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Gender Equality, Climate Action, and Technological Innovation for Sustainable Development in Africa

Ogechi Adeola · Olaniyi Evans
Innocent Ngare

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From Ogechi: *To my lovely goddaughter, Golibe Nnaji, whose love for sustainability is demonstrated through her beautiful prose and poetry. And to my beloved son, Tochi Adeola, whose passion for nature and dedication to creating a more sustainable world fills my heart with pride and joy.*

From Evans: *Dedicated to Ayomi Ini-K, Olami Oba-X, and Iremi Teni-D, whom I love to the moon and back.*

From Innocent: *To my wonderful parents, Nathan and Elizabeth, and my lovely family, Susan and Allen. Your support is indispensable.*

Foreword

I am pleased to offer my personal perspective on this pioneering book, which explores the crucial intersection of gender equality, climate action, and technological innovation for sustainable development in Africa.

Addressing climate change can only be successful with a holistic approach that includes the most vulnerable at heart. Women, who make up half the global population, are the most impacted by the adverse effects of climate change due to existing social inequalities.

Integrating gender equality across all levels, right from climate policy development to project implementation, is critical to ensuring effective, inclusive, and more sustainable climate action that takes into account the different ways in which climate change affects different groups and, in particular, the disproportionate burden on women.

Gender Equality, Climate Action, and Technological Innovation for Sustainable Development in Africa is a forward-thinking and challenging book that calls for policymakers and practitioners to tackle the climate crisis from a gender lens whilst utilising the benefits of technology. It focuses on the African region and the agriculture sector, which have been identified as one of the most vulnerable regions and sectors to climate change.

The book provides an in-depth understanding of the prevailing climate change issues in Africa, the gender gaps to be bridged in the region's agricultural sector, and African indigenous knowledge of climate action. It also puts forward a set of recommendations for the green reskilling of women, as well as climate-smart technologies for the empowerment of African women farmers.

In a unique way, the authors have shown a clear link and the benefits of women integration for climate action for achieving the United Nations Sustainable Development Goals (SDGs), particularly SDG13. Looking through the gender lens and within the African agricultural context, I want to call attention to two important aspects the book highlights: skills for a gender-just transition and collaboration between modern and indigenous technologies and practices.

I am delighted with this book which will serve as a useful reference tool for policymakers and practitioners. It provides relevant information for addressing climate change with the approach of ensuring the engagement of all, including women and young people, as positive agents of change and not only beneficiaries, with their inclusion in all aspects of climate action, from decision-making to implementation.

Adviser, Climate Change Uzoamaka U. Nwamarah
The Commonwealth Secretariat

Preface

Climate change has been responsible for disasters, destruction, and deaths across the globe. The United Nations' Sustainable Development Goals (SDGs) include SDG 13: Climate Action, which outlines specific measures that can be taken to mitigate and adapt to climate change issues with long-lasting effects on the earth's sustainability. The target achievement goal for these actions is set for 2030.

Africa's women and girls have been given insufficient attention in programmes aimed at addressing climate change issues that threaten the availability of food and clean water—necessities that are fundamental to their traditional roles as caregivers. To effectively tackle climate change, dialogues must include an analysis of gender-specific loss and damage, adaptation, mitigation, funding, and justice. Stakeholders must prioritise protecting this most vulnerable group by developing gender-inclusive policies and strategies.

This book chronicles the influence of Africa's women and girls, who are at the same time victims of climate change and protagonists of climate action towards sustainable development. Their perspective is shaping the continent's culture and politics when it is incorporated into climate debates, policy formulations and implementations, funding distributions, and mitigation through innovative approaches and adaptations. Authors document the inclusive policies that will protect women and girls from the harsh effects of climate change, the various roles they can play in promoting equitable and sustainable climate action, and ways both genders can collaborate at all policymaking levels to develop frameworks that can mitigate the consequences of environmental hazards.

In Africa and other parts of the world, women play a crucial role in any discussion about the future of the climate, the role of technology in facilitating climate action outcomes, fostering climate change resilience, enhancing the utilisation of renewable energy and resources, creating jobs, and improving health and well-being. This book advocates for women to have a representative voice in every climate change conversation. Gender equality in Africa will not accord less value to men's role, but complement it by providing the objectivity needed to build a collaborative effort to achieve the United Nations' SDG 13, mainstream gender priorities, implement action plans, and achieve effective and sustainable outcomes.

This book adopts an integrated approach to sustainable development, focusing on the interconnectedness of gender, climate action, and technological innovation within the context of the vulnerability of African women. Embedded in these topics is the need for infrastructural development and education to protect women and offer life-long learning and skill achievement opportunities. The enhanced Gender Action Plan (GAP) adopted in December 2019 at the 25th Conference of Parties of the United Nations Framework Convention on Climate Change (COP25) included a veritable framework of well-defined priorities to advance knowledge of gender-responsive climate actions. One of the recommendations of the book is the adoption and implementation of the GAP by identified stakeholders.

Robust frameworks that include gendered perspectives and technological innovation are needed to mitigate the effects of climate change disasters and pandemics: disease, displacement, inadequate food and clean water, impaired sources of livelihood, and infrastructural and environmental damage. This book contributes to the growing body of knowledge on the impact of climate change and technological innovation on women, and the need for response, protection, and recovery plans. Policymakers, activists, students, academics, gender specialists, and anyone interested in climate change, gender equality, and social justice can benefit from this resource.

Part A: Gender and Climate Change

Chapter 1: Introduction

This introductory chapter sets the tone for understanding why and how women in Africa are disproportionately affected by climate change events

that damage or destroy their environment. The chapter introduces the core discussions in the book, including climate change and relief actions, sustainable development, and the impact of climate disasters on women and girls. Evidence is presented to support the notion that women can play a significant role in mitigating climate disasters in Africa through climate adaptations.

The chapter provides a background of global climate actions aimed at advancing progressive strategies to combat Africa's climate change challenges, implement policy directions to protect women, and incorporate the priorities of the United Nations Framework Convention on Climate Change Gender Action Plan (GAP). The chapter also recommends innovative technology interventions as tools to promote women's social and economic roles in efforts to mitigate the hazards related to climate change.

Chapter 2: Gender and Climate Issues in Africa: Regional Insights, Challenges, and Recommendations

Africa has many volatile regions with varying unprecedented social and political conflicts compounded by climate change. Some regions suffer from food insecurity, especially in rural areas where women and girls engaged in agriculture lose their livelihoods to unstable climate conditions. In other regions, severe exponential cases of high temperatures cause drought and severe clean water shortages, which have a disproportionate effect on women responsible for the care and feeding of families. Climate-related disasters such as fires, flooding, and torrential rainfall have resulted in displacement, forcing women and children into internally displaced persons (IDP) camps, where they are at greater risk than men of assaults and forced marriages. Women, therefore, must be given an opportunity to influence actions on climate-related issues that affect their well-being. This chapter offers valuable insights into gender and climate issues specific to the four regions of Africa, as well as how women can be integrated into the core of decision-making processes.

Chapter 3: Explaining Gendered Vulnerability to Climate Change: The Contextual Conditions

Recent climatological events around the world, particularly in Africa, are clear evidence that climate change poses a severe threat to the human race. The dangers of global warming—a related primary concern—and cultural

issues affecting gender norms and the involvement of women in combating climate change are receiving global attention. This chapter discusses gender differences in a climate change context: How do women and men experience unique vulnerabilities to the effects of climate change?

Chapter 4: Climate Change and Gender Gaps in Africa's Agricultural Sector

In Africa's agricultural sector, gender gaps exist in the legal ownership of land and resources. The adaptive capacities of men and women differ due to inconsistent legal access to information, financial support, and control of resources. Additionally, cultural traditions that limit ownership rights exacerbate these gaps. The agricultural sector in Africa is highly vulnerable to climate change, with smallholder farmers, mostly women, being the most affected. This chapter explores the complementary phenomena of climate change and gender gaps in Africa's agricultural sector. It emphasises the importance of promoting equity between male and female farmers. Addressing gender gaps in access to resources and information can enhance women's adaptive capacities and build resilience to climate change impacts. By fostering gender equity, we can create a more inclusive and sustainable agricultural sector that benefits all farmers.

Part B: Technology and Climate Change

Chapter 5: Leveraging ICT for Climate Change Adaptation in Africa: A Focus on Women

Information and Communications Technology (ICT) is a vital tool for driving transformative reforms necessary for effective climate change mitigation in Africa. It is a crucial enabler of sustainable development, and emerging advanced technologies can help mitigate the impacts of climate change. This chapter contributes to the ongoing discourse on climate change and digitalisation in Africa, introducing the section on technological innovation and climate change. It discusses the potential of ICT-enabled energy transitions for climate change mitigation and provides recommendations on how Africa can leverage technology to mitigate the impact of climate change, particularly in the context of growth opportunities. In addition to climate change mitigation, adaptation is also a critical factor that must be considered when adopting ICT innovations. The

ability to adapt will help ensure the resilience of African nations in the face of climate change impacts.

Chapter 6: Climate-Smart Technologies for Empowerment of Women Farmers in Africa

Women are well represented in the agricultural sector in Africa, and they contribute immensely to all aspects of the sector's value chain. The sector is also one of the most vulnerable to climate change-related disasters, often displacing women economically and socially. This chapter examines the ways climate-smart technologies empower women farmers in Africa and elaborates on the crucial need for the adoption of these technologies to protect the food chain and livelihoods of stakeholders in Africa and within the world marketplace.

Chapter 7: Cleantech, Telehealth, and Other Emerging Technologies for Improving African Women's Adaptation to Climate Change

Despite the progress in recent decades regarding gender equality, specific issues remain unaddressed. One such issue is the lack of women's access to cleantech, telehealth, edtech, blockchain, and artificial intelligence. The benefits associated with these technologies are numerous and can improve the socioeconomic status of African women in diverse areas such as the financial markets, entrepreneurship, and the labour market. This chapter, therefore, explores the potential of these identified digital technologies for women's development in Africa.

Part C: The Way Forward

Chapter 8: African Indigenous Knowledge and Climate Change Mitigation: Towards an Afro-Sensed Perspective

Mitigating the harmful effects of climate change, along with the urgent need for the implementation of adaptation measures, has become an issue of global concern. Indigenous African knowledge embodies inherited wisdom, ideologies, attitudes, and practices that could be marshalled to become vital contributors to the mitigation and adaptation of climate

change in Africa. This chapter emphasises the need for an Afro-sensed perspective in mitigating climate change risks and adapting to its impacts.

Chapter 9: Green Reskilling of African Women for Climate Action

Transitioning to an inclusive green economy requires green competencies to ensure gender equality and empowerment for women and girls. Enhancing sustainable responses to climate challenges should reflect inclusive gender and resilient, eco-friendly approaches. This chapter identifies potential skill-acquisition opportunities that gender and green economy paradigms offer to counter proliferating climate change consequences in this era of climate change in Africa. It also positions women as agents of positive change for enhanced climate action.

Chapter 10: Gender Equality, Climate Action, and Technological Innovation for Sustainable Development in Africa: Conclusion and Recommendations

This chapter presents a cohesive argument for the purposeful consideration of gender equality, climate action, and technological innovation as building blocks for sustainable development in Africa. Previous chapters have introduced salient issues emerging in the four regions of Africa, highlighting crucial climate issues that particularly affect women and girls. This closing chapter focuses on how to address these issues (climate change, gender inequities, and technological innovations) to meet the humanitarian goals established by the United Nations and policymakers within Africa and other developing regions.

Recommendations include strategies for African countries to address the risks associated with climate change and implement effective response plans to protect vulnerable groups, including women and girls. Finally, the chapter provides salient recommendations for gender-inclusive climate change policies, gender integration in climate change planning, and technological innovations for climate change mitigation and adaptation in Africa that will lead to sustainable development.

Lagos, Nigeria — Ogechi Adeola
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Ogechi Adeola is a Professor of Marketing at Lagos Business School, Pan-Atlantic University, Nigeria, and a member of the Board of Directors at the University of Kigali, Rwanda. Her multi-dimensional research advances knowledge across the intersection of marketing, tourism, and gender. She is the editor of two books that advocate for gender equity: *Empowering African Women for Sustainable Development–Toward Achieving the United Nations' 2030 Goals* (2020) and *Gendered Perspectives on Covid-19 Recovery in Africa–Toward Sustainable Development* (2021), both published by Palgrave Macmillan. She is the founder of the Digital Business Tutelage for Women Empowerment in Africa Initiative, a platform designed to help young African women achieve personal and career success. Ogechi has been a guest speaker and key discussant at local and international conferences, including the 2019 World Bank-sponsored Freedom Forum on Women's Entrepreneurship in Tourism in Sierra Leone. She has served as a Gender Specialist Consultant on women empowerment for various organisations, including the International Labour Organization. She has also coached utility companies in Liberia and Ghana under the USAID Engendering Industries Workforce Accelerated Program, focusing on improving gender equality and increasing economic opportunities for women in male-dominated companies. In 2022, Ogechi received the Female Achievers' Recognition Award, co-sponsored by American Corner Ikeja, Lagos.

Olaniyi Evans is a Nigerian economist and university lecturer at Pan-Atlantic University, Lagos, Nigeria. He is a recipient of the 2009 University of Lagos Certificate of Excellence and the 2019 Emerald Literati Award for the Highly Commended Article. He holds degrees such as BSc first class, MSc distinctions, and PhD, all in economics, from the University of Lagos, Nigeria. An economist of the new Keynesian tradition, Evans is known in academia for his impactful and award-winning work on the digital economy (including ICT, cryptocurrency, digital finance, and fintech), climate change, financial inclusion, tourism, and economic models from the African economy perspective. As a keen educator, Evans is the inspired author of several best-selling textbooks (including *University Mathematics, Business Mathematics and Statistics*, and *The Firstclass You*). As an avid researcher, he is the prolific author of a substantial number of increasingly cited scholarly articles published in top-rated academic journals. He is also the managing editor of *BizEcons Quarterly*, an open-access peer-reviewed scholarly journal.

Innocent Ngare is an environmental scientist and a climate change specialist. He holds a PhD in Environmental Studies and Sustainable Urban Development and a master's in Climate Change and Sustainability from Kenyatta University, Kenya. His expertise spans climate solutions, urban studies, environmental security, and green studies. He is an accomplished researcher and scholar who has published extensively on the field of the environment and its related disciplines. He is a lecturer and a climate change specialist at Kenyatta University, Kenya. Innocent served as lead researcher for Kenyatta University's UNESCO-Chair Programme on Higher Education Development for a Green Economy (HEDGES) project, successfully guiding the technical research team to deliver a successful baseline survey, research publications, and co-fundraising. Prior to this, he worked as a senior lecturer at Amoud University, Somalia.

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PART I

Gender and Climate Change

Gender Equality, Climate Action, and Technological Innovation for Sustainable Development in Africa: A Background

1 Introduction

Women hold the key to climate's future.
– Wangari Maathai, environmental activist and winner of the 2004 Nobel Peace Prize

Across the globe, as climate change threatens lives and livelihoods, it continues to widen the gender-related poverty gap among nations that do not have the mechanisms needed to mitigate its deleterious outcomes. According to the State of the Climate in Africa 2019 report (WMO, 2020), increasing greenhouse gas emissions, rising temperatures and sea levels, changing precipitation patterns, and threatening weather conditions endanger human health and safety, food and water security, and socio-economic development in the continent (UNFCCC, 2020).

Unfortunately, climate change has yet to receive the necessary attention on the continent. As the climatic conditions become more susceptible to natural disasters, it is critical that Africa begin to put in place measures to control the continuous depletion of the ozone layer and protect the most vulnerable population (Ray, 2021). A United Nations Climate Change (2020) study found that change is more deleterious in countries that depend on natural resources for survival. They also have limited capacity

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to respond to natural disasters caused by climate change, the most notable in Africa being flooding due to heavy rainfalls, regional droughts, and rising sea levels.

Africa's women and girls form a large proportion of the poor and those most vulnerable to the effects of climate change. The adverse biophysical impacts of climate change, along with the loss of energy sources, disrupt the agriculture sector and access to food and clean water, perpetuating a ruinous effect on the ability to provide nutrition and healthcare, societal roles placed on women that are often not placed on men (Awiti, 2022; Reckien et al., 2017; WHO, 2014; World Bank, 2011). Empirical research shows that the workdays of women engaged in agriculture fall by 11% more than men's during periods of drought (Afridi et al., 2021). Physiologically, women are more susceptible to the adverse health effects of climate change (Sorensen et al., 2018). In addition, social disruption with loss of family and community has a disproportionate effect on women when climatic crises trigger a psychological effect that is often overlooked or played down (Moosa & Tuana, 2014).

Interestingly, women are both victims of climate change and potential architects of climate action, a dyadic lens that supports the study of climate effects in Africa (Osman-Elasha, n.d.). Natural disasters proliferate poverty, and women, who account for a larger number of the world's poor at any point in time, suffer as this gap widens (United Nations Climate Change, 2020). This disaster-led inequality is exacerbated by women's lack of participation in the climate change mitigation policy planning and implementation processes (UNFCCC, n.d.). Their gender-specific perspective enables women to influence climate change decisions and play active roles in adaptation, mitigation, and support of gender-responsive climate actions.

To mitigate the effect of climate change in Africa, women have been identified as integral actors as recipients and proponents of climate-oriented policies. In this chapter, we introduce the book's core focus—the collective influence of gender, climate action, and technological innovations on sustainable development. This chapter offers an in-depth discussion of the three phenomena that are the focus of this text: climate change and the United Nation's Sustainable Development Goals, the impact of climate change in Africa, and the social and geopolitical links between gender and climate change in Africa.

2 Climate Change and the UN Sustainable Development Goals (SDGs)

Two words—climate change—have become ubiquitous, permeating the media, politics and governments, and the scientific world. Tony Blair, a former Prime Minister of the United Kingdom, called climate change the "world's greatest environmental challenge" (Blair, 2006). The Intergovernmental Panel on Climate Change (IPCC), in their 2018 document, defined climate change as "a change in the state of the climate that can be identified … by changes in the mean and/or the variability of its properties and that persists for an extended period." Another definition points to a shift in climate patterns caused by greenhouse gas emissions that result from natural systems and human activities (Fawzy et al., 2020; Grossman, 2018). In simpler terms, climate change is a long-term change in the average weather, generally referred to as the climate, of a region (Santos & Bakhshoodeh, 2021).

Left unaddressed, climate change will impede the attainment of the UN's Sustainable Development Goals (SDGs) by 2030. The 17 SDGs adopted by the UN in 2015 are complex and include intricate links that assure that the attainment of one goal is inevitably connected to the attainment of another. However, the importance of Goal 13: Climate Action lies in its being the foundation of the sustainability of all other SDGs because of its spin-off effect on other goals. "The SDGs are designed to represent the full range of sustainability issues on a global scale" (Dannevig et al., 2022). The UN's 2030 agenda is, at its heart, a manifesto for sustainable development that will fail if steps are not taken to combat climate change.

Because the SDGs are interlinked, the achievement of one goal will improve the chances of achieving the others. For example, SDG 7: Affordable and Clean Energy calls for "affordable, reliable, sustainable and modern energy for all" by 2030. Currently, the most available source of energy for the world is fossil fuels. A transition to clean energy can be expected to meet the objectives of SDG 7 (Hernandez et al., 2020).

Access to food and clean water are currently at risk as a result of environmental damage (Ebi & Hess, 2020; Steffen et al., 2006). If climatic conditions continue to worsen, attainment of SDGs 1 (No Poverty), 2 (Zero Hunger), and 6 (Clean Water and Sanitation), indeed most of the SDGs, could be stalled. Therefore, the tradeoffs and synergies between SDG 13 and other SDGs need to be aligned, leveraged, and adapted holistically. Sustainable development and the attainment of the SDGs require

actions to counteract climate change locally, within countries and communities, and globally (Dannevig et al., 2022).

Women are most affected by climate change disruptions due to their active participation in the agricultural sector (ReliefWeb., n.d.). In Africa, about 62% of women are involved in agriculture (inclusive of all aspects of its value chain). Farm proceeds are threatened when climate disruption manifests through flooding, delayed rainfall, and other soil-mitigating conditions (Kamau-Rutenberg, 2018), including rising sea levels, increasing temperature, and extreme weather conditions.

3 Climate Issues in Africa

Africa is getting warmer. Increasing temperature levels related to climate change are the source of severe consequences to human health, water security, food, and the socio-economic development of the continent (WMO, 2022). Issues on climate change are gaining traction in Africa as the likely consequences of a climate disaster threaten this vulnerable continent (Adenle et al., 2017; African Development Bank Group, n.d.; Aryal & Marenya, 2021; Leal Filho et al., 2018; Leal Filho et al., 2019).

Climatic issues in Africa had attracted attention since the pre-industrial era (1850–1900) when Africa's climate warmed more than the global average (WMO, 2022). Warming in Africa has continued to increase since 1900 (WMO, 2022), further fuelling the narrative that Africa is at risk of climate disaster if no action is taken.

