than female farmers. This disparity in support was reported in four out of the five domains of empowerment. The authors suggest that closing the gap between women and men would positively improve women's adoption of CSA by facilitating their access to credit and financing options, enabling them to make investments. This can be achieved through partnerships with microfinance institutions, initiatives tailored toward women, and innovative financing approaches such as impact investment. Alternatively, it can be achieved by providing resources like vehicles and information and communication technology equipment and increasing the recruitment of extension agents [92].

In the same way, financial inclusion can help women access agricultural inputs and, consequently, improve CSA practice implementation [74]. In Osun State (Nigeria), smallholder rice farmers reported that financing, access to off-farm income, access to cooperatives, and access to credit can decrease the gender gap and improve the adoption of CSA technologies [127].

7. NGO Activities and Gender Integration in CSA Adoption: AWARD Case

Alongside public technical institutions, the role of NGOs is also decisive, especially in the process of capacity building, training, and women's empowerment programs [128–130]. For example, it was reported in Malawi that CSA adoption and implementation using NGO trainers and farmer clubs can increase male and female farmers' knowledge. However, these gains were lower for female farmers [131]. More recently, African Women in Agricultural Research and Development (AWARD-NGO) developed an innovative strategy that targets several actors involved in the agri-food sector at the same time (smallholder farmers, scientists, research institutions, and agribusinesses) [132]. In this vein, the main aim was to build agriculture-driven prosperity for the African continent through the development of gender-responsive agricultural research and development in Africa and the capacity building of scientists, especially women. The built pool will be capable, confident, and able to interact with and influence policymakers [132].

In the literature, several studies were analyzed and criticized for the methodologies developed and employed by NGOs in empowerment programs. This is probably due to the cultural differences between the intervention facilitator (a Western-based NGO) and the rural community (southern nations, nationalities, and people's regions) [133], and to resolve this constraint, AWARD NGO programs are co-constructed between African and European partners. Moreover, because of the complementary relationship between men and women in societies, the role of women cannot be understood if the role of men is neglected [134]. AWARD considered that it is essential to include male scientists from both Africa and Europe in their program. Moreover, several studies have reported the primordial role of men in achieving both women's empowerment and gender equality [135–137]. Intergenerational mentoring cultures developed in AWARD programs could give scientists the skills to better understand existing intergenerational conflicts in the agriculture sector in Africa [138] (Figure 1).

Figure 1. AWARD strategy (from AWARD [132]).

8. Conclusions, Recommendations, and Future Trends

This review explored the remaining gender gaps existing in African agriculture and highlighted the benefits of the adoption of CSA strategies, which can ensure food security and promote agriculture sustainability. We also discussed the drivers and barriers that maintain gender gaps in CSA adoption in African countries and provided recommendations needed to scale up CSA adoption among women farmers (Figure 2).

It is important to point out that given their in-depth knowledge of natural resource management and coping strategies, women have been shown to be potent agents of change. Therefore, it is vital to boost their skills in order to advance CSA in Africa.

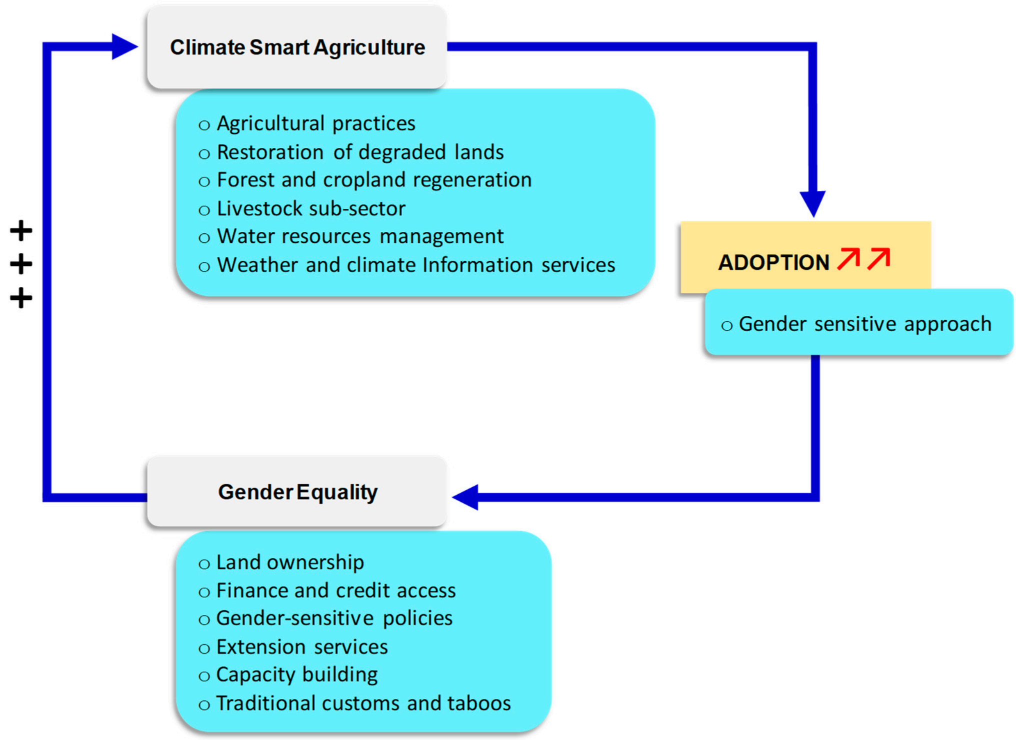

Figure 2. Impacts of gender equality on CSA practices using a gender-sensitive approach.

To promote gender equality and enhance the implementation of climate-smart agriculture (CSA) strategies in African countries, several recommendations are suggested. These include prioritizing research efforts that collect gender-disaggregated data and qualitative insights to understand the diverse needs and roles of women and men in agriculture, alongside fostering accessible training and capacity-building programs tailored toward gender-specific requirements. Furthermore, initiatives should focus on enhancing women's control and access to productive resources like land, credit, and equipment while dismantling legal and social barriers to resource ownership. Additionally, gender-sensitive social support schemes must be established to safeguard women during climate-related disasters, and extension services and climate information should be customized to address the distinct needs of both genders. Encouraging women's leadership and participation in agricultural decision making, fostering cooperation among various stakeholders, integrating gender concerns into CSA policies, and promoting awareness of the significance of gender mainstreaming in CSA among policymakers, extension agents, and communities are also emphasized to foster inclusive and effective CSA implementation.

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