The rising sea level along coastlines exceeds the global mean, contributing to the severity of erosion, flooding, and freshwater salinity in low-lying cities (WMO, 2022). Melting ice will possibly trigger more flooding of low-lying regions in Africa, causing extreme water shortages for farms and clean drinking water. Inevitably, high cholera, schistosomiasis, malaria, typhoid, and hepatitis-A cases ravage the communities. Landslides are another by-product of flooding in Africa, rendering many displaced communities.

Climate change has hampered food security in Africa. Of the world's 36 countries dealing with food insecurity globally, 21 are in Africa, and about a third of Africa's populace is facing starvation (Tumushabe, 2018). Climbing food prices also contribute to food instability and malnutrition among the poor. Though highly constrained by their resources, a few African nations are making efforts to augment food supply; others have not yet succeeded in establishing food distribution systems.

The growth of cities has come with the high price of losing rainforests in most African countries. African nations rely on sourcing wood from forests, an unsustainable approach that stresses the climate, sparking tempests, fires, and floods (Tosam & Mbih, 2015). This, unfortunately, interferes with access to safe drinking water, food, health services, and business transactions. Environmental dynamism restricts or decimates entirely the availability of food, medicine, homes, and livelihoods, and prompts inadequate nourishment and avoidable illness, leading to more hospitalisations and fewer workers, all of which have financial implications for every economic sector.

Northern Cameroon experiences long spells of extreme heat during its dry season (November to February), which brings desertification and health complications in its wake. Since the 1970s, the region has been equally prone to flooding during the rainy seasons (Molua & Lambi, 2006). Cholera follows these floods at an alarming rate due to overflow of toilets and septic tanks, for example, the 1996/1997 cholera crisis in Babungo town, Northwest Cameroon, was triggered by contaminated water from sewage overflows (Kometa & Ebot, 2012). Regular floods and dry spells are hurting horticultural efforts in several African nations, including Cameroon, Chad, Nigeria, Kenya, Ethiopia, and Somalia (Rao et al., 2019). Lake Chad and Lake Fianga in the Sahara Desert significantly drained in December 1984 (Molua & Lambi, 2006), leaving border towns in Cameroon, Chad, Nigeria, and Niger Republic without irrigation or drinking water.

The WMO identified some notable problems resulting from climate change in African countries (Table 1).

The World Meteorological Organization reports that only 28 African countries provide basic-level climate services, and only 9 fully provide these services. Even more alarming, drought forecasting and warning signs are available in only four countries. This is concerning considering the climate crisis vulnerability that Africa is currently experiencing and could still experience without well-designed interventions, including the widespread introduction of extant technological tools capable of tracking climate change. Technological empowerment of women should be a major consideration.

It should be stressed that Africa contributes only 2% to 3% of the global greenhouse gas emissions yet suffers disproportionately due to the economic, social, and environmental factors (WMO, 2022) associated with low mitigative and adaptive climate change action plans. Lacking

Table 1 Climate change challenges and descriptions

Climate change challenge	*Description*
Food insecurity	• 34% decrease in agricultural production since 1961, surpassing all regions worldwide. • 9% reduction in the maize yield in West Africa and a 20–60% reduction in wheat yield in Southern and Northern Africa—projected impacts of global warming of 1.5C
Displacement	• About 14.1 million people in sub-Saharan Africa were internally displaced in 2021; 11.5 million due to conflict and 2.5 million as a result of disasters.
Water stress	• Africa has a high water consumption rate, increasing pressure on already scarce water resources. • Unavailability of water is projected to cause disruption and conflict among people living with severe economic challenges. • An estimated 418 million people in Africa do not have access to good drinking water; another 779 million do not have access to basic sanitation services.
Water management	• About 27 out of 51 countries surveyed in Africa do not have the capacity to adopt the integrative water management policy

Source: World Meteorological Organisation (2022)

mitigative and adaptive responses to climate change, deforestation, degradation, social and economic vulnerabilities, and biodiversity loss will endure in Africa.

Sy (2016) suggests that Africa's vulnerability to climate change, when compared with other continents, can be traced to a dependency on agriculture for food and employment, a sector most harshly affected by climate change. Additionally, about 30% to 40% of Africa's GDP comes from agriculture, with an 80% dependency on low-yielding and rain-fed harvests (Sy, 2016). Hence, any climate change that abates agricultural production has a multiplier effect on livelihoods and economic sectors across the continent.

4 Gender and Climate Change in Africa

The March 2019 landfall of Cyclone Idai in Mozambique, Malawi and Zimbabwe caused the deaths of hundreds of people (Africanews, 2019; OCHA, 2019); destroyed homes, schools, and healthcare facilities; ruined crops; interrupted potable water supply; heightened risk of water-borne

and other communicable diseases; and eliminated sources of livelihood. This disaster can potentially exacerbate gender-based violence and displacement risk (OCHA, 2019). Even climate change, it has become clear, is not immune from gender wars (New Scientist, 2007).

SDG 5: Gender Equality seeks to overcome the reality that in all spheres of life, women and girls are currently underrepresented, even in developed countries. Although the Gender Inequality Index (GII) shows a steady decline in most countries, gender inequality is still relatively high globally (UNDP, 2020). The gender-related effects of climate change have received little attention in the social sciences and humanities research, though in many societies, physiological, social, and cultural gender norms put constraints on the roles and rights of women and girls (Awiti, 2022; Huyer et al., 2021; Pearse, 2016; Sorensen et al., 2018). Research into the gender effects of climate change will contribute to SDG 5 policy considerations.

African countries are too often unprepared to shelter and care for their people during natural disasters. The immediate and long-term effects of climate disasters on women need to be documented with the aim of creating protections for this vulnerable population. Given their traditional care responsibilities in domestic functions, women are generally in the greatest need of assistance as they seek birthing shelters, childcare facilities, and help to care for elderly family members (Adeola, 2020). Premium frameworks for disaster management would mitigate the effects of displacement, illness and injury, loss of livelihood, and environmental and infrastructural damage in line with UN SDG 3: Good Health and Well-Being, SDG 6: Clean Water and Sanitation, SDG 11: Sustainable Cities and Communities, and SDG 13: Climate Action (Adeola, 2020). Any proposed policy should integrate gender considerations in national climate change planning, mitigation, and investment opportunities (Hall & Rojas, 2022).

The documented increase in natural disasters, such as floods, drought, and storms, has become a norm on the continent and is linked to changing climatic conditions. Most worrisome is the death toll and property loss, especially for women who, because of the inequities of property rights and social standing, become the most vulnerable victims (WHO, 2014). Especially hard hit are impoverished women who are most susceptible to malnutrition, malaria, displacement of homes and families, and death. Without meaningful action, billions of women in the coming decades will suffer the effects of climate change disasters (Costello et al., 2009; WHO, 2014).

Africa is already experiencing the horrors predicted by Costello et al. (2009), for example, severe famine anchored on drought spells has bedevilled women in sub-Saharan Africa (Tirado et al., 2015). Malnutrition and associated health-related complications were documented among South African women by Ansah et al. (2021), who found a direct correlation between extreme heat waves and specific health issues—particularly exhaustion, psychological stress, cardiovascular and respiratory issues, cancer, and kidney diseases. Heat waves are tough on women because, as the larger percentage of Africa's farmers and suppliers of 90% of the continent's food supply, they work outdoors when the sun is shining and lose their crops when it floods (Memunatu, 2017), for example, in 2017 floods in Sierra Leone destroyed farms and ruined several women-owned agricultural firms.

Rape remains a distressingly lingering crime in a number of African countries. The internally displaced persons (IDP) camps worsen the situation for African women. The UN reports of 2015 on the conditions in IDP camps in Malawi established multiple cases of sexual assault and rape within the campgrounds. A flood caused by climate change indirectly enabled these cases by forcing young African women in their prime out of their comfort zones into camps housing sexual predators. Displacement also raises the issue of female hygiene in the camps that lack essential sanitary kits, leaving women uncomfortable during their menstrual cycle and causing unhealthy habits that spiral into more health complications.

The IDP camps in Northern Nigeria recorded a high rate of child marriages between girls in the camps and men from neighbouring states, a problem blamed partly on the absence of government support and supervision. In some cases, young women turned to prostitution to survive in the camps (Egwu, 2018; Ewepu, 2022).

Documentation of such climate disasters will show that men also bear a burden of loss as they struggle to provide for their families, homes, and communities in the aftermath of a disaster. Nevertheless, a connection between climate change and its impact on women in Africa must be addressed in research and in humanitarian services. Globally, there is increasing acknowledgement of the importance of incorporating gender-sensitive approaches to combating climate change (World Bank, 2011) and growing cognisance of gendered responses through concerted and targeted climate actions.

5 Global Climate Actions

The realisation of the dangers of climate change has been gradual, with the world coming to terms with the dangers only as time went by and as more scientific evidence emerged along with the increased frequency of extreme weather events. Consequently, global actions to combat climate change and its dangerous impact have gradually risen in momentum over time. Today there is no debate among governments worldwide that the science of climate change is settled. Climate change activists such as NASA scientist James Hansen, former U.S. Vice President Al Gore, Sweden's Greta Thunberg, and other activists have helped to shed light on the realities of the dangers of climate change and spurred world agencies to take action (Butler, 2018).

Though many attempts have been made to combat the dangers of global climate change, none have been as urgent or decisive as the response of world leaders to the COVID-19 pandemic. The global response to the pandemic proved that governments could avert imminent danger even when scientific evidence is uncertain and inconclusive. However, hope for climate change remediation is not lost. Beginning with the Montreal Protocol, international climate accords have shown that decisive global actions can be taken on climate issues, and goals can be met when countries work together.

5.1 The 1987 Montreal Protocol

The Montreal Protocol of 1987, a global agreement signed in September 1987, was designed to protect the ozone layer by phasing out the production and consumption of ozone-depleting substances (ODS) (UNEP, 2022a). The Protocol was the first treaty to achieve international ratification; it has been ratified by all United Nations members. The 2016 amendment to the Protocol, the Kigali Amendment, also adopted by all members, added the production and consumption of widely used alternatives to ODS to the list of substances dangerous to the ozone (UNEP, 2022a). Scientists have hailed the Montreal Protocol as a remarkable success, given the manner in which it has successfully reduced ozone-depleting substances and contributed to the protection of the climate (Albrecht & Parker, 2019; Goyal et al., 2019; McKenzie et al., 2019; Newman, 2018; UNEP, 2022a; Velders et al., 2007).

5.2 The United Nations' Participation in Global Climate Change Actions

The earliest documented response to global climate change implications can be traced to 1972 when the United Nations Conference on the Environment identified air pollution as a major issue. Conference participants adopted a series of principles and resolutions for sound management of the environment, including the Stockholm Declaration and Action Plan for the Human Environment and the creation of the United Nations Environment Programme (UNEP) to coordinate responses to environmental issues within the United Nations system (UN Conference on the Human Environment, n.d.).

In 1979, the first international scientific conference on climate change was held in Geneva, Switzerland, when the World Meteorological Organization (WMO) gathered a group of scientists to discuss the then-emerging research and scientific evidence on climate change and the dangerous impact of the use of fossil fuels along with other human actions on the world's temperatures and climate (Fawzy et al., 2020; WMO, 1979). In 1988, in collaboration with the United Nations Environment Programme (UNEP), WMO established the Intergovernmental Panel on Climate Change (IPCC), which enlists leading scientists to assess rigorously conducted scientific research that contributes to the formulation of climate-related policies (Fawzy et al., 2020; IPCC, 2013).

The United Nations Framework Convention on Climate Change (UNFCCC) was established in 1992 but only came into force in March 1994. UNFCCC borrowed a leaf from the 1987 Montreal Protocol by binding members to act in the interest of global safety even though the scientific evidence of the hazards of climate change was then uncertain. The ultimate objective of the Convention was to stabilise and eventually reduce greenhouse gas emissions below dangerous levels. The Convention pressured developed countries to lead the way in this effort because they bore the greatest responsibility for the emission of greenhouse gases. UNFCCC is a member of the UN's "Trio-Rio," which includes the Convention on Biological Biodiversity and the UN Convention to Combat Desertification, both of which embrace the study of the adverse effects of climate change (UN, 2022). To date, 198 countries have ratified the UNFCC Convention (UN, 2022).

The principal decision-making body of UNFCCC, the Conference of the Parties (COP), comprises all national parties to the Convention. COP members meet annually. Two notable agreements have emerged from their annual meetings: The Kyoto Protocol in 1997 and the Paris Agreement in 2015.

5.3 The 1997 Kyoto Protocol

The third annual meeting of the Conference of the Parties (COP3) was held in Kyoto, Japan, December 1–11, 1997. The Kyoto Protocol was amended by the UNFCCC in 1997 but only came into force in 2005 (UN, 2022; Fawzy et al., 2020; Kim et al., 2020). The Protocol called on developed countries to commit to emission reductions to 5.2% below 1990 levels between 2008 and 2012 (Fawzy et al., 2020; Rosen, 2015; UN, 2022). This was in accordance with UNFCCC's principle of "common but differentiated responsibilities and respective capabilities" (Kim et al., 2020; UN, 2022). Developed countries were to invest in emission reduction projects in developing countries as a means of driving sustainable development in the host countries as well as offsetting their own emission levels (Fawzy et al., 2020; Kim et al., 2020). The Protocol's policies and monitoring and reporting systems ensured the commitments were met.

Three market-based mechanisms—International Emissions Trading, the Clean Development Mechanism, and the Joint Implementation Mechanism—encouraged developed countries to cut emissions in a cost-effective manner (Fawzy et al., 2020). The Protocol provisions were designed to help the developing countries (listed in Annex 1 of the Protocol) to meet their greenhouse gas reduction commitments as they were the only ones specifically bonded to the Protocol but recognised the need for developing countries to continue to grow. According to the Kyoto Protocol, greenhouse gases to be limited included "carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases such as hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6)" (Fawzy et al., 2020, p. 4).

At the 2012 Qatar meeting, COP18 amended the Kyoto Protocol to include Doha Amendment, which adjusted the commitment period to 2013–2020 (UNFCCC, 2012). The Doha Amendment set a more ambiguous target, aiming to reduce greenhouse gas emissions by at least

18% below 1990 levels (Fawzy et al., 2020). However, the Doha Amendment only came into force in December 2020, the end of the proposed commitment, when the required minimum of 144 countries reached an agreement. Clearly, the Kyoto Protocol, by its Doha Amendment, was an indication of developing countries' failure to meet the initial deadline.

Unlike the Montreal Protocol, research into the success of the Kyoto Protocol, and by extension, the Doha Amendment, has been mixed. Some studies (e.g., Aichele & Felbermayr, 2012, 2013; Almer & Winkler, 2017; Grunewald & Martinez-Zarzoso, 2016; Kumazawa & Callaghan, 2012; Kim et al., 2020) reported that the Protocol has been somewhat successful. However, most studies have been sceptical, citing the challenges inherent in the design of the Protocol itself, the actions of some parties following the issuance of the Protocol, and most importantly, the substantial evidence of an overall increase in greenhouse gas emissions (Almer & Winkler, 2017; Eckersley, 2007; Grubb, 2016; Rosen, 2015). Challenges to the Kyoto Protocol emerged right from the beginning. The United States refused to ratify the Protocol, Australia vacillated during the process, and Canada backed out of the agreement (Eckersley, 2007; Grubb, 2016; Rosen, 2015). However, failure to meet the emission reduction targets may not mean that the Protocol has been unsuccessful. At the very least, the Protocol was a definite step towards combating climate change by setting emission reduction targets. Though reduction targets were not met, the carbon dioxide levels of the binding countries could have been much higher but for the Protocol (Aichele & Felbermayr, 2012, 2013; Almer & Winkler, 2017; Grunewald & Martinez-Zarzoso, 2016).

5.4 The 2015 Paris Accord

The Paris Accord (sometimes referred to as the Paris Climate Agreement or Paris Climate Accord), enforced in 2016, added more objectives, commitments, and enhancements to existing monitoring and reporting frameworks. The Paris Accord is seen by many as a climate change landmark because it is more flexible, and unlike the top-down approach of the Kyoto Protocol that handed down commitments to countries, the Accord calls for a bottom-up approach (Grubb, 2016; Thakur, 2021). Unlike the Kyoto Protocol, the Paris Accord encourages parties to take adaptation

actions that are country driven and gender responsive, and that take vulnerable groups, communities, and ecosystems into consideration.

Paris Accord member countries agreed to work towards limiting global average temperature to 2° centigrade above pre-industrial levels by the year 2100 and to continue to work towards limiting the increase to 1.5° centigrade (Fawzy et al., 2020; UN, 2015; NRDC, 2021). Countries are required to communicate and maintain Nationally Determined Contributions (NDCs) and self-determined successive targets (UN, 2022). NDCs are climate action plans geared towards reducing greenhouse emissions and adapting to climate impacts (United Nations Climate Action, n.d.). Each member nation that signed on to the Paris Agreement is required to establish an NDC and update it every five years (United Nations Climate Action, n.d.). NDCs are at the heart of the agreement and were constituted to be submitted by all parties by 2020 and every five years thereafter (UN, 2015). Each country's successive NDC report is expected to show progress, reflecting significant efforts in mitigation, adaptation, financial assistance, innovative technology adoption, capacity building, and transparency (Raiser et al., 2020; UN, 2015). Essentially, the NDCs serve as a country's national climate action plan (Pauw et al., 2019; Roelfsema et al., 2020).

The Paris Accord can be seen as purely voluntary as individual countries make and periodically renew their pledges (Clémençon, 2016). Also, unlike the Kyoto Protocol, which required only selected countries to commit to reducing greenhouse gas emission levels, the Paris Accord calls on all parties to work towards reducing dangerous emissions. Consequently, the Accord recognises the need for countries to individually and collectively adapt to climate change and combat its dangers.

The Paris Accord obligates developed countries to provide financial and technological support as well as capacity building to developing countries (Fawzy et al., 2020; UN, 2015). The fundamental goal of the agreement is to promote sustainable development through mitigation and adaptation strategies, mainly through the use of alternative and sustainable sources of energy, and cooperative support through financial and technology transfer to developing and least developed countries. Despite the developed countries' obligations, some see the Paris Accord as sidelining equity and environmental injustice as it puts pressure on the poorest and most vulnerable countries to control their future emission levels, leaving the developed countries that have contributed the most to climate change conditions off

the hook (Clémençon, 2016). Consequently, the Accord's commitment to "reflect equity and the principle of common but differentiated responsibilities and respective capabilities, in the light of different national circumstances" (UN, 2015: article 2), some analysts perceived that a fundamental principle of the UNFCCC has been broken. The agreement, though, recognises that developing countries will take longer to reach their peak emission levels and consequently longer to contribute to excessive greenhouse gas emissions.

5.5 Climate Finance

UNFCCC, through its various conventions, notably the Kyoto Protocol and the Paris Accord, calls on developed countries to assist developing countries with funding and transfer of green technologies. This aligns with its basic principle of common but differentiated responsibilities and respective capabilities, recognition that not all countries have contributed equally to causes of climate change, and the least contributors to dangerous greenhouse emissions bear the brunt of the adverse effects of dangerous climate events. The convention's insistence on developed countries providing funding for climate change mitigation and adaptation is a subtle but unmistakable reminder that "the polluter pays" (Mahat et al., 2019).

The UNFCCC describes climate finance as local, national, and transnational financing drawn from public, private, and alternative sources that seek to support the mitigation and adaptation actions to address climate change (Chowdhury & Jomo, 2022; Hong et al., 2020). A body of knowledge is now dedicated to the study of climate finance, such as the costs of carbon and emissions and the hedging of climate risks (Hong et al., 2020). Although climate finance is closely related to green finance, sustainable finance, low-carbon finance, and climate-related development finance (GRI, 2018; Mahat et al., 2019), it is much more encompassing than these narrowly defined concepts. Climate finance encompasses all finance issues relating to climate change and the study of such issues, or as aptly put by Mahat et al. (2019), "finance for climate change-related activities".

In 2009 at COP15, held in Copenhagen, Denmark, developed countries pledged to collectively mobilise $100b annually towards climate finance by 2020 (Chowdhury & Jomo, 2022; GRI, 2018). However, that pledge was not met, and the timeline was shifted from 2020 to 2025 (Chowdhury & Jomo, 2022). Specific funds set up by the UNFCCC as

part of the climate finance drive include the Green Climate Fund (GCF), the Adaptation Fund (AF), the Least Developed Countries Fund (LDCF), and the Special Climate Change Fund (SCCF) (Garschagen & Doshi, 2022; Omukuti et al., 2022).

The GCF is the UNFCCC's biggest climate finance fund (Garschagen & Doshi, 2022; Omukuti et al., 2022). It is a critical part of the historic Paris Agreement with a mandate "to support developing countries raise and realise their Nationally Determined Contributions (NDC) ambitions towards low-emissions, climate-resilient pathways" (GCF, n.d.). This multilateral climate finance fund was established in 2010 by UNFCCC to help the most vulnerable countries limit or reduce their greenhouse gas emissions. GCF invests in eight spheres to mitigate or adapt to climate change. Areas where actions are required for mitigation and adaptation are identified in Table 2:

Climate finance funds outside of the governance of the UNFCCC include the Climate Investment Funds (CIF), The Clean Technology Fund (CTF), and the Strategic Climate Fund (SCF) (Amerasinghe et al., 2017; Garschagen & Doshi, 2022). The UNFCCC climate funds give priority to least developed countries, small island developing countries, and African countries (Garschagen & Doshi, 2022; UNEP, 2022b). These countries can access funds as loans or grants after a project development, review, and approval process (Chowdhury & Jomo, 2022; Omukuti et al., 2022).

The current burden of providing climate finance lies heavily on the shoulders of developed countries. This is increasingly being seen as a form of climate justice, the concept of ensuring fair treatment and freedom from all forms of discrimination against the adverse impacts of climate change (Porter et al., 2020; Saraswat & Kumar, 2016). Although the provision of most of the climate finance by developed countries will not

Table 2 Mitigation and adaptation areas of GCF action in Africa

Mitigation	*Adaptation*
• Energy generation and access • Transport • Forests and land use • Buildings, cities, industries, and appliances	• Health, food, and water security • Livelihoods of people and communities • Infrastructure and built environment • Ecosystems and ecosystem service

(AfDB, n.d.-a)

entirely quell the cries for climate justice, it is seen as a step in the right direction.

As mentioned earlier, women in Africa, in particular, are disproportionately affected by climate change due to pre-existing gender inequalities that limit their access to resources, education, and economic opportunities. To address this issue, climate finance initiatives have been put in place to support African women in adapting to and mitigating the effects of climate change. One of the main forms of climate finance for African women is through the Green Climate Fund (GCF), which was established in 2010 under the United Nations Framework Convention on Climate Change (UNFCCC). The GCF aims to provide financial resources to developing countries to support their efforts to mitigate and adapt to climate change. In 2020, the GCF approved a grant of $10 million to support climate-resilient livelihoods for women in sub-Saharan Africa. The project, which is implemented by the United Nations Development Programme (UNDP), aims to provide women with the skills and resources to adapt to the impacts of climate change, such as droughts and floods, and to diversify their income sources through sustainable agriculture practices (Green Climate Fund, n.d.).

Another example of climate finance for African women is the African Women's Climate Finance Fellowship, a programme that seeks to empower African women to become leaders in climate finance. The fellowship is funded by the African Development Bank and other partners, and provides training and mentorship to African women to develop their skills and knowledge in climate finance. The goal is to increase their participation in decision-making processes related to climate finance (African Development Bank, n.d.).

Recently, at COP27, the US Agency for International Development (USAID) announced programmes to advance gender-responsive climate action. For example, the Gender Equity and Equality Action (GEEA) Fund, which is worth about $21.8 million, is committed to gender-responsive climate action (USAID, 2022). Also, as relates to Africa, an inaugural amount of $23 million has been invested by the US Agency for International Development (USAID) in a new project named "Egyptian Pioneers," which aims to foster a more proficient and comprehensive Egyptian labour force, with an additional objective of promoting climate goals. The project will provide over 500 Egyptian women with scholarships for undergraduate and postgraduate studies, along with offering leadership and professional training and study abroad opportunities in the United States. The project is expected to span nine years (USAID, 2022).

Despite these initiatives, access to climate finance for African women remains a challenge, as they continue to face barriers such as limited access to financial institutions, inadequate legal frameworks, and insufficient representation in decision-making processes. Therefore, it is crucial for governments, international organisations, and the private sector to continue to support and prioritise climate finance initiatives for African women, in order to promote gender equality and sustainable development in the face of climate change.

5.6 Current State of Climate Change

Despite global climate actions, annual estimates of greenhouse gas emissions continue to rise. Between 1990 and 2019, greenhouse gas emissions increased by 67% (Crippa et al., 2020). Although a recent report shows a 5.1% decrease between 2019 and 2020 (Olivier et al., 2021), the reduction was due to the COVID-19 pandemic, additional evidence that human activities and industrialisation account for the rise in emissions. Early investigation of the effects of the Paris Accord through in-depth analysis of the NDCs and INDCs (intended NDCs) (ABD, 2015) of several countries (e.g., Nieto et al., 2018; Roelfsema et al., 2020) shows only minimal success. The world still has a long way to go to limit the long-term global temperature rise target of 1.5° centigrade, given the current implementation of countries' NDCs.

The effects of the Kyoto Protocol and the Paris Accord may be significant in the sense that climate change is seen as urgent and important enough to cause countries to want to halt greenhouse gas emissions. Through its various climate finance initiatives, such as the GCF, costs of investments in the mitigation and adaptation to climate change are being financed. However, given the state of global temperatures, more still needs to be done, and done soon. African countries, in particular, need a sharper focus, given the effect of climate change on the continent. Africa must rise to the challenge.

5.7 Africa's Climate Change Actions

Africa's Climate Change Actions

Although the African continent has the lowest levels of greenhouse emissions and has contributed the least to global warming, it is the most vulnerable to the hazards and risks of climate change (AfDB, n.d.-b). It has

been projected that by the twenty-second century, the average temperature on the continent is bound to be warmer than the average global temperature (Ofori et al., 2021). The World Bank estimates that a 3° centigrade temperature level increase could mean catastrophic disruption to food security in Africa (Kray et al., 2022). Africa stands exposed to continuous collateral damage from increased global temperatures into the next century if appropriate climate actions are not taken. So far, major actions against climate change by African countries have been in response to those taken at the global level. At the national level, the major thrust of climate change actions in African countries has been through their NDCs. These NDCs outline the climate actions that each country plans to take in order to reduce greenhouse gas emissions and adapt to the impacts of climate change. Here are some examples of NDCs in Africa:

- Morocco's NDC sets a target of reducing greenhouse gas emissions by 42% below business-as-usual levels by 2030. The country plans to achieve this through a range of measures, including increasing the share of renewable energy in the electricity mix, promoting energy efficiency, and reducing emissions from the transport sector (NDC Partnership, 2021).
- Kenya's NDC aims to reduce greenhouse gas emissions by 30% below business-as-usual levels by 2030. The country plans to achieve this through a variety of measures, including expanding renewable energy generation, promoting energy efficiency, and increasing forest cover (UNFCCC, 2020).
- South Africa's NDC sets a target of reducing greenhouse gas emissions by 28% below business-as-usual levels by 2025 and by 42% by 2030. The country plans to achieve this through a combination of measures, including expanding the use of renewable energy, improving energy efficiency, and reducing emissions from the transport and waste sectors (South African Government, 2021).
- Nigeria's NDC aims to reduce greenhouse gas emissions by 20% below business-as-usual levels by 2030 and by 45% with international support. The country plans to achieve this through a range of measures, including promoting renewable energy, increasing energy efficiency, and reducing emissions from the oil and gas sector (UNFCCC, 2020).

In addition to NDCs, many African countries are also involved in regional and international initiatives to address climate change. For example, the

African Union has adopted a number of climate-related policies and initiatives, including the African Renewable Energy Initiative and the African Adaptation Initiative. Many African countries are also members of the United Nations Climate Change Conference (COP), which is the main forum for international climate negotiations. There has also been assistance from global agencies. UNEP, for example, offers support to African countries to implement their NDCs (UN, 2022). African countries must begin to take more deliberate and specific climate actions. At the recent COP27, African countries demonstrated their commitment to taking action towards climate change across various areas (Africa NDC Hub, 2022). Furthermore, 37 African countries have pledged to reduce greenhouse gas emissions by improving energy efficiency, reducing emissions from transportation and waste, and transforming industries (Africa NDC Hub, 2022)

Gender, Climate Action, and the Role of Technological Innovation in Africa

> Inclusivity is not a tick-box exercise. It's about how we internalise and mainstream women in decision-making at all levels. Uplifting women is not about putting men down, but how we all work together. *Mandy Rambharos, 'Presidential Climate Commission, South Africa'?*

Women are natural leaders in resource management, sustainable household practices, and community involvement, all of which have yielded greater responsiveness to citizens' needs and sustainable peace when applied to politics (United Nations Climate Change, 2020). Women's inclusion in climate change matters at the leadership level improves outcomes on climate-initiated projects and policies. When women are involved in meaningful participation in issues or climate change projects, more impactful outcomes are achieved.

Responsive measures are needed by and for women in the fight against threatening climate change. For example, in drought conditions in northeastern Nigeria, women displaced from their homes were targeted by the Boko Haram terrorists; in Malawi, over 1.5 million girls are at risk of becoming child brides, and many others have been forced into marriage due to economic losses related to climate change (Sirleaf, 2020). This vulnerability of women and girls to child marriage, sexual violence, human trafficking, and domestic violence has increased, and women are in a better position to plan against the reoccurrence of such realities. Women need to be part of the process of mitigating the gender-specific outcomes of

climate change while also preventing the occurrence of natural disasters informed by climate change. Advancing the gender equality narrative towards women's empowerment for the mitigation and response to climate change is invaluable at both grassroots and national levels, a topic that has been neglected for far too long.

It must be reiterated that the role of women in combatting climate change disasters is not only as victims but also as leaders. It was no surprise that the 2022 United Nations Conference on Climate Action adopted the theme Gender and Climate Change (Agenda 14) and emphasised the need for gender-responsive climate action that acknowledges the vulnerability of women and the girl child, how they can be protected, and how they can contribute to strategies to combat climate change (United Nations Climate Change, COP27, 2022).

The trend of natural disasters as a result of climate change has revealed the limited action channelled towards environmental sustainability globally and in Africa, especially as it pertains to women, especially those who are poor and earn their living off the land (United Nations Woman Watch, 2009). The United Nations Woman Watch (2009) identified four building blocks upon which women can stand to fight this climate war: mitigation, adaptation, technology transfer, and financing:

Mitigation focuses on how women can contribute to reducing unsustainable practices that increase carbon emissions.
Adaptation is a type of resilience needed to reduce vulnerabilities associated with climate disasters.
Technology focuses on innovative resources that can predict threatening climatic conditions and alert the public and appropriate protection services.
Financing generates funds to pursue the ultimate goal of climate sustainability through research and innovation aimed at reducing greenhouse gas emissions and stabilising greenhouse gas concentration.

Some greenhouse gas emissions can be brought under control not only by replacing fossil fuels with renewable sources but by halting deforestation. Women in Africa reduce carbon emissions by engaging in sustainable domestic practices and farming practices that limit vulnerabilities associated with climate change. Women play a role in establishing sustainable climate-friendly practices when they are part of the decision-making process of funding projects and identifying appropriate areas for investment that will further promote the protection of people and property.

Technology can aid in the reduction of carbon emissions at home, on the farm, and in hospitality businesses—areas where women are fully represented. However, it will require the inclusion of women in the formation of access policies, practices, and training required to reach women in rural areas. Emerging technologies identified elsewhere in this book include integrated soil management practices, biotechnology, renewable energy, plant breeding, and synthetic biology. Renewable energy resources for climate change mitigation and energy sustainability must be encouraged.

Also, climate-smart technologies for empowering women farmers in Africa should be prioritised to promote user-friendly tools that are effective and affordable. Climate-smart agricultural practices can be adopted by women in African countries to address the problems of land degradation and desertification, and these could be extended to food security, the enhancement of timber production, and lowering the vulnerability of crops and livestock to climate change. Digital technologies are becoming nearly ubiquitous as societies around the world are significantly dependent on them. A chapter of the book examines the potential that cleantech, telehealth, edtech, blockchain, and artificial intelligence have for women's development in Africa.

To curb climate change effect and adopt technological innovation, women must contribute their expertise and guidance in the development process to incorporate women-friendly technological tools. Additionally, training and empowerment programmes that women will need to fully have the capacity to adopt these practices would be identified and implemented.

The authors of this book call for the inclusion of women at the core of climate action remediation in Africa. Innovative technologies and progressive policies are key, but women and girls must be a central theme, particularly in green innovations.

6 Towards Implementing Gender-Responsive Action Plans: Policy Directions to Achieve Protection of Women in Africa

> Climate change affects women and men differently … because of the different roles they play in society and their different access to resources. *Vanessa Moungar, Director, Gender, Women and Civil Society, African Development Bank*

Because climate change affects women and men differently, decision-makers should not craft policies that are gender-neutral. Climate change

action plans should be utilised to identify gender-specific opportunities and relief strategies. In December 2014, the Conference of the Parties (COP) at the 20th Session (COP20) held in Lima, Peru, established the Lima Work Programme on Gender (LWPG) and created the Gender Action Plan (GAP) to advance gender balance and integrate gender consideration into climate change discussions (UNFCCC, n.d.).

In December 2019, COP25 parties agreed on an enhanced GAP focusing on five priority areas to "advance knowledge and understanding of gender-responsive climate action and its coherent mainstreaming in the implementation of the UNFCCC and the work of Parties, the secretariat, United Nations entities and all stakeholders at all levels, as well as women's full, equal and meaningful participation in the UNFCCC process" (UNFCCC, n.d.).

These five priorities include:

Priority Area A: Capacity building, knowledge management, and communication
Priority Area B: Gender balance, participation, and women's leadership
Priority Area C: Coherence
Priority Area D: Gender-responsive implementation and means of implementation
Priority Area E: Monitoring and reporting

The enhanced GAP's five priorities include objectives, 20 activities, 35 outputs, and a scheduled review of implementation in 2022. Figure 1 provides a diagrammatic representation of the priority areas.

Priority A: Capacity-building, knowledge management, and communication focus on strategies that will equip women to contribute to mitigating climate change through their individual practices and actions. Africa's largely women-managed domestic activities were reported to contribute about 40% of the continent's CO_2 emissions (African Development Bank, n.d.). With adequate training and orientation on sustainable practices, these adequately monitored domestic activities could prove to support sustainability and positively drive the continent's climate action.

Priority B: Gender balance, participation, and women's leadership suggest that women should occupy leadership roles and participate in the policy formulation process in a way that promotes the policies' effectiveness.

Priority C: Coherence seeks to synergise and strengthen numerous gender-centred programmes and policies that focus on women and climate actions to create a consistent and meaningful direction for gender and climate action.

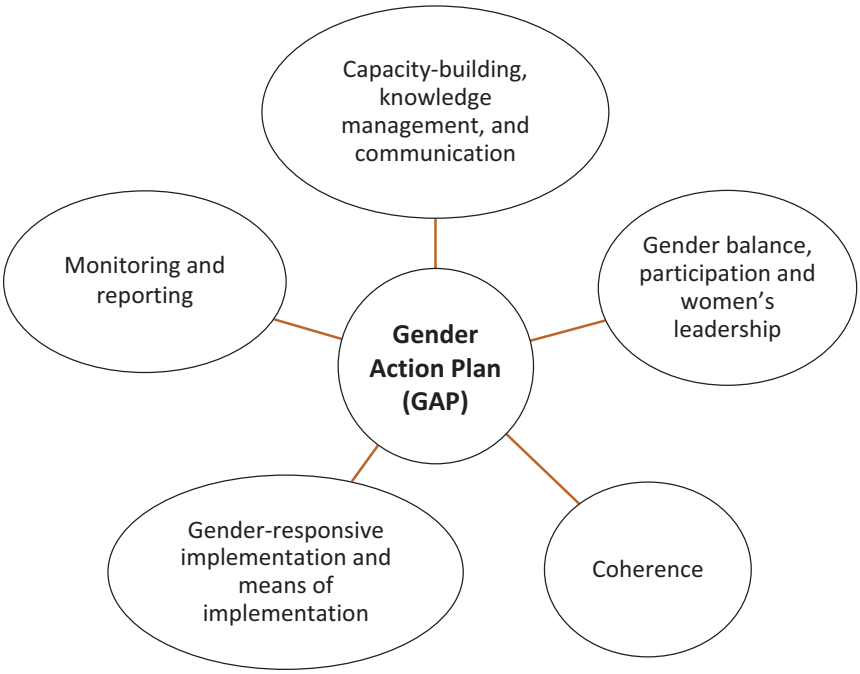

Fig. 1 Enhanced gender action plan. *Source: Adapted from UNFCCC,* n.d.

Priority D: Gender-responsive implementation and means of implementation affirms that gender and climate plans must move from gender awareness to gender responsive. The focus must be on responding to the identified issues, not merely creating awareness of the issues.

Priority E: Monitoring and reporting note the importance of feedback on the plans that have been implemented to integrate women. Feedback would be shared amongst members to ensure improvement and better performance.

Overall, the enhanced GAP framework provides guidance for policy development and implementation at both the micro- and macro-level analyses of gender and climate action. According to Hall and Rojas (2022), countries are increasingly utilising climate change GAPs to identify gender-specific climate action plans and determine priority sectors through a participatory multi-stakeholder approach and putting in place a blueprint for action. African nations need to prioritise GAP too.

7 Conclusion

Gender and climate action have become a topical issue due to the imperative to integrate women into the creation of strategic plans and policies geared towards curbing climate disasters. Africa is one of the most vulnerable continents to escalating climate change issues, and it is more urgent now than ever that stakeholders across the continent respond accordingly.

First, a thorough review of existing policies will reveal opportunities for gender-specific climate actions and blueprints that can put Africa in a position to tackle climate change. To be meaningful, policies must advocate for strategies that address the effects of climate change on the economic, social, and cultural realities of women in Africa.

Second, African nations' leadership can design adaptive interventions acceptable to both women and men by conducting gender analyses to discover family and community vulnerabilities, identify regional climate-related hazards, and create risk-reduction initiatives, particularly for women in rural areas.

Third, African nations must leverage the GAP framework to develop an inclusive climate action plan that will be impactful, efficient, and effective within varying geological and socio-economic regions.

Fourth, technological innovations must be introduced to capture climate change risks, suggest mitigations and adaptative opportunities, and protect sustainable energy resources.

Finally, whether local or national, climate adaptation decision-making groups must unfailingly incorporate women to ensure diverse and informed representation. Failure to do so will result in policies and practices that will put all Africans, women and children foremost, at risk of loss of lives and livelihoods.

When women are empowered to have a voice in discussions to ensure a sustainable, climate-resilient, and climate-smart future, the African continent will flourish.

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Gender and Climate Issues in Africa

Regional Insights, Challenges, and Recommendations

1 Introduction

Gender issues encompass a wide range of cultural expectations, social learning, and themes that pertain to access to resources, shared responsibilities, and inclusiveness in policy formulation (Bouchama et al., 2018). In Africa, women often face unequal opportunities and disadvantages compared to men, particularly in access to basic services and gender gaps in the labour market (Musavengane & Leonard, 2019; Georgalakis, 2020). The intersection of gender equality, women's empowerment, and environmental sustainability is well established, but climate change can further exacerbate existing gender inequalities as women are particularly vulnerable to its impacts (Lau et al., 2021).

Women possess unique knowledge and skills that can enhance the efficacy and durability of efforts to tackle climate change. Advances in gender equality and social inclusion can support efforts to address climate change if policies that take into account differences in gender vulnerability and the distinct roles of women are implemented (Ergas et al., 2021). It is essential that, as the world shifts towards a new climate regime, governments recognise the relationship between gender and climate change and include women in policymaking.

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African nations face several challenges in addressing the gender dimensions of climate change (Satterthwaite et al., 2020), including a lack of national competence on gender and climate change and its implications for sustainable development (Rieckmann, 2018). Recent studies reveal the gendered nature of climate change vulnerabilities and their social implications (Rao et al., 2019). In semi-arid regions of Africa, varying climatic, political, and socio-economic conditions exist. Continuous exposure to severe weather events has impacts on agricultural production, ecological services, and social relations, due to diverse terrain, biodiversity, and fluctuations in precipitation and micro-climatic conditions.

By 2050, the global temperature is projected to increase by a range of 0.5°C to 3.5°C due to climate change, with increased weather unpredictability and reduced rainfall in some regions (Allen et al., 2018). Climate resilience and adaptation are being threatened by the unpredictability of weather, particularly changes in rainfall patterns. African communities, already grappling with poverty and relying heavily on environmental livelihoods such as agriculture, are expected to experience the impacts of climate change more severely than wealthier populations (Ngare et al., 2022). African countries, as a result, are considered hot zones for climate change. According to Georgalakis (2020), women are more vulnerable to the adverse effects of climate change than men, particularly impoverished women farmers who rely heavily on rain-fed agriculture (Eastin, 2018; Cianconi et al., 2020). Women bear a disproportionate share of the negative effects of climate change, further amplifying the existing gender gap.

Both men and women are negatively impacted by climate change; however, the impacts are experienced differently by each gender (Rao et al., 2019). Bouchama et al. (2018) suggest that this disparity arises from differences in resource access and gender roles. Women are particularly vulnerable to the challenges of climate change due to cultural norms, inequalities in gender roles, and socio-economic status (Georgalakis, 2020). In Africa, where climate change has led to increased frequency of drought, higher temperatures, and floods, the awareness of these dynamics varies between men and women (McOmber, 2020). Climate change worsens the already-existing issue of women's marginalisation, complicating pre-existing social concerns about gender equality (Onwutuebe, 2019). Women's reliance on men for financial support increases as climate change affects agricultural productivity and the ability of female farmers to earn a livelihood.

The unequal distribution of economic power between men and women is a major factor contributing to patriarchal oppression and increased susceptibility to climate change, which disproportionately affects women (Azong & Kelso, 2021). Patriarchy and gender inequality limit women's ability to adapt to the impacts of climate change. This chapter provides unique perspectives on gender and climate issues across African regions. It also highlights the importance of considering the distinct experiences of men and women in addressing the impacts of climate change.

2 Part One: Gender and Climate Issues in West Africa

West Africa is facing a dual challenge of climate change and gender inequality (Makina & Moyo, 2016), which is negatively impacting the lives of women and girls. Climate change issues such as increased drought frequency, rainfall variability, high temperatures, and flooding are making the situation worse for women, who are already facing inequality in the region. The impacts of climate change will be felt more by women, as they will lose their socio-economic dependence on agriculture, especially in rural areas. The sustainable use of natural resources in the region, such as water, land, and forestry, is dependent on proper management. However, women are not actively involved in decision-making processes, leading to unequal distribution of resources and hindering their participation. To address this issue, it is important to include women in community-wide consultation processes and ensure their active involvement in decision-making and policymaking processes related to climate change and biodiversity conservation.

In West Africa, the impact of climate change on gender is intertwined with food security, water access, land use, assets, forestry resources, women migration, policy, and climate knowledge. Climate change has a disproportionate effect on women, who make up a large portion of the world's poor and bear a greater share of the risks and costs of climate change (UNFCCC, 2018).

Female-headed households in West Africa are more likely to experience food insecurity than male-headed households due to a lack of financial support. Climate change affects the livelihoods of communities dependent on natural resources, and women are often responsible for fetching firewood and water. In areas where climate change has led to drought, women

have to travel long distances to access water. In Senegal, declining rainfall has led to a 35% decrease in total rainfall in the past two decades, causing women to walk long distances to fetch water (Assan et al., 2018). This highlights the importance of considering gender in climate change interventions.

In West Africa, climate change has led to an increase in the frequency of drought and maladaptation of livelihood security, resulting in the migration of herders and escalation of farmer-herder conflicts (van der Land et al., 2018). Women are more vulnerable to gender-based violence, including human trafficking, child marriage, and conflict-related sexual violence, due to the perceived threat multiplier of climate change. The agricultural sector is a main source of employment for women in African countries, but they are dependent on rain-fed crops and face challenges in accessing weather and climate information services. This leads to disparities between men and women in accessing resources such as land ownership, distribution of quality seeds, and financial and agricultural extension services (Assan et al., 2018; Nyasimi et al., 2018). In Senegal, women have opted to receive climate and weather information via SMS messages in their local dialect due to the challenge of accessing such information. In Ghana, men were found to be more responsive in adopting climate information services due to their financial resources and control over household income (Trémolières & Walther, 2019).

The rising temperatures and precipitation in West Africa are leading to disastrous consequences, and women are more likely to face harm and low survival rates in the case of a disaster. Gender inequalities limit women's access to information, resources, training, and decision-making, making them unable to access relief provisions and assistance (Partey et al., 2020). The health of women is threatened, and their limited access to healthcare services, facilities, and social amenities, including hospitals, is wiped out during a climate-related disaster (Davenport et al., 2020). Women in West Africa are often responsible for sourcing water for the household, leading to increased workloads when water scarcity is heightened by climate change (Nahar & Tajuddin, 2022). Climate change impairs women's ability to make a decent living, forcing them to migrate to sustain themselves and their children (Kabir & Serrao-Neumann, 2020). Despite the crucial role of women in disaster adaptation, their role as agents of change has been largely ignored (Partey et al., 2020).

West Africa lacks national-level attention to gender mainstreaming, which underscores the need for expansive policy dialogue. For effective implementation of climate change initiatives that are sensitive to the needs and interests of women, gender must be considered at every stage of the process. This typically entails idea development to programme design, implementation, monitoring, and evaluation, with equal representation of women. The Paris Agreement and Agenda 2030 for Sustainable Development both emphasise the importance of gender equality and the well-being of women. Integrating inclusive gender initiatives within national climate actions is imperative for West African nations to reposition beyond gender policy disparities.

According to the Women and Trade Networks (WTNW) for West Africa, there are gender disparities in education and opportunities, particularly in rural regions, where most women and girls are educationally disadvantaged (Njoh, 2016; Connell, 2020)). This hinders their ability to adapt to the effects of climate change. Girl-child education can serve as a long-term strategy for ensuring communities' adaptability and survival. Training programmes for women, who are out of school, is an adaptation option as it provides them with new skills and opportunities for making a living. Equal access to education and formal programmes for both men and women can give households different but complementary ways to adapt to climate change.

There is agreement among researchers and policymakers on the existing gap between climate change and gender. The identifiable gaps are driven by social, economic, and environmental inequalities, as well as discriminatory laws and policies that restrict women's rights and empowerment (Dawit et al., 2022; McOmber, 2020; Gonda, 2019). In West African countries such as Mali, Nigeria, and Burkina Faso, customary family laws on marriage, which provide for girls to be married off as young as 15 (Goemans et al., 2022), impede women's participation in policy and decision-making (Cattaneo et al., 2020). Policies related to employment, political participation, and resource access have not sufficiently addressed the relationship between climate change, gender vulnerability, and discrimination in West African countries (Bouchama et al., 2018). There are efforts to include gender in climate-related policies, such as the African Development Bank's green growth strategies, but most of these efforts are limited by technological access, financial resources, and policy inconsistencies. McOmber (2020) argues that the Paris Accord has failed to address the needs of vulnerable groups, such as women and children, who are

disproportionately affected by the impacts of climate change (Mulema et al., 2021; Georgalakis, 2020; Cattaneo et al., 2020).

Despite the Paris Agreement providing a platform for African countries to improve gender responsiveness in their contributions to climate mitigation and adaptation, they face limitations such as a lack of technological access, financial resources, and policy inconsistencies (Bouchama et al., 2018). Although there have been initiatives in the agricultural sector in some West African countries, such as Senegal, Mali, and Burkina Faso, where farmers are involved in Participatory Integrated Climate Service for Agriculture (PICSA) (Dayamba et al., 2018), West African countries still face significant issues regarding gender inequality and the impacts of climate change. Women are particularly affected due to their social roles and responsibilities. Nevertheless, women play a crucial role in mitigating climate change and should be actively engaged in such efforts.

3 Part Two: Gender and Climate Issues in East Africa

According to a study by the World Meteorological Organization (WMO, 2019), climate change impacts are not gender-neutral. There are long-standing disparities between men and women regarding access to and control over natural resources in East Africa. Despite advancements in women's empowerment, gender inequalities remain an issue, and women play a major role in managing natural resources, especially in agriculture (96% of women in Burundi, 76% in Kenya, 84% in Rwanda, 71% in Tanzania, and 77% in Uganda are represented in agriculture, according to USAID, 2022). Climate change poses a threat to socio-economic activities, particularly in climate-dependent sectors like agriculture, and it is important to understand how men and women are specifically impacted by considering local gender regimes and norms, risk perception, response preferences, and decision-making power. Climate change adaptation and mitigation strategies should be gender-sensitive to reflect the varying experiences of men and women.

Gender inequalities expose women who depend on natural resources more vulnerable to climate change risks than their male counterparts. Instructively, the men usually own the land in East African countries, while women are mainly involved in farming and cultivation (Gaddis et al., 2018). Men derive the most profits from agriculture, and consequently

women are more vulnerable to climate risks. Women are also vulnerable due to their social status, education level, location, and income-generating activities. Women in arid areas, such as those who practise agriculture, are especially vulnerable to the impacts of extreme weather brought about by climate change (Balehey et al., 2018; Quandt, 2020). These impacts result in decreased education opportunities, increased poverty levels, and domestic violence. Climate change can also present an opportunity for promoting gender equity. However, the possibilities in closing the gender gap can be realised by adopting gender-sensitive approaches that focus on vulnerable women. Strategies that focus only on male landowners overlook the role of female caretakers (Jerneck, 2017).

The impact of climate change must be analysed from a gender perspective, as it affects men and women differently (Markowitz & Bailenson, 2021; Rabitz et al., 2021). Gender mainstreaming is a solution to climate-related disasters, as it can address gender inequalities and build resilience in both men and women (Chineka et al., 2019). The UN Framework Convention on Climate Change (UNFCCC) report (2021) recognises the importance of gender in climate change action and has encouraged the collection and analysis of sex-disaggregated data. East African countries like Kenya, Eritrea, Uganda, Tanzania, and Burundi have ratified and integrated global environmental policies from the UNFCCC and Kyoto Protocol that include gender-sensitive policies as a mechanism for adaptation and mitigation. These countries can receive technical and financial assistance from UN agencies such as UNEP, UNESCO, World Vision, and the EU.

East African governments are improving in adapting and mitigating climate change through gender-responsive policies and practices. Studies show that these policies have reduced the negative impact of climate change on agriculture and natural resources (Ampaire et al., 2020). Addressing climate challenges through a gender lens provides an opportunity for East African countries to solve gender inequalities and create a gender-inclusive society. Both men and women should be recognised as owners of resources and participate in decision-making processes regarding climate change. Advocating for peace within communities can also reduce instances of vulnerability. Diversifying crop and livestock production and intensifying gender trends in farming systems can help reduce the impact of climate change on rural livelihoods and improve food security (Tavenner et al., 2019).

The impacts of climate change are felt by society directly and indirectly, as outlined by the Intergovernmental Panel for Climate Change (IPCC). The IPCC (2021) reports the increasing risk of severe and irreversible change resulting from high levels of global warming and lists several impacts, including floods, droughts, storms, rising oceans, disease, conflicts, loss of species, health risks, poverty, land degradation, and heat waves. Huyer et al. (2021) state that the impacts of climate change are lived and experienced differently by different individuals. In East Africa, particularly in arid and semi-arid areas like north-eastern Uganda, north-eastern Tanzania, and Northern Kenya, both men and women are more vulnerable to the impacts of climate change than in other areas.

The socio-economic effects of climate change on vulnerable men and women in East Africa are substantial and impact multiple aspects of their lives. Climate change has a significant impact on agricultural productivity, leading to a reduction in land productivity and the loss of species, affecting men and women who depend on farming and pastoral activities. Women are more affected as they control farming activities, especially in rural areas. Pastoral men, who depend on livestock production for their livelihood, are also affected by the loss of livestock due to excessive heat (Walker et al. 2022).

The availability of water is also impacted by climate change, causing droughts, and exacerbating the vulnerability of marginalised groups, such as women (Gebremeskel et al., 2019). Women are more vulnerable due to the division of labour, and they have to walk long distances to find clean drinking water, making them susceptible to health issues and sexual violence. Men, who have to walk long distances to take their livestock to water sources, are also at risk of health issues and attacks. Climate change has a direct impact on food insecurity, affecting food production, access, distribution, availability, quantity, quality, and nutritional levels. This has a significant impact on the health of both men and women, leading to food deficiencies and malnutrition. A case study showed that the locust invasion in East Africa was mainly attributed to climate change, which led to food insecurity in the region.

Climate change leads to physical disasters such as famine, floods, droughts, and disease outbreaks, which have direct consequences for gender roles, experiences, and responsibilities. Women are more severely affected by the hazards caused by these natural disasters, including loss of life, damage to property, water-borne diseases, heat strokes, poor air

quality, physical injuries, and increased poverty (Kalantari et al., 2018). Other social impacts of climate change include displacement, migration, and conflicts. Climate change is a major cause of resource depletion, leading to conflicts and violence over scarce resources (Mueller et al., 2019). Women are often vulnerable to violence during these conflicts and may face physical, sexual, and psychological violence. The effects of climate change also impact education, as children, especially girls, may have to drop out of school to help their families cope with the impacts of climate change.

4 Part Three: Gender and Climate Issues in North Africa

Ecosystems and rural livelihoods across the world are being threatened by new issues related to climate change, including pandemics, environmental degradation, and mass migration (Huyer et al., 2020). Climate change is causing severe heat waves, drought, and aridity in North Africa, which is projected to be severely affected by future climate change (Waha et al., 2017). Algeria is the country most at risk due to its extreme susceptibility to the effects of climate change, while Morocco's vital agricultural sector is expected to be the most affected (Abdelmajid et al., 2021). Wheat yields in Egypt and Libya are also expected to decrease due to climate change. The Intergovernmental Panel on Climate Change (IPCC) projected a drop in durum wheat yield in the central northern region of Algeria between 2017 and 2021 compared to the baseline period between 1980–2009 and 2020.

Climate change has unequal impacts on daily lives and livelihoods, with different gender groups being impacted differently. According to Bhadwal et al. (2019), gender vulnerability to climate change is different due to differences in roles and responsibilities, as well as the exacerbation of gender sensitivity due to limited resources, poor employment markets, and cultural constraints on women's activities (Schwerhoff & Konte, 2020). Gender inequality plays a critical role in increased vulnerability to climate change dangers, making it necessary to integrate gender into policies, development plans, and implementation techniques with financial backing. Effective investment in both men and women requires systemic agriculture, governance, education, and industry reforms, using metrics such as impact evaluations, vulnerability assessment budgets, and quotas to measure gender parity (Glazebrook et al., 2020).

The United Nations has made progress in raising awareness of gender concerns in North Africa. The 1992 Earth Summit (United Nations, 1992) focused on sustainable development, and the non-binding UN action plan on sustainable development, Agenda 21, included Chap. 24 on Global Action for Women Towards Sustainable and Equitable Development. The UN Framework Convention on Climate Change also addressed social components, including gender issues, and the UN Convention on Biological Diversity recognised the importance of women's full involvement in sustainable development (Huyer et al., 2020). In 1995, the Beijing Platform for Action was formed to address environmental challenges, and the United Nations later included "gender equality" as a sustainable development goal in the UN 2030 Agenda. These efforts show a recognition of the importance of gender in environmental policy and sustainable development (Bastian et al., 2019).

Despite advances in sustainable development and gender equality, there are still disparities in the area of climate change. The Rio Convention and Agenda 21 have not directly addressed climate change, and gender equality issues have not been featured in UNFCCC outcome papers (Huyer et al., 2020). However, there has been a willingness to mainstream gender issues in policy and governance. The policy landscape after the Paris Agreement (2015) presents new challenges for gender equality in the face of climate change. North African countries are concerned about gender disparity in climate change mitigation and adaptation. Development is hindered by persistent gender stereotypes, and gender roles have not received sufficient attention.

The COVID-19 pandemic has impacted the North African economy through lockdown measures causing a decline in exports and negative effects on both supply and demand. The pandemic and climate change are linked by the systemic marginalisation and structural inequalities revealed in the region. The pandemic has created new challenges while exacerbating established concerns of climate change and gender inequality. The impact of COVID-19 has also hindered efforts to address climate change and promote gender equality, as well as the ongoing problem of famine in North Africa (Sultana, 2021; Otekunrin et al., 2020; UNECA, 2020).

The link between climate change, gender dynamics, and migration is widely documented (see Lama et al., 2021). Climate migrants, who flee areas with limited access to water and lower productivity in agriculture due to rising sea levels, are estimated to number 19.3 million in North Africa alone (9.0% of the total population) (World Bank, 2021). Women, who

are already disadvantaged in terms of access to resources, are especially sensitive to the negative effects of migration. Climate change, characterised by droughts, unpredictable rainfall, and rising temperatures, is expected to exacerbate gender inequality and other socio-economic problems in North Africa. To effectively address the issue, adaptation strategies must consider the unique factors of exposure and gender sensitivity. A more holistic perspective is needed to appreciate the full scope of the problem, considering that increasing women's opportunities and capabilities are impossible without men's support. A broader sense of belonging is critical because of gender inequality and proactive measures and actions on climate change adaptation.

5 Part Four: Gender and Climate Change Issues in Southern Africa

In Southern Africa, patriarchy dominates with men having control and decision-making power over natural resources, while women are expected to be caretakers of the land and support their husband's decisions. Globalisation has exposed both genders to the same challenges and opportunities, leading to more apparent gender inequality. Education is often viewed as a hindrance to women's roles in society, causing them to miss out on opportunities and face abuse (Bassey & Bubu, 2019). Anthropogenic activities, including energy production and industrial activities, are responsible for 74% of greenhouse gas emissions (United Nations Environmental Programme, 2020). Climate change has caused changes in weather patterns, reduction in agricultural yields, loss of biodiversity, food insecurity, health risks, and poverty. Women are disproportionately affected by these impacts, highlighting the need for a more holistic approach that addresses gender inequality and tackles the effects of climate change.

A study by Pearson et al. (2017) highlights the relationship between gender and climate change, stating that gender stereotypes shape how individuals perceive and respond to climate change. A solar mini-grid project in Zambia, described by Johnson et al. (2019), disrupted or reinforced gender norms and practices in energy behaviour. Climate change has affected traditional energy sources, and gendered approaches were found to be more effective in promoting clean energy and women's access to it. Climate-related disasters, such as the 2022 flood in South Africa, have a disproportionate impact on women, particularly those who are poor and vulnerable. The floods caused many girls to drop out of school.

Modernity, Christianity, and colonialism have shaped gender relations in Africa (Tomalin & Starkey, 2022), but cultural traditions have perpetuated inequalities between men and women. Climate hazards have made society vulnerable, and women, who are often overlooked, are particularly susceptible due to their limited involvement in climate change-related activities (Reggers, 2019). The agricultural sector is dominated by women in rural areas, but in South African countries, women are excluded from owning land, which impacts their access to information and control over resources. A study by Nyahunda et al. (2021) in the Vhembe district of South Africa found that women's vulnerability to climate change was heightened by their dependence on climate-sensitive livelihoods and patriarchal dominance. Therefore, gender-sensitive solutions are crucial in reducing vulnerability to disasters.

The link between gender and climate change has been largely neglected in policy development and implementation. South Africa has a Gender Action Plan as part of the United Nations Framework Convention on Climate Change (2019) to address gender issues in adaptation, mitigation, capacity building, technology, and finance. Namibia's constitution addresses discriminatory customary laws in inheritance, but married women only have land ownership rights if their husband dies. Zimbabwe has a local Gender Action Plan and is working on connecting gender and climate change for mitigation, but it still needs to mainstream gender into its policies (United Nations Development Programme, Zimbabwe, 2020). In the South African region, there is significant gender disparity and a lack of progress. The lack of progress is due to limited laws, legislative frameworks, and institutional frameworks, making women particularly vulnerable to the effects of climate change (Basiru et al., 2022).

Climate change poses greater risks to women in the Southern African region than men (Zhou et al., 2022). Women are more vulnerable to the impacts of climate change due to their limited resource ownership and economic opportunities (Louis & Mathew, 2020). As a result, the impacts of climate change exacerbate existing gender gaps in the region. In rural areas, where most of the population relies on climate-related resources for their livelihood (Khan et al., 2022; Dibakoane et al., 2022), women are left to face food insecurity, water shortages, conflicts, and health issues. Climate-related challenges such as droughts and decreased rainfall have a significant impact on agriculture, which is the main source of income for many in the region. This leads to decreased productivity and income,

particularly for small-scale farmers and those relying on irrigation development. Climate change is also affecting the tourism industry in the region, particularly in Livingstone, Zambia, where there has been an increase in temperature, extreme rainfall patterns, and a decline in rainfall (Dube & Nhamo, 2018). The projected decrease in rainfall will also affect men and women who rely on irrigation for their livelihood (Hamududu & Ngoma, 2020).

Climate change negatively impacts mental health, reproductive and maternal health, food security, nutrition, and mortality rates, as well as contributing to increasing weather disasters and infectious diseases. Women are more susceptible to the majority of these infectious diseases due to a physical sensitivity to climate change. In Swaziland, the Lubombo and Hhohho regions have been affected by an increase in malaria cases due to prolonged precipitation creating a conducive environment for mosquito breeding (Chuang et al., 2017). Climate change is also linked to HIV transmission and spread in Lesotho due to poverty resulting from food insecurity and impacts on livelihoods (Low et al., 2019; Braun, 2020). Women and young girls in rural Lesotho are vulnerable to HIV/AIDS in times of poverty, leading to desperate measures such as child labour and precarious employment.

Southern African countries including Botswana, Mozambique, South Africa, Zambia, and Zimbabwe face water shortages due to an increase in temperatures as a result of changing climatic conditions (Mpandeli et al., 2018). This, in turn, affects other resources like food and energy, escalating the region's vulnerability to climate change. The high dependence on climate-sensitive sectors like water and agriculture and the reliance on hydropower for energy make Southern Africa particularly exposed to climate variability and change. Food insecurity in South Africa is a crisis due to drought incidence resulting from unpredictable rainfall patterns, leading to a decrease in agricultural productivity (Kwame et al., 2022). Additionally, gender sensitivity to climate change is becoming an issue, with females affected in more significant respects than males. This further raises the society's inequality threshold and exposes women to negative impacts on their livelihoods, resources, and health. Gender-sensitive policies can reduce the region's vulnerability, and laws that undermine women's leadership and decision-making power in climate-related decisions should be abolished or amended.

6 Insights and Recommendations for the African Region

As discussed above, climate change has direct and indirect effects on gender, leading to vulnerabilities. Hence, societies need to take action to address these vulnerabilities in a resilient manner. Climate change response actions must be gender-sensitive, as noted by Awiti (2022), to be effective. Wheeler (2011) highlights the reasons for this vulnerability, including poverty, dependency on natural resources, lack of inclusive governance, and gender inequality. These differences, experiences, and societal roles limit the response to climate change and require inclusive approaches.

To effectively respond to the impacts of climate change, governments, institutions, and society must prioritise gender mainstreaming. Climate change affects rural areas in considerable respects, especially in arid and semi-arid land (ASAL) regions, thus, the solutions must be rural centred. The success of climate change initiatives and programmes in Africa requires equal participation from both men and women, and the utilisation of women's knowledge and leadership in mitigation efforts. National climate change policies (NCCPs), which consist of laws, regulations, and strategies enacted by individual countries to address the impacts of climate change, must prioritise gender equality. African countries must make gender equality a fundamental aspect of their climate action as they formulate nationally determined contributions (NDCs), which are countries' commitments under the Paris Agreement to address and tackle the impacts of climate change. Hence, the implementation of NDCs, NCCPs, and other strategies for reducing and adapting to climate change in Africa should demonstrate measurable progress towards promoting gender equality.

Climate change can be effectively addressed through policies that promote gender equality regarding access and ownership of information and technology, as well as in education and training. It is important to ensure that climate change action strategies are inclusive and gender-sensitive, so that they benefit all members of society equally. Women and men must be actively involved in policymaking and response measures related to climate change in Africa. African countries should also evaluate their financial and fiscal needs to implement effective gender-sensitive policies and measures to address climate change. Despite efforts to mitigate the effects of climate change, vulnerable groups in Africa, including women, are still susceptible to its negative impacts due to gaps in gender vulnerability. African countries must prioritise closing the gender gap as a key measure in mitigating

climate change and ensuring the achievement of the Global Sustainable Development Goals. The following are gender-sensitive guidelines for climate change action and gender mainstreaming in Africa:

a) At the national level:

- Develop a Gender Action Plan to support women in addressing the impacts of climate change.
- Implement strategies and establish institutions that advance gender equality and increase women's empowerment in climate change efforts.
- Address discriminatory policies and biases against women.
- Invest in gender-sensitive solutions and tools.
- Amend outdated laws and policies that negatively affect women.
- Strengthen women's access to resources and support their participation in leadership roles.
- Integrate gender perspectives in all aspects of climate change planning and implementation.
- Ensure equal representation and decision-making power for women in climate-related bodies and committees.
- Provide gender-sensitive financing and funding mechanisms for climate change initiatives.
- Create opportunities for women's entrepreneurship and economic empowerment in the green economy.
- Support the development of gender-sensitive technologies and innovations for climate action.
- Promote gender-sensitive adaptation measures for communities affected by climate change.
- Ensure that the impacts and benefits of climate change interventions reach both men and women equally.

b) At the institutional level:

- Collect and analyse sex-disaggregated data to understand the gender dimensions of climate change.
- Develop and implement gender-responsive climate policies.
- Reduce carbon footprint through sustainable practices such as reducing energy consumption, recycling, and reducing waste.
- Raise awareness on the importance of gender and climate change.
- Mobilise resources for gender-sensitive approaches to climate action.

- Advocate for gender equality in climate change efforts and hold the government accountable.
- Provide training and resources for women to lead and participate in climate action.
- Support and collaborate with gender-sensitive organisations and initiatives.

c) At an individual level:

- Advocate for equal educational opportunities for girls and boys.
- Advocate for fairness and equity in gender-related matters.
- Encourage active engagement in gender and climate action plans within communities.
- Advocate for climate action that addresses the gender dimensions of the issue.
- Participate in mitigation efforts such as conserving energy, reducing waste, and practising sustainable agriculture and land use in the community.
- Promote sustainable lifestyles and consumption patterns.
- Support community-based climate change initiatives that prioritise gender equality and women's empowerment.

It is, therefore, imperative that gender-based approaches should be developed to mitigate and adapt to climate change. Women have a great potential to influence climate adaptation but are hindered by cultural and socio-economic constraints. To overcome these obstacles, financial instruments and education and leadership opportunities for women should be encouraged. Gender-sensitive legal frameworks and climate information services should also be put in place. The adoption of climate change adaptations and mitigations is influenced by factors such as gender, age, and access to information. Women should be engaged as key stakeholders in decision-making processes and have equal opportunities in policy formulation, governance, and land use. The World Meteorological Organization (WMO) emphasises the importance of considering gender-specific needs when making access to climate information for farm management available (WMO, 2019). This approach to decision-making is crucial in mitigating the risks associated with climate change.

African countries should implement gender-sensitive policies and plans to address the unequal impacts of climate change. This includes collecting

and analysing sex-disaggregated data to identify and address vulnerabilities, promoting gender equality in education through the use of tools like Gender-Responsive Education Sector Planning, and providing gender-responsive financial aid during climate-related disasters (GRESP, 2017). Investing in girls' education is crucial as it fosters climate participation and leadership, enhances life skills, and strengthens a country's resilience to climate-related disasters. Gender-responsive technologies, such as Climate Smart Agriculture, should also be promoted to address food insecurity. Ultimately, African countries must recognise the gendered impacts of climate change and adopt gender-sensitive approaches to achieve sustainable development.

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Explaining Gendered Vulnerability to Climate Change: The Contextual Conditions

1 Introduction

Climate change is an urgent and inescapable global concern. Rising temperatures are leading to changes in environmental processes, making rainfall and soil moisture content less predictable. Contemporary events have shown that a change in climate conditions poses a serious threat to the human race, particularly in the light of challenges to life and security. The poor, who frequently rely on ecosystem services, are significantly impacted. Climate change has varying effects on different demographics, such as age groups and genders, and it has important consequences for women due to differences in social responsibilities and access to economic resources.

The most vulnerable citizens of developing nations, women, in most cases, face enormous challenges due to climate change (UN Women, 2022). Women, particularly young girls, constitute one of Africa's most vulnerable populations, providing a regular supply of domestic labour similar to many contexts around the globe. Studies (Lambrou & Piana, 2006; Neumayer & Pluemper, 2007) have shown mounting evidence that climate change effects are gendered, and women are highly prone during and after climate events, especially in locations subject to climate variability and disasters. According to some of these studies (e.g., Neumayer & Pluemper, 2007), households react to the negative shocks of climate change by inequitably redistributing the available resources to women and girls.

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The main justification for making distinctions between men and women in terms of climate change in this chapter is based on the different social roles of each gender and how these influence the impact of climate change. Despite the biological disparities between men and women, it is essential to specify these differences and consider them when developing and implementing response strategies to climate change in Africa. The disparities in gender roles suggest that men and women would be affected differently by climate change, depending on their respective social and professional positions. Therefore, it is necessary to explore gendered vulnerability to climate change in Africa. In this chapter, this exploration is accomplished by reviewing the emerging issues on the impact of climate change on gender differences.

2 Gendered Effects of Climate Change

Climate change is a phenomenon unlike any other in recorded human history (Ajani et al., 2013). The macro-level effects of climate change are anticipated to raise proximate hazards from disease outbreaks, cyclones, droughts, floods, landslips, fires, and heat waves throughout most of the planet. Women frequently struggle more with adaptation when a climatic change affects revenue flow and food production or calls for modifications to water sources or crop distribution. Particularly, the gendered divisions of work in the home increase women's susceptibility to climate change. Both genders contribute to the maintenance of the household, with women typically in charge of managing the resources required to maintain family nourishment and health, and men often responsible for wage work or cash crops.

In Africa, climate change has peculiar consequences because of the differences between men and women, their societal responsibilities, and their access to socio-economic and physical resources. Inequalities caused by social class and women's roles in the family and community are made worse by climate change, as it affects important elements of livelihood (i.e., water, food, and energy supply) (African Development Bank, 2011). Onwutuebe (2019) cited African societal norms that place gender-based duties in different social categories as a reason for the dissimilarity in climate change effects between men and women. In addition, Dercon and Krishnan (2000) further stressed that women are still the most susceptible to negative shocks and frequently shoulder the consequences in many developing nations.

For example, a 2018 study by the United Nations Development Programme (UNDP) found that women in Africa are disproportionately affected by the impacts of climate change, including food and water insecurity, loss of livelihoods, and increased conflict. The study also highlights that women in Africa often have limited capacity to adapt to the impacts of climate change and limited access to resources, including education, finance, and technology, which exacerbates their vulnerability. These findings are consistent with other studies, such as a 2016 report by ActionAid, which found that women in Africa are often more vulnerable to the impacts of climate change due to existing gender inequalities and traditional gender roles, which limit their access to resources and decision-making power.

Beyond Africa, Gaalya (2015) stated that Cyclone Nargis, which struck Myanmar in 2008, highlighted the underlying climate change inequality, as 61% of the fatalities were females. These statistics support the findings of Aguilar et al. (2007) that gender disparities make women and children 14 times more susceptible to climate change than males. Gaard (2015) asserts that the exclusion of women from decision-making, lack of empowerment, and limited insights into the dangers of climate change account for a large number of natural disaster casualties.

3 Climate Change and the Gendered Effects on Human Capital

Climate change has varied effects on human capital in terms of mortality, education, and physical and mental health (Eastin, 2018; Lawson et al., 2020). Women appear to be more negatively affected as a result of their physiological makeup, their duties as caregivers, and limited access to food and nourishment. These factors support the tendency for women's vulnerability to climate change. In emerging economies, girls' education is regarded as less important than boys' (Behrman & Knowles, 1999). Similarly, when faced with climate-related income shocks, parents may alter their investments in children's education in ways that are harmful to females. For example, using district-level data from Uganda between 1975 and 2003, Björkman-Nyqvist (2013) found that poor rainfall shocks significantly reduce female participation in primary school, particularly among older females. The study reveals that a 15% drop in rainfall decreases female enrolment by 5%, whereas a change in rainfall has

no impact on male enrolment. According to these findings, older females engage in labour to offset the damaging consequences of the rainstorm shock. This is a widespread phenomenon whereby a loss in income results in an increase in child labour and the engagement of children's assistance in managing consumption levels and freeing up hours for the elderly (Basu & Van, 1998). Households in the Kagera region of Tanzania had a 30% rise in child labour due to negative shocks that impaired agricultural production (Beegle et al., 2006). According to Bandara et al. (2015), agricultural shocks lead to an increase in the exploitation of children for work, especially for male children, while also increasing the likelihood that girls will drop out of school by 70%. Although rodents, insects, or other pests are the predominant source of agricultural shocks in these studies, their impact on yields is equivalent to the effects resulting from climate change.

The adverse effects of climate change, such as long-term changes in average temperature; changes in the intensity, timing, and geographic distribution of rainfall; an increase in the frequency of extreme events, that is, droughts and floods; and sea-level rise, have become more evident in recent times (IPCC, 2007; Verner, 2011). Women are frequently referred to in discussions about climate change as a "marginalised population." They are represented as "victims" of development due to their lack of resources, yet bear the hardship of existence as subsistence food producers, water and firewood carriers, and household food security guardians (Okali & Naess, 2013). They are also significantly more impacted because they are (climate) refugees. In addition to their social roles, women are primarily responsible for providing the utmost care for the sick, and in cases where the rate of illnesses increases, the most affected by the responsibility of care are women.

Different studies have demonstrated how gender inequality, resource access, and education can all intersect to sway judgements about the education of the female child (Alston et al., 2014; Ahmed et al., 2019). According to Alston et al. (2014), many families in Africa claim to have chosen to keep their kids home away from school as a means of coping with the effects of climate change. Others stress the connection between education and resource availability, noting that economic shocks caused by environmental catastrophes make it difficult for families to have enough financial resources to cover the cost of education (tuition, books, supplies, and transportation) (Ahmed et al., 2019). When resources are

limited, many families are likely to give preference to male-child education.

In addition, the impacts of environmental shocks on human capital may not only be felt immediately after the shock but can continue for a long time, affecting future income, health, and educational opportunities. Maccini and Yang (2009) investigated how early-life rainfall shocks influenced individuals born in Indonesia between 1953 and 1974. While early-life rainfall shocks had no effect on males, they discovered that older females who received positive weather shocks like rainfall as children had improved health. They grew taller, received more education, and this, in turn, enhanced their socioeconomic status in adulthood.

4 Climate Change, Marriage, and Fertility Decisions

Women's education is a significant predictor of fertility and labour market participation (e.g., Osili & Long, 2008). According to Bbaale and Mpuga (2011), any shock that has an impact on females' education might indirectly affect fertility. There is modest but rising evidence that climate change affects fertility and marriage. For the female gender, access to resources and educational opportunities is unequal, and climate change and other environmental challenges worsen the disparity. Importantly, the Intergovernmental Panel on Climate Change (IPCC) cautions that if global warming reaches1.5 degrees Celsius, millions of citizens may be driven into severe poverty, with the effects being experienced predominantly in Africa and South Asia (IPCC, 2014), where early marriage and circumcision are widespread.

Equally, understanding the repercussions of environmental crises on child marriage is crucial in an unstable and changing environment so that human rights may be protected and steps can be taken to increase resilience to the effects of climate change. Interviews with families and members of civil society groups in Kenya, Uganda, Malawi, Ethiopia, Zimbabwe, and Namibia revealed that one of the leading causes of child marriage is the economic consequences of environmental problems (Chamberlain et al., 2017; Porter et al., 2011; Mudavanhu, 2014; Marchetta & Sahn, 2016). A coping mechanism for the loss of possessions and income during catastrophes like droughts and floods is child marriage. According to research, child marriage rates in Bangladesh rise following periods of

drought or intense heat that reduce household resources (Tsaneva, 2020; Asadullah et al., 2020). This finding is supported by interviews with families, who described limited finances as a major driving force in how environmental crises affect decisions about when their children get married (Glaser et al., 2019).

According to studies (Drèze & Murthi, 2001; Grimm, 2021; Corno et al., 2020), early marriage and procreation are strategies to reduce income instability. Hence, the economic effects of environmental crises are a lens through which child marriage decisions are shaped. When dowry payment is anticipated, child marriage rises (Corno et al., 2020). This has been demonstrated in sub-Saharan Africa, where studies reveal that in nations that practise bride price settlements, droughts increase the number of underage marriages. Similar tendencies have been seen in other regions around the world. Traditions like bridal payment play a significant role as people desire to balance consumption and decrease the impacts of climate change (Corno & Voena, 2016). Child marriage has become more prevalent among the Maasai due to climate change. Many families go through extreme starvation as a result of the protracted droughts, and young girls—as young as 12—are being given away as brides in return for livestock (Grimm, 2021).

There are conflicting views and data regarding whether and how climate change impacts reproduction. In many parts of Africa, there is a prevalent belief that having many children is an "insurance" mechanism for securing economic resources. As a result, people may have more children than they would like in the event that some of them do not survive (Finlay, 2009; de Sherbinin et al., 2008), increasing fertility shocks and subsequently raising the risks associated with large family sizes. Such regions will consider high and early fertility as a method of ensuring economic stability (Cain, 1981), lowering family or lifetime uncertainty, in accordance with the Malthusian-inspired "vicious circle model" (Dasgupta, 1995; de Sherbinin et al., 2008), or increasing the likelihood of having more children who live to adulthood and are successful financially (Guarcello et al., 2002). The surviving children can participate in family business ventures and contribute to household finances and intergenerational care (Finlay, 2009).

Both earlier and more recent empirical studies indicate that climate change has both positive and negative effects on fertility. Research in cultures with limited access to modern contraception or differing opinions on family planning might be a good place to start. Here, reproductive

patterns and long-term family size aspirations are addressed either overtly or inferentially—in harmony with external conditions and underlying population-resource balance. The variation in natural fertility patterns is one example (Leridon, 1977); the various fertility regimes are connected to regions at risk of drought and flooding, and family size and farm size are frequently correlated; this is known as the "Land-Labour Demand Theory" (Mueller et al., 1984).

Although a population's stage of fertility tends to have a role in this impact, future environmental change might alter fertility behaviour in ways that correspond to the values deriving from that particular population-resource balance transition. For example, fertility is typically lower in regions where a protracted drought threatens children's health and labour costs in rain-fed agricultural regions (Cain, 1981), where agricultural expansion has reached the limits of arable land, and when landowners have a strong title (the Land-Security Theory). Contrarily, fertility is higher in regions where child labour is pervasive despite environmental changes (Cain, 1981). The "Vicious Cycle Model" (VCM) holds that poverty drives fertility and, if unabated, will worsen the social, economic, and environmental circumstances of the family (Lutz & Scherbov, 2000; Filmer & Pritchett, 2002; Dasgupta, 1995). VCM is present among impoverished rural populations characterised by diminishing natural capital (Sasson & Weinreb, 2017), while child morbidity increases as a result of altered infectious disease patterns linked to climate change (Aksan, 2014).

Climate change impairs fertility, and by extension, this alters the dynamics of early marriages. As previously indicated, children are a possible source of labour in homes experiencing economic shocks, as their contributions may be effective in facilitating adjustments to economic changes. In the light of this, reproduction is viewed as a kind of risk mitigation. According to Grimm (2021), fertility rates in late nineteenth-century US counties differed between farm and non-farm families. It was found that whereas non-farm households did not see the need for an increase in fertility, agricultural households did. Increasing the rainfall variability distribution from the 10th to 19th percentile results in a 12% increase in the fertility gap between agricultural and non-agricultural families. Furthermore, the delayed demographic change occurring in Africa and dry regions may be explained by the findings of Grimm (2021), which imply that reproduction is a component of the response to hazards caused

by climate change. Interestingly, in another study by Abiona (2017), unpleasant adverse shocks boost the desire for birth control in Uganda, albeit with different consequences. At first glance, this finding appears to be at odds with that of Grimm (2021); however, it is complementary as it implies that, when given the option and control over their reproductive decisions, women may decide to put off having children due to experiences of negative shocks.

5 Climate Change and Violence Against Women

Gender-based violence (GBV) is violence committed against a person based on their gender. It is also the worst example of discrimination against women and girls, as well as gender inequality. Since the 1990s, more research have shown how the catastrophic impacts of climate change, coupled with inadequate preventive measures, exacerbate gender inequality and violence against women and girls (VAWG). At all economic phases and in a number of geographic regions, there is evidence of sexual, physical, economic, psychological, partner-inflicted violence, trafficking, child marriage, and several other types of VAWG. In particular, sexual assault shows the continuity of pervasive inequality, cruelty, and discrimination and is seldom a "unique" outcome of climate change. Intimate partner violence (IPV) and abuse by relatives or individuals not in the immediate family are all factors that contribute to gender inequality.

For many women, the fight against climate change is a direct cause of many types of sexual and gender-based violence (SGBV), even though it has evolved into a campaign to protect our environment holistically. Different kinds of SGBV affect women and girls both within and outside of the family. Environmental changes brought on by external forces, like climate change, make them more exposed (Desai & Mandal, 2021). For instance, when disasters or emergencies like pandemics, tragedies, and wars occur, gender disparities become much more pronounced, especially when climate change has gender-specific effects. According to the UNICEF (2023) study, all types of gender-based violence against women and girls increase during disasters and conflicts, further exacerbating already existing inequities, vulnerabilities, and harmful gender norms. For instance, Darfur has seen frequent droughts and poor rainfall, both of which have worsened food security and resource shortages. These risks are catastrophic for girls and women who must travel long distances to obtain

drinking water. In a nation like Malawi, where food is scarce owing to climate change, young girls are compelled to get married (Curry, 2017).

During droughts and prolonged dry spells, Ugandan women experienced domestic abuse, child marriage, sexual assault, female genital mutilation (FGM), and other forms of violence. In 2016, UNESCO called attention to how climate change disproportionately impacts women, including through natural disasters, forced migration brought on by the consequences of climate change, sexual trafficking, and an increase in rape cases, as a result of their endless search for water and firewood. Therefore, during and after catastrophes or emergencies brought on by climate change, existing gender disparities increase, and new types of SGBV occur. Such impacts are both permanent and harmful and comparable to what happens in times of war.

Numerous factors that contribute to violence against women have been examined in past studies. Poverty, cultural standards, illiteracy, and lack of socio-economic empowerment are a few of them (Cools & Kotsadam, 2017). Gender inequality and the labour participation rate are only two instances of labour market variables (Aizer, 2010; Anderberg & Rainer, 2013; Bhalotra et al., 2018). According to Benson et al. (2003), another source of violence against women is the economic shock caused by climate change. A Tanzanian research found that shocks attributed to rainfall increase the frequency of domestic violence; the study shows that one variance in severe rainstorm shocks raises spousal abuse by 18.8%, which is more pronounced in lower-income households (Abiona et al., 2016). Another Tanzanian study, based on data from 67 communities between 1992 and 2002, discovered that homicides of women aged 50–60 suspected of witchcraft are twice as common during heavy rain years (Miguel, 2005). Although it might be challenging to distinguish the role of non-economic elements like social values, in this case, financial shocks are the leading causes of witchcraft charges.

6 Climate Change, Gender Roles, and Economic Differentials

Gender roles imply that climate change would affect women and men differently, owing to their distinct roles and duties in their community, as well as their level of access to natural and other resources, including information. In this context, climate change-related issues include (but are not limited to) increased competition for water across sectors and population

groups, raising the risk of violent conflict over water resources; increased frequency and severity of droughts, floods, and other extreme weather events; crop productivity losses; sea inundation of low-lying regions; and changes in natural resource-based industries such as forestry, fisheries, and tourism. Almost all of these issues are prevalent on the African continent. For example, with global warming of about 28 degrees Celsius beyond pre-industrial levels, a net income loss to Africa's agricultural sector of about 5% of GDP is predicted (PACJA, 2009). Water stress is also expected to worsen, impacting between 350 and 600 million people and increasing the danger of extinction for up to 40% of species in sub-Saharan Africa. Climate change, according to the conclusions of several studies, would result in lower food yields (IPCC, 2014).

Gender discussions in southern Africa (Meena, 1992; Iipinge & Williams, 2000; Wamukonya & Rukato, 2001) corroborate gender inequity, lack of empowerment, and restricted access to assets. For instance, women in southern Africa have subordinate legal positions; restricted access to resources such as land, technology, credit, education, formal employment, and training; and are vulnerable to HIV and AIDS (Lopi, 2004). These factors not only exacerbate gender disparities but also render women more vulnerable to poverty, catastrophes, and violence, as well as climate change. A framework for analysing climate change's effect on women's rights is vulnerabilities. Impoverished populations are more vulnerable because they rely more on ecosystem services for a living, are more likely to live in environmentally vulnerable areas such as flood plains or on degraded hill slopes, and have fewer resources to adapt to changing environmental conditions. The impoverished are not a homogeneous group; however, disproportionate domestic and familial duties, as well as a relative lack of control over economic assets, can make women more vulnerable than men (Goh, 2012).

Natural disasters can have a wide range of effects on women's occupations. Productive assets may be lost, forcing women to choose low-wage work. Women outnumber men in the informal and small business sectors. These sectors are frequently the worst affected by disasters and the least able to recover. Natural disasters disproportionately affect women's employment, working hours, and conditions. On the other hand, some women, particularly those in the middle class, may profit from increased access to work possibilities (Enarson, 2000). Hazards have a wide range of consequences, including death and morbidity. Gender relations are unlikely to improve, particularly when there are multiple risk factors. In

the aftermath of a disaster, there are gender components to what happens in the relief, coping, and recovery stages, as exemplified by significant inequity between men and women.

Inequalities in household asset ownership and control, as well as rising familial burdens due to male out-migration, declining access to food and water, and increased exposure to disaster, can undermine women's ability to achieve economic independence, improve human capital, and maintain overall well-being. Reduced intra-household bargaining power when women become less capable of obtaining independent funds is one of the consequences of gender equality. Outside the house, gender discrimination and socio-economic status disparities worsen as women become less able to participate in formal labour markets, join civil society groups, or mobilise collectively for political change. The upshot of these processes has the potential to diminish a society's degree of gender equality by creating barriers to the adoption of laws and practices that promote co-equal status.

Owning property can symbolise financial independence for women in marriage because it would provide an alternative source of income. The distribution of resources among households is also connected to risk-coping strategies. Men and women react to disasters separately, and joint ownership assets are harder to deal with since spouses may find it hard to share (Rakib & Matz, 2016). This helps to understand why women are more vulnerable to economic shocks caused by climate change. For example, Quisumbing et al. (2018) discovered that climate-induced shocks affect assets owned by men and women differently in Bangladesh and Uganda.

Women's propensity to adapt to the changing climate is limited by a lack of freedom and decision-making power. Often, women have little or no control over the family's finances. Women are frequently underrepresented in local politics, which limits their ability to influence laws that support women's goals and rights. Plans to replace agricultural production processes with ones more suited to the changing environment tend to only consider the needs of male farmers without taking into account the problems women experience as agricultural workers. Restrictions on cultural mobility may make it more difficult for women to acquire services and knowledge. In addition, women might be unable to relocate amid extreme weather conditions without a male relative's consent. Women's ability to run or swim may be hampered by traditional clothes, making it more difficult for them to flee disasters. As they are unable to access public locations, women who have lost clothes in catastrophes may be less likely to get food and medical treatment.

According to Yavinsky (2012), women constitute the bulk of the world's poor population and depend more on natural assets for survival than men. In comparison to men, women are more prone to being wholly dependent and earning lower incomes. For example, men could use their savings and financial independence to invest in other earnings or make other adjustments when a drought or exceptionally heavy rain harms agricultural production. In times of famine and drought, women usually put their spouses' nutritional needs ahead of their own. The lack of information and expertise that would allow them to manage weather risks to agriculture makes women more susceptible.

Growing livestock is important to women in improving their financial status. Globally, women are heavily involved in this sector. It is estimated that 400 million individuals, or two-thirds of poor livestock keepers, are women (FAO Working Paper, 2011). Women are at the forefront in taking care of daily animals, managing poultry, and caring for other animals. FAO reports that an estimated 45 million people were involved in the fish industries. Moreover, an estimated 135 million people are employed in the secondary sector. It is estimated that women comprise 30% of the fisheries labour force (FAO Working Paper, 2011).

Through increased competition for natural resources, decreased feed quality and quantity, an increase in livestock diseases, increased heat stress, and decreased biodiversity, global warming will influence livestock production. As temperature rises, cellular wall and lignin elements may increase, decreasing the pace of digestion and the amount of nutrients available in forage and diets (Thornton et al., 2009). It is projected that a decline in the supply of maize crop residue due to a reduction in maize yield by 2050 may have an indirect impact on animal production in quasi-mixed cropping regions of East Africa (Thornton, 2010). Climate change is anticipated to have an impact on the frequency and regional distribution of human geometric diseases, including malaria and Rift Valley fever (Cadot et al., 2011). Thus, initiatives to improve adaptation and resilience must take into account the gendered implications for pastoral families (Walker et al., 2022).

7 Some Initiatives and Policy Development Efforts for Gender Inclusivity in Africa

Gender inclusion in Africa is supported by several programmes and policies. Due to their gender, women in Africa frequently suffer from abuse, exploitation, and discrimination. The feudal system is responsible for one

of the most serious acts of abuse towards women of all ages (Gaddis et al., 2018). A few instances of discrimination that African women routinely experience with impunity and that are often sanctioned by religion and culture include land ownership, labour exploitation, and others.

Initiatives and policy development attempts to promote gender inclusion have received much attention at the continental, regional, and national levels. Notably, the African Union (AU) is spearheading attempts to enhance gender parity and women's empowerment across the region. The AU's support highlights women's rights in several key continental treaties. The Maputo Protocol, which adds a broad range of basic rights safeguards for African women and girls, continues to be one of the most complex legal treaties. The Maputo Protocol guarantees complete and fundamental human rights for women, including all facets of political rights, socio-economic and cultural rights, as well as ecological rights, in contrast to past accords addressing the position of women (AU, 2022).

Africa has evolved as a result of substantial discussions about gender equality. Despite persistent waves of restrictions and antagonism, there have also been substantial advances towards gender equality as the African Women's Decade (AWD) started in 2010 (AU, 2022). The bulk of the topics discussed by the African Women's Decade is congruent with domestic and international accords such as the Beijing Platform for Action, the SDGs, the Joint Resolution on Gender Equality in Africa, and the Maputo Protocol (AU, 2022). Other efforts that African leaders have made to indicate their support for the advancement of women's rights include the Joint Proclamation for Gender Equality, the Protocol to the African Charter on Human and Peoples' Rights on the Rights of Women in Africa, the Gender Parity Principle, the African Agenda 2063, and the Solemn Declaration on Gender Equality in Africa (Stefiszyn, 2005; Ntlama-Makhanya & Lubisi-Bizani, 2021).

Agenda 2063 is a plan tagged *the Africa We Want*, which was unanimously approved by heads of state and government in 2013 (AU, 2022). Aspiration 6 of Agenda 2063 calls for "An Africa whose growth is people-driven, dependent on the potential of African people, particularly its women and youth, and caring for children." Thus, Agenda 2063 calls for a more equitable society where everyone actively participates in decision-making and no child, woman, or man is left behind or discriminated against on the grounds of gender, party leanings, religion, ethnic affiliation, geography, age, or other considerations. Furthermore, women play a critical role in attaining inclusive development, and Article 3 of the African

Union Protocol on Amendments to the Constitutive Act calls on the AU to advance the active involvement of women in decision-making, especially in political, economic, and social areas (AU, 2022).

The AU considers gender equality a fundamental human right and a vital component of regional integration, growth, and social progress and has developed the Gender Equality and Women's Empowerment (GEWE) policy to ensure women's participation in Africa's development agenda (AU, 2022). The Women, Gender and Development Directorate was established to create the African Women's Decade 2010–2020, which focused on expanding initiatives towards gender equality and women's empowerment at the grassroots level. The GEWE method has six main pillars (AU, 2022). First, a development that is both sustainable and scalable requires the economic empowerment of women. Social justice, safety, and women's rights are all examples of human rights. The second pillar looks at leadership and government, where women must contribute equally and effectively to the government. The third is gender management systems, which will provide access and funds (financial and other technical resources) to assist women. The other pillars look at peace and security, promotion programmes, and the provision of ICT skills for women in Africa.

In addition, African strategic growth groups have contributed significantly to closing gender disparities. For instance, in 2015, the African Development Bank provided the Africa Gender Equality Index (AGEI) assessments for 52 of Africa's 54 countries (AFDB, 2015). The index aims to solve the impending bottlenecks to women's growth in Africa (AFDB, 2015). From a global view, all United Nations members agreed to the Sustainable Development Goals in 2015, based on criteria similar to some of the regional initiatives, action plans, and the Convention on the Elimination of All Forms of Discrimination against Women (CEDAW) (UNWOMEN, 2016).

8 Conclusions and Implications

Climate change affects agricultural production negatively, resulting in decreased crop yield and a reduced amount of food available for consumption, indicating impoverishment. Poverty causes early marriage, poor health, and decreased life expectancy. For instance, it may force families to use the marriage bonus as a source of income for sustenance and also imply that there are fewer dependents to cater for. Additionally, it can also

result in a greater need for children's input to the household, increasing reproduction.

It is pertinent to emphasise that gender-differentiated consequences of climate-induced shocks also reflect gender disparity in access to healthcare and education, in decisions about marriage and having children, in the experience of or likelihood of violence, and in the range of economic prospects. The first step should be to rectify this inequity, completely consistent with SDG 5, which calls for attaining gender equality and the empowerment of women and girls. It is crucial to encourage positive trends that will increase female empowerment and gender equality, which will strengthen society and promote sustainable development. Furthermore, access to financial markets might both minimise consumption volatility and function as a shock absorber (Bandara et al., 2015; Corno et al., 2020). Women who have influence over alternate options and life decisions, such as fertility, can reduce the negative effects of climate shocks (Abiona, 2017).

Finding and implementing initiatives to support training and educational initiatives that would encourage vulnerable rural women to obtain the skills necessary for income generation should remain a top concern (Ajani et al., 2013). It is advised that women be given the power, at every stage, to make strategic decisions to withstand climate shocks. Steps must be taken to provide the essential structural foundations for women's long-term economic empowerment. In doing so, a comprehensive approach, including institutional and political players, is necessary. Meanwhile, policies for both adaptation and mitigation will need to incorporate measures to improve social protection and business growth and create jobs for women affected by climate shocks.

Finally, this study emphasises the need for more empirical research on the short- and long-term relationship between gendered vulnerabilities and climate change. More cross-country and microeconomic assessments that offer a broader perspective would be interesting. A deeper investigation of the gendered impacts of climate change on political involvement and other economic aspects, including labour market results, is necessary. Future studies might consider whether there are additional explanations for the consequences of climate change that transcend agricultural production or how the effects on crop returns interact with other critical variables.

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Climate Change and Gender Gaps in Africa's Agricultural Sector

1 Introduction

With about 60% of the world's arable land, Africa has the potential to meet global food demands (Oxford Business Group, 2021). Agriculture continues to be one of the most critical sectors in Africa, employing a majority of citizens and accounting for around 14% of Africa's Gross Domestic Product (GDP) (Oxford Business Group, 2021). It is estimated that women constitute about 43% of agricultural workforce in developing countries (Oxford Business Group, 2021). At the international level, women account for two-thirds of small-scale agricultural livestock managers (Huyer, 2016). However, the productivity of these women, especially in Africa, is sometimes impeded by limited access to land (FAO Gender, 2020). Gender differences further hinder women's output in terms of ownership, access, and control of more than six crucial agricultural resources and inputs, including land, workforce, finance, knowledge, outreach, and technology (Njobe & Kaaria, 2015; Huyer, 2016).

The statistics of property holders in Africa outnumbers documented ownership. Generally, men hold registered deeds and other forms of official documents at a higher rate than women (Gaddis et al., 2018). According to Slavchevska et al. (2021), while maintaining a lower land rights rate, most women landowners lack the essential legal documentation, restricting their capacity to make major decisions on land usage.

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Similarly, norms sometimes make it less likely for women to be allowed to legally possess land or have any role over how it is utilised (Slavchevska et al., 2021). For example, in-law marriage reduces a woman's chances of land ownership or having little or no say on related matters. Additionally, climate change results in ecological and land deterioration, and failure to plan adequately places an added burden on women as the small proportion of fertile land drops (Mandelsohn & Dinar, 1999). This demonstrates that even when women claim to be landowners, they frequently experience weaker tenure security than men (Mbaye, 2020).

The unequal access of women to major agricultural resources, including land, labour, knowledge, fertiliser, farming practices, and other inputs, contributes to the persistent gap between men and women (Farnworth et al., 2016). According to Kristjanson et al. (2017), women confront extra sociocultural and institutional hurdles to acquiring and implementing agricultural technology. Most of the time, women in Africa lack adequate access to resources, including farmland, capital, livestock, tools, and expertise. As a result, they are substantially less likely to increase economic power and make positive contributions to their communities. Women are seldom considered when making decisions on how to manage natural resources (Tantoh & McKay, 2020). There is an absence of political will and dedication at both national and regional levels to change feudal customs and privileges, such as gender-based discrimination in communal preoccupations.

It is worth noting that the inclusion of African women, that is, creating equal opportunity for men and women, has some socio-economic implications in the light of the changing climate. Consolidating women's rights to land ownership might significantly boost family earnings and well-being (Quisumbing & Maluccio, 2003). To promote equality between men and women farmers, this chapter explores the diverse gender dimensions in agriculture and how climate change impacts these roles. The gender gap in access to vital farm produce and inputs (farmland, manpower, information, fertiliser, extension services, and seedlings) contributes to the gendered discrepancy in land rights in Africa (Farnworth et al., 2016). Therefore, it is crucial to identify the gendered dimensions of these differences and consider them when developing and implementing agricultural response strategies to climate change in Africa. Gender disparities in roles suggest that men and women would be affected differently by climate change, influenced by their social and professional status. As such, it is necessary to explore gendered vulnerability to climate change and recommend appropriate interventions for Africa's agricultural sector. This

chapter aims to provide insights and recommendations that can help policymakers and practitioners promote gender equity and enhance the resilience of Africa's agricultural sector in the face of climate change.

2 Land Ownership, Gender Differences, and Climate Change in Africa's Agricultural Sector

Farm owners, herders, workers, and dwellers rely on land as one of the cornerstones of income generation and socio-economic growth. In addition, land is a repository for cultural legacy and identity (Odeny, 2013). Across Africa, there are significant discrepancies between men and women regarding land ownership, use, and control (Agarwal, 2003). Gender disparities in land ownership rights, which is a crucial revenue source for Africa's impoverished, are especially pronounced where land is concerned (Gaddis et al., 2018; Alkire et al., 2013). In Ghana, a study found that women own land in only 10 percent of households, while men own land in 16-23 percent of households, with the mean value of men's land ownership being almost three times that of women (Deere & Doss, 2006). Results from an FAO study conducted in 20 countries show that the majority of families are headed by males, who also manage bigger lands than families headed by women (Agarwal, 2011). Furthermore, a recent study by Gaddis et al. (2018) indicates that only about 13% of African women (aged 20–49) have exclusive land ownership, compared to 36% of African men. Even when joint ownership is considered, the gender gap remains significant, with 38% of African women owning land (alone or jointly) compared to 51% of African men (Gaddis et al., 2018). Age-long cultural practices regarding land relations in many parts of Africa have made several African women reliant on male relatives' status and benevolence for land access (Allendorf, 2007).

Land tenure practices in the region impose severe conditions on women, relegating their efforts to adapt to climate change. In addition, statutory and customary regulations continue to limit women's access to land and other resources in many developing nations (Perez et al., 2015). Nearly two-thirds of developing nations' laws do not ensure that both genders have the same inheritance rights. Again, in some of these nations, customary discriminatory practices against women are observed (Perez et al., 2015). In Mali, for example, women constitute around 50% of the population who engage in agriculture (UN Women, 2018), yet they are dissuaded from agricultural production due to their inability to access land (USAID, 2015). Mali traditionally forbids women from owning land. While women may farm or utilise land for a limited period, such access can be revoked at any time (WFP, 2016).

Given that property is often used as a form of security, women's limited capacity for property ownership has a detrimental effect on their access to finance (Antwi-Agyei et al., 2015). Lack of land tenure security causes less access to loans, resulting in inefficient land use and poorer yields (United Nations, 2015). Africa's land tenure structures heavily restrict women, which makes it difficult for them to adapt to climate change (Fletschner & Kenney, 2014). In addition, the likelihood of women in Africa having the knowledge and resources needed to improve farming is generally low (Beuchelt & Badstue, 2013), thereby limiting their influence in decision-making on farm management and climate change (Phiri et al., 2022).

In some African countries, village leaders, kinship groups, and extended relatives are involved in aspects of property transfers that exclude women from land ownership (Doss et al., 2015). Land allocation and heirship, for instance, may fall under the jurisdiction of older men, while purchases and/or alienations outside of the bloodline require the approval of village chiefs (Doss et al., 2015). Men in many African countries primarily own land, while women are often engaged in the ownership and breeding of livestock. This ultimately makes women more vulnerable to the effects of climate change, as the malnourishment of animals brought on by inadequate meadows and water shortage has an intense impact on livestock farming (Gumucio et al., 2020).

Additionally, women lose their rights due to pest incidences as they are unable to afford prevention remedies (Palacios-Lopez et al., 2017). This is exacerbated because they often use most of their income for the sustenance of their children, unlike their male counterparts, who usually have money set aside to address the consequences of temperature and rainfall unpredictability (AfDB, 2016). Detrimental impacts of global warming, namely the drought that has been extensively reported in several African countries, have made women journey hundreds or thousands of miles in the hunt for meadows and water for their animals and family (Phiri et al., 2022). This implies that, in the event of unfavourable weather patterns, women will have little or no production on their farms (Njue et al., 2018).

3 Gender Inequalities and Access to Meteorological Information

Information and technology access are critical to mitigating climate-related hazards that undermine productivity in agriculture (Patel et al., 2021). Accessing weather and climate information can help Africa adapt

to global warming (Eissle et al., 2019; Gumucio et al., 2020). This is because a significant number of African women are exposed to extreme weather, as they rely on rain-fed farming (World Bank, 2016). According to Kristjanson et al. (2017), a number of nations in Africa are contending with widespread poverty and are regularly affected by climate changes that require specialised information and timely interventions. Climate information is defined as a collection of information or facts and scientific proof of knowledge about weather patterns created systematically at different time frames for a variety of contexts (Eissle et al., 2019).

Climate change in the form of flooding increases the prevalence of water-borne illnesses like malaria, especially among children and women. Timely forecast is essential in managing the unpleasant consequences of flooding (Amegnaglo et al., 2017) as it provides the opportunity to respond appropriately. Many cultural, socio-economic, and institutional factors are entwined with changes in weather patterns and may either support or impede coping capacity (Shackleton et al., 2015). Several studies (e.g., Henriksson et al., 2021; CARE International, 2010) suggest that males are more likely to have access to resources and hence may be more adaptable than females. However, others (e.g., Goh, 2012) find that information and communication technologies are progressively transforming the economic prospects of disadvantaged and low-income women. Most women in Africa are much more susceptible to under-nutrition since they depend on subsistence farming and are exposed to food insecurity. Due to power disparities occasioned by gender structures, women have limited access to assets and are less empowered in decision-making processes (Jerneck, 2018). Compared to men, women often have less education and fewer career options, making farming their primary source of livelihood (Henriksson et al., 2021). Women's poor access to information and extension services may prevent them from using adaptive strategies (Henriksson et al., 2021). Other challenges to the uptake of agricultural systems in Africa include inadequate funding, limited agricultural inputs, and unsecure land rights (Goh, 2012). Men often have greater access to information than women due to property ownership, education, and travel (Nyasimi et al., 2018). Consequently, they are prominent in decision-making on issues of agriculture, power generation, water management, and preservation of natural resources, amongst others (Phiri et al., 2022).

Although there are many sources of information, women access fewer outlets than men. For instance, in South Africa, women in agricultural areas did not have the same access to climate forecast information as men

(Archer, 2003). Men favoured radio as a source of information, while women preferred seasonal predictions offered by extension staff in a "teach-in" setting (Archer, 2003). In another study, Roncoli et al. (2009) discovered that gender, ethnicity, and politics significantly impacted climate prediction information. For instance, participatory workshops in Burkina Faso showed that the majority of attendees (93.44%) were men (Roncoli et al., 2009). Additionally, Kristjanson et al. (2017) found that across Africa, women farmers had much less access to several types of agricultural (e.g., CSA practices) and climate-associated knowledge compared to men (Kristjanson et al., 2017). However, there may be exceptions to women's limited information depending on the context within which they live (Kristjanson et al., 2017). For example, in Kenya, women report having more access to agricultural, animal production and post-harvest management information compared to men (Twyman et al., 2014).

In many settings, women rely mostly on non-institutional sources and local relationships than men, who typically prefer to explore broadly for sources of climate and agricultural advice (Kristjanson et al., 2017). For instance, in Colombia, both genders mostly get their knowledge through family members, technicians, radio, television and other external sources. Nevertheless, a greater proportion of men than women claimed to have access to these informational sources (Twyman et al., 2014). Media and non-governmental organisations (NGOs) in Nicaragua are the principal providers of agricultural and climate-related information. Men have more access to these sources than women (Kristjanson et al., 2017). In Africa, Senegalese women seek forecasts on dry seasons and rain stoppage dates as they plant afterwards due to a lack of influence over the factors of production (Tall et al., 2014). Men in Uganda utilise mainstream media, while women prefer loudspeakers or news from village elders and other local organisations. In Ghana, men organise agricultural production using weather information (Jost et al., 2016).

Studies (e.g., Behrman et al., 2014; Jost et al., 2016) show that women are more likely to have time constraints that limit them from participating in local climate adaptation initiatives or modification of policies that increase their workload. Rural women are more likely to be affected by environmental stress in farming systems because of increased family and agricultural duties. An increase in women's workload and a decline in the asset of low-income households are two of the most important effects of environmental stress (Goh, 2012; Jost et al., 2016). According to Huyer

(2016), when women have the opportunity to acquire and deploy knowledge effectively in the management of resources, it narrows the gender gap. However, the significant influence of cultural systems persists, giving men a comparative advantage in adjusting to the adverse repercussions of climate change (Diouf et al., 2019; Stucker & Lopez-Gunn, 2014).

In sum, women's access to information on the effects of climate change, weather, and alternative agricultural production strategies is a critical factor in adaptation and mitigation (Huyer, 2016). It is pertinent that stakeholders comprehend the many risks of global warming and the unequal ramifications of these challenges. Africa primarily relies on rain-fed agriculture, which is especially susceptible to temperature fluctuations (Serdeczny et al., 2017). Hence, all hands must be on deck to ensure the sustainability of the sector. For example, just 3.7% of Eastern Africa's agricultural land is watered. Knowledge regarding precipitation and temperature occurrences should be disseminated to all stakeholders, especially rural women (Serdeczny et al., 2017). For farmers to make effective decisions, they must have access to practical meteorological information (Vincent et al., 2013). Periodic projections provided by weather forecasts facilitate the formulation of risk reduction measures. Farmers who are subject to a definitive agricultural production schedule will profit immensely from a detailed daily forecast (Vincent et al., 2013).

4 Gender Dimension in the Mitigation and Adaptation to Climate Change in Livestock and Crop Production in Africa

In Africa, agricultural productivity often displays a gender disparity, with female farmers' output being lower than that of male farmers (World Bank, 2015). Women and men employ productive inputs differently, which has been explained by ineffective intra-household allocation, women's limited access to cash crop markets, as well as cultural, political, and economic factors (World Bank, 2015). Female farmers in sub-Saharan Africa are particularly vulnerable to climate change and are impacted disproportionately (Beuchelt & Badstue, 2013). The impact of gender differences in agriculture is estimated to be $100 million in Malawi, $105 million in Tanzania, and $67 million in Uganda (World Bank, 2015). The value of crop yield per unit of cultivated land varies from 5% to 25%, depending on the nation and crop (World Bank, 2015). With around

40%–60% of African women active in agriculture, strengthening their resilience to climate change is an essential step towards improving food security in the region (Doss et al., 2018).

The amount of productive land, techniques, and accessibility to resources are determinants of the agricultural sector's vulnerability to climatic shocks. One of the most urgent concerns for African farmers is how to deal with these problems to mitigate the consequences of harsh weather as a result of the increasing incidence of global warming. Farmers are adjusting their cropping techniques in response to climate change, with differing effects on crop income availability, control, and relative workloads (Jost et al., 2016). The capacity of both men and women to acquire and employ agricultural resources to meet their needs will significantly impact production judgement and projected outcomes. For instance, women in the Benin Republic opted for maize and rice to supplement household consumption, whereas the men opted for cotton, which is heavily subsidised (Toulmin & Guèye, 2005). Men in Ghana were found to strongly favour growing food for commercial purposes (Doss, 2002). Conversely, women participate across the agricultural production value chain (Doss, 2002); which may enable them to diffuse the effects of climate change (Doss, 2002).

Women are particularly constrained because of their relative lack of access to chemical fertilisers, which are usually purchased at market-determined prices (Mutenje et al., 2019). For instance, Ethiopia's agricultural variation is explained by gender inequalities in agrochemical use (Ragasa et al., 2012). Thus, women frequently depend on natural manure, which is produced by domesticated cattle. In Senegal and Benin Republic, women's fields are often planted last as men predominately employ the available agricultural assets such as donkey carts and labour. Consequently, the harvesting of crops by women is delayed until the end of summer, making the venture susceptible to failure during an extended dry season (Kinkingninhoun-Mêdagbé et al., 2010). In Kenya, women are more likely to be seen using manual farming implements rather than mechanised processes to execute a range of farming activities (Wanjiku et al., 2007). Thus, this shortage of alternatives limits the avenues for female farmers to mitigate the broadening effects of climate change (Doss & Morris, 2000).

Food security is threatened in low-income and agriculture-based economies like Africa due to rising temperatures, decreased precipitation, and increased rainfall variability (Dixon et al., 2001). Therefore, the effects of

climate change are adverse to nations where agriculture is the primary source of income, many of which are in tropical Africa. Agriculture influences climate change by releasing greenhouse gases (GHG) from various farming practices (Maraseni et al., 2009). Evidence shows that growing carbon dioxide emissions are causing the atmosphere's climate to change quickly (Stern, 2006). This is why Africa is anticipated to warm faster than the rest of the world, with rainfall becoming more unpredictable (Field et al., 2014). Droughts, floods, dry spells, and decreasing precipitation are becoming increasingly common across Africa's agro-ecologies (Belay et al., 2017). As a result, smallholder farmers' ability to produce crops and livestock is jeopardised (Belay et al., 2017). Household demographics, farm size, income, market accessibility, animal output, access to climate information, and extension services affect farmers' ability to select appropriate adaptation strategies. This indicates the necessity of providing institutional, policy, and technological support for various smallholders to facilitate indigenous adaptation techniques (Belay et al., 2017).

African farmers often alternate farming methods in the light of regional climatic variations and associated problems (Otzelberger, 2011). This outlook is further exemplified in the knowledge application regarding intervention programmes, strategies, and plans to mitigate the effect of global warming on food production (Bradshaw & Fordham, 2015). Both men and women comprehend the effects of global warming and adopt response techniques that embrace enhanced agricultural varieties. Farmers use various techniques to deal with climate change, including shifting crop growing dates, recurrent planting, administering agrochemicals, diversifying crop production, adopting different agricultural techniques, including automation, and producing better cultivars.

Farmers in developing countries also depend on their livestock, especially as it is a vital source of nutrition and provides a valuable source of income (Tall et al., 2014). In addition, livestock serves as a means of transit, a provider of fertiliser, an energy source during droughts, and a form of insurance for peasants. As the poor typically do not have access to the traditional financial system, livestock functions as "a bank account" (Randolph et al., 2007). However, the level of livestock dependency, coupled with food security, can vary between men and women (Gallina, 2016). There are considerable differences in the proportions of men and women who own livestock. In Ethiopia's combined cultivation agricultural system, men and women possess cattle, goats, and sheep, though

men account for a larger share of livestock (Yisehak, 2008). Women possess more domestic animals than men in Kenya and Rwanda (Aklilu et al., 2013). In Nigeria, women nourish and provide for vulnerable livestock, clean barns and dairy cattle, and make butter, while men regulate concerns of animal health and disease (Ayoade et al., 2009).

While measures to address food insecurity brought about by climate change may be characterised by gender inequities, the role of women in livestock farming has received little attention (Lambrou & Nelson, 2010). Although women are involved in livestock farming, they do not have complete control over consumption. In Ethiopia, where women's involvement cuts across all facets from production to sales, men only participate when the income flow from raising livestock increases. Women who care for cattle in Africa are more susceptible to climate change than men. They have less economic influence over assets, which is attributable to their low technical and intensive farming skills. To support women in adapting progressively to the harmful effects of climate change, these inequalities must be resolved.

5 Gender Dimensions in African Forestry Management

Women rely on a variety of economic sources, both agricultural and non-agricultural, to make ends meet. Non-agricultural sources of rural family income have been found to be important in empirical studies (e.g., Vedeld et al., 2004), but their benefits are frequently neglected in poverty surveys (Cavendish, 2000). Given the rising threats of climate change to agriculture, boosting and sustaining revenue from non-agricultural activities would increase farming households' adaptive capability. Forest benefits differ based on socio-economic variables (e.g., wealth status, family size, education level, sex, and age of the household head) (Abebaw et al., 2012), and such benefits include access to forests, markets, institutional systems, marketing channels, and prospects for off-farm employment. Forest revenue is especially essential, as poorer households earn a bigger share of their income from low-value, high-volume forest goods (Escobal & Aldana, 2003). Forests are one of the non-agricultural assets that sustain rural livelihoods worldwide, particularly in developing countries. According to a World Bank (2016) report, 350 million people worldwide depend on forests for survival, and many

more rely on these resources for supplementary income. Forests provide provisioning services to the poor, particularly during times of need, and contribute to livelihood security in rural areas (Vedeld et al., 2004). Forest product collection and sale might also promote building assets and investing in a more meaningful existence that fosters educating children, acquiring agricultural inputs, or investing cash in activities that create extra income.

Despite their deep relationship with the environment, women lack secure ownership over land and related natural resources like forests and still contend with discrimination in their occupation. Also, decision-making processes for disaster risk reduction typically exclude the knowledge and suggestions of women. Gender mainstreaming in climate change mitigation entails reducing inequality and reliance on forests and natural resources. In Africa, females' land ownership status is not equivalent to that of male players, and their accessibility to forests and environmental assets is limited. For instance, Burkina Faso's restriction of women's access to and ownership of forest land assets is associated with discrimination against women (Coulibaly-Lingani et al., 2009).

Africa's forests are fertile for the gathering of non-timber forest products (NTFPs). According to Ruiz-Perez et al. (2002), gender is a key issue to consider when analysing forest reliance. Men and women typically have different responsibilities regarding the gathering, cleaning, and selling of forest resources. In most underdeveloped nations, women are responsible for fulfilling household fuel and energy needs, whereas men are significant extractors of large products such as timber (Prema, 2002). For instance, in Cameroon, NTFP extraction is closely tied to the tasks and activities of various household members, with women collecting more food products in fields, stubbles, and secondary forests. Men are more generally aware of the major forest species observed during hunting activities (Russell & Tchamou, 2011). In Congo Basin, women organise and control Mid-Market Enterprises (MMEs) for the gathering of NTFP (Dkamela, 2001). Forest-based agriculture is done in the Congo Basin using a shifting cropping technique, with food crops as the principal (Bayol et al., 2012). Men are primarily responsible for clearing the main forest for agriculture, while women prepare the soil, plant, tend, and harvest the crops. However, men also cultivate cocoa as cash crops along with other food crops (Brown & Lapuyade, 2001).

Although women generally dominate the gathering and marketing of NTFPs, they lack security of access to these goods, land, and natural resources. In general, women in sub-Saharan Africa rely more on forest resources for a living but have less access to financing (Asfaw et al., 2013). For instance, in Cameroon, a woman gets access to forest resources in most circumstances because of her relationship with the men in the family (Diaw, 2005). Local elites dominate village forest management committees, while other groups are excluded (Oyono et al., 2005). Women are mostly underrepresented on these panels and do not occupy major decision-making positions (Bandiaky & Tiani, 2010). In Congo Basin, the management of animals and wood is typically the duty of males (Tiani, 2001).

6 Socio-economic Implications of Gender Inclusivity in Africa's Agriculture Under the Changing Climate

African women are vital to the continent's agricultural economy. They constitute the sector's backbone, accounting for 52% of the entire population and accounting for nearly 50% of all agricultural labour on farms in sub-Saharan Africa (Njobe & Kaaria, 2015). In addition, African women produce 60%–80% of the food on the continent (Njobe & Kaaria, 2015). However, African women continue to be under-leveraged in the agricultural sector since neither their level nor the quality of their engagements results in long-term socio-economic development advantages (Njobe & Kaaria, 2015). Women who work as farmers, livestock owners, industry workers, and business owners frequently have limited access to productive resources compared to their male counterparts (ILO, 2020). Women seem to have little control over farm yields and, compared to men, are unable to obtain loans or agricultural inputs. Building the capability required for low-income countries to handle catastrophic occurrences like significant floods is crucial. The severe restrictions women experience in many facets of life are primarily the result of ineffective, gender-blind legislation and ingrained patriarchal customs. In terms of having access to land, having control over resources, being able to command and get paid labour, having the capability, and having methods for income diversification, gender inequality persists.

To encourage and promote equal access to land and resources, increase production, and manage environmental and soil conservation, legal and structural impediments must be removed, to give room for gender-sensitive land tenure regulations. Some African nations have established legislation recognising women's right to land ownership; the political will to implement these legislations is critical to closing the gender gap that will benefit current and future generations. A woman's ability to manage finances gives her more influence over important family decisions, especially those concerning her children. Families with female decision-makers spend more money on food, healthcare, education, and the nutritional needs of their children. Raising a generation of Africans who are better fed, educated, and able to contribute to personal and national development in all sectors is important to promoting gender equality (AU, 2015).

If women had a similar degree of control over resources as men, Africa's agricultural output would likely increase. For instance, in Ghana, women contribute 70% of crop production while men contribute 30%. Reducing gender disparities in agricultural output might abolish starvation for more than 100 million people worldwide (FAO, 2020). According to the UN Food and Agriculture Organization (FAO, 2010/2011), advances in agricultural productivity alone might lift 100–150 million people out of poverty. Similarly, research reveals that gender is not just a significant moral issue but also a vital economic concern (AU, 2015). The increased inclusion of women in sustainable farming is a potential game changer in lowering the impact of climate change (AU, 2015). In truth, altering the status quo requires massive effort to achieve a deliberate, planned, and far-reaching shift in the present gender dynamics.

Women's inclusion in socio-economic activities helps boost agricultural output, decreases poverty and hunger, and supports economic growth. The scaling back of limits imposed by the gender gap in agriculture has the potential to deliver enormous rewards for society (Adeola et al., 2018; Adeola et al., 2021; Aronu et al., 2022). In brief, empowering women farmers and enacting laws to close the gender disparity may positively affect women and their households, towns, and nations. For Africa's expanding population, which is expected to triple in the next 90 years, bridging the gender disparity is integral to economic well-being and food security.

7 Conclusions and Implications

Climate change necessitates new methods of agriculture; hence farmers' activities must be adaptable to the changing environmental conditions, and gender is important to this transformation in the short and long terms. Agriculture is a critical component of women's livelihoods worldwide, particularly in least developing countries (LDCs), where four-fifths of economically active women describe agriculture as their principal economic activity (FAO, 2011). As males shift to seasonal or paid labour, more females are participating in agriculture, even as women farmers have limited access to productive inputs and resources (FAO, 2020). To improve women's access to agriculture under the changing climate, proper utilisation of new agricultural methods and technology can assist women farmers in managing the diverse challenges of climate change. They may also have different priorities when it comes to implementing new technology. Farms owned by female-headed households typically have fewer farm labourers at their disposal. Women and men have various resources accessible to them and distinct time restrictions. Agricultural programmes to assist farmers in adapting to climate change must be resource and demand suitable (Huyer, 2015).

Farming and climate information are critical for agricultural development and food security in a changing environment (Tall et al., 2014). However, women have less access to development programmes and participate in fewer demonstration sessions (Ragasa, 2012). To improve women's access to agriculture in Africa, creating multiple communication channels will be beneficial (World Bank, 2020). Women's access to radio, extension events, SMS, and voice messaging, as well as local groups, clinics, and schools, must all be improved (Tall et al., 2014). Notably, the communication platforms and message content must be tailored to diverse audiences. Other departments beyond agriculture may occasionally have a wider audience (for instance, through campaigns emphasising nutrition's role in health). Collaboration amongst other ministries, such as agriculture, health, and the environment, will aid in spreading messages. In addition, partnerships with civil society, colleges, and community-based organisations (CBOs) will help broaden information reach and accessibility (Huyer, 2015).

Given the right environment and resources, women may become successful innovators, capable of inventing new technologies, as well as adapting current ones. However, simply having the ability to innovate is not enough; an enabling environment must support women's innovation

processes by giving access to facilities, services, and incentives. Understanding and recognising women's engagement in value chains will be critical to ensuring that the private sector incorporates gender considerations into market access and climate change insurance activities. To improve women's access to resources, especially in agriculture, women farmers must be acknowledged as successful innovators with distinct objectives and interests, and they must work with others to develop and build appropriate labour-saving solutions. Creating tools to encourage and legitimise women's climate-change-related inventions will enhance livelihood outcomes for rural and urban dwellers (Huyer, 2015).

Women are prominent land managers impacted by climate change policies affecting agriculture and forestry. Limited understanding of the practicalities of women's careers, unjust laws, income utilisation preferences, educational restrictions, and childcare responsibilities are among the causes (UN Women, 2015). Increasing women's voices at all levels of policymaking is likely to result in the fairer allocation of the benefits of climate change programmes. If women and men are represented equally in leadership positions, it will facilitate policy translation into action (Huyer, 2015). In addition, support for mitigation actions will undoubtedly be more successful if it leverages women's traditional strengths (AfDB, 2011). Priority should be given to women's land ownership, participation in crisis prevention and response, and reconciliation initiatives.

Women are crucial to the maintenance of rural livelihoods and family sustenance through the creation of greenhouses (Howard, 2006). They are the keepers of traditional knowledge on crop biodiversity. Cropping systems are more resilient to the adverse effects of climate change when crop production is maintained and diversified (Altieri et al., 2015). Therefore, it is necessary to educate women about current agricultural techniques and, more crucially, to improve their access to valuable tools and resources (Farnworth et al., 2016). It is essential to provide female farmers with the requisite knowledge, instruments, and resources to succeed (Falk & Bessonova, 2018). This is an important initial step to minimising gender disparity in agriculture and a strategic paradigm for managing climate change and ensuring national sustainability. Therefore, empowering women in agriculture is crucial for achieving sustainable development goals and addressing climate change.

In conclusion, gender disparities in agriculture, particularly in land rights and access to resources, pose significant challenges to the livelihoods and well-being of women farmers in Africa. These disparities are

further exacerbated by the impacts of climate change, which disproportionately affect women. Addressing these gender inequalities in agriculture and increasing women's access to resources and decision-making can improve women's livelihoods and contribute to the achievement of sustainable development goals in Africa. Policy interventions and programmes that promote gender equity and provide women with the necessary resources and support can help build resilience to climate change and improve regional food security. Therefore, achieving gender equality in agriculture is crucial to building resilience to climate change and improving food security in Africa.

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PART II

Technology and Climate Change

Leveraging ICT for Climate Change Adaptation in Africa: A Focus on Women

1 Introduction

The United Nations (UN) Climate Change Conference of Parties (COP26) took place in Glasgow, United Kingdom, in 2021, bringing together a diverse range of stakeholders, including policymakers, scientists, activists, business leaders, and women, to discuss the many dimensions of climate change (United Nations, 2021). The conference aimed to build support for consistent progress towards the Paris Agreement and UN Framework Convention on Climate Change, which aim to achieve zero global emissions by 2050 (Masson-Delmotte et al., 2018). Most of Africa's key economic sectors, such as agriculture, water, manufacturing, and tourism, which are crucial to women, heavily rely on land and other natural resources and are highly vulnerable to the impacts of climate change (Balogun et al., 2020). This is compounded by the ongoing challenges of poverty, malnutrition, water shortages, and epidemics, all of which are linked to climate change. For example, the more frequent and intense rains and floods in Maputo, Mozambique's main city, have resulted in widespread water stagnation, leading to the spread of malaria and cholera epidemics (Balogun et al., 2020).

Climate change is a wide-ranging ecological shift in the current and future functioning of the climate, with the potential for fatalities to

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ecological creatures and the destruction of natural habitats (IPCC, 2014). The gradual progression of climate change has evidently increased oceanic and atmospheric temperature levels and is associated with the intensity of different categories of ecological disasters (IPCC, 2014). In recent decades, Africa has experienced a yearly increase in flood and storm disasters. Similarly, studies have shown that floods have increased in frequency due to climate change across many parts of Africa (Bryan et al., 2009). These manifestations and climate change consequences pose peculiar risks for Africa, considering its distinctive geography and human capital concerns, which have disproportionate effects on women. This explains why the continent must prioritise climate change adaptation and other connected environmental issues (Bulkeley et al., 2014). Thus, at the continental, national, and community levels, collaborations involving African women must be centred on the development of effective climate adaptation and mitigation policies.

An examination of information and communications technology (ICT) possibilities in the context of climate change reveals its relevance not just as a tool for processing and sharing data but also as a research platform for environmental preservation, particularly for African women. The task of building Africa's regional resilience to a changing environment is considerably dependent on technology innovation and adaptability (Ospina & Heeks, 2010). According to research (e.g., Norris et al., 2008), ICT may assist fragile ecosystems in managing climate change shocks and uncertainties by enhancing their adaptive capacity.

The convergence of the digital and net-zero imperatives is gaining momentum in scholarly discussions (George et al., 2021; Balogun et al., 2020). While many of the important impediments to net zero from the digital viewpoint have been highlighted in different conversations, there has yet to be a consensus regarding the presentation of a comprehensive perspective (Chen et al., 2016; George et al., 2017). Most African nations continue to experience the effects of climate change as there is insufficient digital infrastructure, pervasive energy poverty, challenges with scaling digital urban farming, and the dissemination of locally relevant digital content. Another drawback is low e-literacy fuelled by the conventional reliance on traditional data-gathering methods and resistance to digitalising farming processes, which particularly affects African women. This chapter analyses a wide range of interconnected ICT issues and contributes to the conversation on climate change, digital technology, and the dynamics of adaptive processes in Africa, with a focus on the experiences and perspectives of African women.

2 Transformational Use of ICT for African Women

Some years ago, the broad scale of ICT integration in practically every industry in Africa (e.g., business, banking, medical, engineering, and agriculture) could not have been conceived particularly for African women. ICTs are fundamental to the development of a digital society, both in public and commercial respects. It has evolved remarkably in terms of global range and accessibility, particularly regarding the possibilities such provides for African women. The ICT industry has become socially and economically significant and constitutes a dominant economic pivot in sub-Saharan Africa (etransform Africa, 2012; Evans, 2019; Evans & Oni, 2022). As the evolution of ICT has advanced the frontiers of innovation and development, culminating in the fourth industrial revolution (Balogun et al., 2022), never in the region's history have African women been as interconnected.

Igwilo and Sibindi (2021) state that ICTs comprise computer systems, embedded processors, audiovisual and data processing, telecommunication, transmission networks, and World Wide Web (WWW) technologies. These technologies enhance the execution of tasks and other activities at both the individual and organisational levels (Igwilo & Sibindi, 2021). ICT is non-exclusive because it gives an equal opportunity for all (Hernandez & Roberts, 2018), including African women, to reap its inherent benefits. Studies (e.g., Oginni & Moitui, 2015; Hernandez & Roberts, 2018; Nothias & Cheruiyot, 2019; Balogun et al., 2020) have emphasised that advancements in ICT, especially in developing economies, have enabled the leveraging of access to digital dividends. These dividends could be social or economic drivers such as environmental, financial inclusion, health, information, economic, and political empowerment for African women.

Although Africa trails behind the rest of the world in terms of ICT readiness, improvements have been made in increasing accessibility and penetration (etransform Africa, 2012). ICT has become more available and affordable as a platform for transforming financial institutions, e-government services, health, education, businesses, and personal effectiveness. For instance, in recent years, an increase in internet usage was recorded at 62.5% of the overall population, with 5.31 billion individuals accounting for 67.1% of the world's total mobile phone population (DataReportal, 2022). The ICT surge in Africa is primarily defined by

investments in communications infrastructure and fixed cellular devices, which have rapidly shifted to the mobile platforms of electronic communications. The improved penetration and effectiveness of ICT infrastructure allow for new possibilities and opportunities that enhance the quality of life for African women. The continent is currently witnessing the rapid expansion of the mobile internet facilitated by the wide choice of smartphones and inexpensive tablets. As a result, it is increasingly less complex to conduct business operations due to better coordination, communication, and cost-effectiveness (eTransform Africa, 2012), which will have broader socio-economic implications in the coming decades for African women.

In effect, the use of diverse technologies has been fundamental to creating an enabling environment for international and local trade, benefiting African women and other marginalised groups. Africa's residents and enterprises, including African women, are increasingly in need of financial initiatives that will enable them to compete favourably as the continent develops and integrates with the global economy (Balogun et al., 2020). ICT and creative business concepts have played a significant part in financial inclusion, particularly for African women. For example, lowering the cost of transactions helps eliminate the barriers African women farmers encounter in applying for financing and travelling to locations for resources. Access to mobile payment providers also aids the reintegration of previously unbanked African women farmers, decreasing transaction costs and liquidity issues.

Evidence that ICT is beneficial in solving pertinent issues with mother and child health and infectious illnesses in rural Africa is developing (etransform Africa, 2012). So far, numerous e-maternal health services have been tested across the continent for a wide range of uses, such as online consultation, medical data management, recommendation, and supply chain control, particularly for African women. Some nations, such as Rwanda, have put in place a comprehensive national e-Health system that tracks patients' information, keeps tabs on infectious illnesses, and manages medical supply chains. Such initiatives might support new business and service models with the right technological infrastructure and visionary leadership, and can greatly benefit African women.

There is no doubt that ICT, ecology, and climate change have a complicated relationship (Shehzad et al., 2021). In Africa, the level of expertise in implementing ICT for climate change adaptation is lower than

obtainable in other sectors such as health and education. Despite this, there are many ways to achieve the convergence of ICT and adaptability practices. Several ICT initiatives and programmes are now being conducted throughout Africa to help with climate change adaptation, particularly for African women. The Climate Change Adaptation Support Programme for Action Research and Capacity Development in Africa is a major regional climate change adaptation programme with a cost of over $50 million (eTransform Africa, 2012). ICT may be employed for activities such as gathering and disseminating agro-meteorological data, monitoring flood projections, and detecting illnesses like malaria and encephalitis, all of which have a significant impact on the lives of African women.

3 Climate and the Transformative Impact of ICT

Studies (e.g., Walter et al., 2019; Roger et al., 2022) have noted ICT as a groundbreaking innovation for achieving long-term sustainability. It involves changing the trajectory of a relatively inefficient system and reconfiguring it to be more functional and productive. The use of ICT digital farming tools in industrialised nations has been linked to transformation in large-scale farming, a benefit which is scarcely available in many developing nations (eTransform Africa, 2012). Africa is still largely typified by subsistence and nomadic farming, making it challenging for African women to access technology and information that could improve their farming practices. Consequently, low-yielding output, information deficit, poor market facilitation, and low financial intermediation services are characteristic of the continent's agricultural landscape. Traditional processes relating to climatic data are not adequately documented, weather services are not readily available, and in some cases, there is a lack of understanding of the existence of climate services (Tumbo et al., 2018), which places African women at a comparative disadvantage.

Many of the seemingly insurmountable social concerns related to climate change now have the potential to be conclusively addressed by the effective application of digital technologies (George et al., 2021). The World Economic Forum (WEF) details how digital technology may dramatically increase the efficiency of industrial, manufacturing, and agricultural operations by automating labour-intensive tasks (World Economic

Forum & PwC, 2021), which may be particularly beneficial for African women. AI-powered systems might contribute to a 4% decrease in global emissions by 2030 (World Economic Forum & PwC, 2021). For example, researchers are developing a computerised tool to help improve, monitor, and predict hotspots and provide important meteorological and climate-related data (Balogun et al., 2020), which can also aid African women in sustainable climate change adaptation.

Sustainable climate change adaptation in Africa can be accelerated through the adoption or increased use of digital technology, otherwise known as digitalisation. While the concept has multiple meanings, its fundamental feature is "the way many domains of social life are restructured around digital communication and media infrastructures" (Brennen & Kreiss, 2016, p. 1), which includes making the environment smarter and fostering connections to optimise efficiency in resource utilisation (Fertner et al., 2019) and thus benefiting African women.

Digital technology involves the use of software support to upgrade conventional methods to promote effective, convenient, and environmentally friendly practices. The use of these technologies can enable Africans, including African women, to respond to dangers like flooding and droughts by helping to create hazard maps, which include information on important risks linked to climate change (Balogun et al., 2020). For instance, in analysing or interpreting weather data, digital technology processes previous observations and establishes the framework for a more accurate evaluation of climatic changes by forecasting extreme weather occurrences and responding to them (Munang et al., 2013). The availability of verifiable meteorological and climatic information helps enhance natural disaster predictions, leading to improved early warning systems (EWS) and disaster response (Balogun et al., 2020), which can also benefit African women.

Scholars (e.g., Cavazza et al., 2018; Grieve et al., 2019; Balogun et al., 2022) have noted that digital technology has given rise to artificial intelligence (AI), such as driverless or ground robots and unmanned drones, which enhance smart solutions to potential environmental challenges, increase production output, and assist in rational decision-making, providing opportunities for African women. African economy can be boosted by automation, supported by digital technology, and data produced by linked devices is a source of innovation that encourages the effective utilisation of raw materials (United Nations, 2014), which can potentially benefit African women.

4 Emerging Advanced Technologies and Climate Change Mitigation Impacts

Africa has become increasingly vulnerable to the negative effects of climate change (Chijioke et al., 2011). Given the continent's already hot temperatures, climate change may further escalate the possibility of environmental hazards. Agriculture is one of the many sectors where climate change has an indelible impact. Hence, deploying the right intervention strategies, especially proven and emerging eco-friendly technologies, is crucial to support agricultural resilience. According to Dow et al. (2013), to sustain high agricultural yields and improved nutritional benefits, adequate technology capable of mitigating climate change impacts in Africa is crucial. For example, in South Africa, the use of advanced technology like tillage and fertiliser increased maize yield in a changing climate (Walker & Schulze, 2008). In Swaziland, farmers' native understanding of climate change mitigation, exposure to technology, financial assistance, and extensions boosted sugarcane output (Knox et al., 2010). Despite these efforts, it is important to note that African women, who constitute a large portion of the agricultural workforce, may face unique challenges in accessing and utilising these technologies.

In recent times, advanced ICT techniques like geographic information systems (GIS) and satellite remote sensing have made notable contributions in the sphere of climate change adaptation and mitigation (Okediran et al., 2018). Specifically, satellite remote sensing enables the seamless transmission of conventional radio programmes via mobile phone medium (Okediran et al., 2018). Thus, people can communicate remotely regarding data threats, cyber-attacks, and crisis management related to climate variability and change (Rafoss et al., 2010; Ospina & Heeks, 2012). Similarly, the agricultural carbon sequestration technique is another critical ICT measure to effectively address the increasingly negative consequences of climate change in developing nations (Papageorgiou et al., 2009). Undoubtedly, advanced ICT will continue to be an effective tool for implementing climate change mitigation and related solutions (Niyibizi & Komakech, 2013; Rafoss et al., 2010). Geographic information systems (GIS), e-governance, early warning systems (including telemetry), and wireless communications are all important ICT options for climate change adaptation and mitigation (Sala et al., 2010). Nevertheless, it is crucial to ensure that these ICT solutions are designed and implemented with the specific needs of women in mind.

Some of the emerging advanced technologies to mitigate climate change impacts for African women are as follows.

Integrated soil management practices (ISMP): This advanced technology tool features techniques like zero to reduced tillage, sparing fertiliser use, nitrogen management, crop residue assimilation, manure, mulch, compost, cover crops, and suitable supplemental irrigation (Lal, 2008). The implementation of ISMP through preservation and zero tillage can reduce energy usage while increasing carbon stocks in soil. However, coordinated implementation is important for the resilience of agriculture, especially for African women. According to Yitbareket et al. (2013), a study on the soil qualities of western Ethiopia's forested, grazing, and agricultural fields in relation to changes in land use found that the influence on the soils of the farmed fields was detrimental to the majority of criteria. The study revealed that land-saving technology plays an essential role in the adaptation and climate change mitigation processes (Yitbareket et al., 2013). The ISMP also includes the management of soil and water resources (Lal, 2008; Smith & Powlson, 2007). The choice of innovative technologies that can improve soil structure and water management is crucial for soil recovery from biological and physical deterioration (Bossio et al., 2008), and it is especially important for African women who are often disproportionately affected by the negative impacts of climate change.

Biotechnology: According to Littlechild et al. (2013), modern science can aid in climate change adaptation and mitigation. Considering the fact that climate change will exacerbate adverse effects on the environment, harsher weather is expected. It is essential to create new, diverse biotech crops that can endure the biotic and abiotic stress brought on by climate change (Goodwin & Piggott, 2020). The rise in ICT tools for climate change mitigation in Africa through biotechnology has birthed genetic modification (GM). There is some proof that genetic modification (GM) technology can significantly decrease GHG emissions. For example, genetically modified canola, a genetically modified crop, fosters nitrogen usage efficiency and decreases the impact of freshwater ecotoxicity, eutrophication, and acidification (Strange et al., 2008). This innovation is an energy efficiency technique that can save natural gas and also reduce fuel consumption for African women.

Renewable energy: To reduce the region's reliance on fossil fuels, such as wood fires and coal-fired power stations, which contribute to the bulk

of GHG emissions, a wide range of renewable sources are being promoted (Otte, 2013). In emerging nations, a variety of energy sources (e.g., solar, wind, hydroelectric, biomass, hydro) are projected to become integral to climate change mitigation (Ondraczek, 2014). Increased energy availability for household use and electricity through renewables can provide societal advantages, such as economic freedom and enhanced access to better health care and education for African women. Solar energy is the most prevalent source of renewable power in the world as it can be deployed for a variety of uses, such as cooking, heating, drying, generating electricity, and purifying water for African women. Studies (Fang & Li, 2013; Otte, 2013; Ondraczek, 2014) have shown that the use of solar energy is rising, given the multiple energy pilot projects in numerous developing nations to mitigate climate change. For instance, there is evidence that hydroelectric generators may be used on a modest scale for industrial and agricultural applications (Zhao & Wan, 2014). Furthermore, other forms of renewable energy, like geothermal energy, can improve African women's ability to adapt by boosting food production, lowering child mortality, and raising general standards of living.

Plant breeding: This has its roots in the early days of agriculture, when healthy plants were moved to new areas to alter their genetic makeup. Reproduced field experiments, controlled crossings, statistical analysis, formal research design, hybrid breeding, proven track record estimations, and accurate scale-up yield assessment were among the advancements in plant breeding during this time (Watson et al., 2018). With the high demand, in these modern times, to fulfil the demand for crops like wheat (*Triticum aestivum*), rice (*Oryza sativa*), and maize (*Zea mays*), traditional breeding techniques are inadequate (Ahmar, 2020) for African women. Breeders now utilise DNA markers to help with selections attributable to the development of second- and third-generation sequencing technologies. "Exotic" allelic varieties have traditionally been introduced into crops by interbreeding with wild cousins, to increase genetic and phenotypic diversity. However, these methods do not always guarantee the production of agronomically useful traits (Stuber, 1992). Given that the world population is predicted to increase by 25% during the next 30 years, reaching 10 billion, advanced genomic selection (GS), genome-wide association studies (GWAS), and speed breeding are just a few of the technological advancements that could improve modern breeding (Turuspekov et al., 2017) for African women.

Synthetic biology: According to the United Nations, the world's population will hit ten billion by 2057. Crop yields must quadruple over the next 30 years to fulfil the needs of the expanding population, including African women (Ofoegbu et al., 2017). According to Shi et al. (2018), a potential answer to current issues may be genetically altering plants to produce more and develop faster. The most effective method to increase agricultural output and ensure food security, is now widely recognised as bioengineering (Roell & Zurbriggen, 2020), which could also bring significant benefits to African women. The creation of artificial metabolic pathways for increased CO_2 absorption and carbon preservation, as well as a decrease in the use of natural and artificial fertilisers, is reported as a possible benefit of bioengineering (Roell & Zurbriggen, 2020).

5 ICT and Climate Change Adaptation Strategies

Some climate change reports from different parts of the world include disappearing glaciers; displaced people, including African women, looking for shelter after floods; crop loss during protracted droughts; or entire towns decimated by storms and hurricanes (eTransform Africa, 2012). Despite being a widespread occurrence, the effects of climate change will differ substantially depending on location and can have a disproportionate impact on women. As a result, interventions might range from those at the regional or national level, to specialised measures to address the needs of communities, particularly African women. Although ICT has been proven to boost the earnings of the agricultural industry (Devkota & Phuyal, 2018), continued effort is necessary to persuade farmers, including African women farmers, to adopt ICT in their agricultural and commercial activities. This is because farmers' perceptions of the importance of ICT in farm information influence their acceptance, utilisation, and overall production outcomes (Kante et al., 2017).

Adaptation to the changing climate is characterised by the adjustment of biological, socio-economic, and societal structures in response to actual or anticipated changes in climatic stressors and their impacts. By lowering risk, and seizing opportunities related to climate change, adaptation seeks to mitigate present and future susceptibility (Eriksen et al., 2011). The understanding of adaptation by dry-land farmers, rural dwellers, fishermen, and pastoral herders, including African women in these communities, is limited in many parts of Africa (Ravindranath & Sathye, 2002). Africa's duty of adapting to the effects of climate change necessitates

widespread awareness, not just among the scientific community but also at the level of the average individual, including African women.

Although ICT has been effective in climate change adaptation, its full potential is yet to be realised (Upadhyay & Bijalwan, 2015). This accounts for why the World Telecommunication Development Conferences have urged developing nations to employ information and communication technology to protect the environment (Heeks, 2010). ICT has already been applied in several nations in a variety of ways, from reducing emissions to creating a database of environmental changes, and can be particularly impactful for African women. It can be utilised for land systems that disseminate early warning information on various natural and man-made catastrophes, meteorological composition databases, ocean parameters, and so on. Early detection systems using ICT are effective to combat climate change and enable unified fire control (Upadhyay & Bijalwan, 2015). Using ICT in climate change adaptation helps create modelling tools to identify susceptible locations and spatial effects and can also empower African women in these communities. It has the potential to improve participation, capacity building, decision-making processes, and long-term adaptation methods. It can also serve as a mass communication medium and to increase the general knowledge of and sensitivity to climate change among the population (Heeks, 2010), including African women.

Data gathering is crucial for the constant monitoring of the earth's climate and is also applicable in the methods for analysing data that will lead to the assessment, development, and execution of prospective adaptation measures (Upadhyay & Bijalwan, 2015). ICT can also function as a communication mechanism, utilising social media and technology to encourage the sharing of knowledge and experiences among African women. In addition to providing knowledge, ICT may make it easier to acquire certain resources and increase the ability to adapt (e.g., by providing access to funding or technology) (Adger et al., 2003; Pelling & High, 2005). The modification of systems to reduce the effects of climate change by taking advantage of emerging ICT solutions is fundamental (Adger et al., 2003). Contrary to the prevalent discourse on adaptation in international forums, which view adaptation as a process that can be accelerated by international development transfers, developing nations must leverage indigenous knowledge, experience, and the appropriate technology. In this regard, the constructive utilisation of ICT in managing climate-related risks is necessary (Adger et al., 2003), especially among African women.

6 ICT-Enabled Energy Transition for Climate Change Mitigation

ICT plays a vital role in achieving economic and social transformation in Africa, specifically regarding the peculiar challenges and successes of African women (Adeola, 2020; Shobande & Asongu, 2022). However, the increase in demand for ICT has also raised the concern for environmental and human survival (Evans & Mesagan, 2022; Shobande & Asongu, 2022). The relationship between ICT and the environment can be either negative or positive, and its impact can disproportionately affect African women, depending on the underlying policies and monitoring agencies or departments (Chien et al., 2021; Evans & Mesagan, 2022). The negative impact of ICT on the environment can be linked to the increase in the consumption of hydrocarbon energy (natural gas, coal, and oil) and unrecyclable materials deployed in the production and distribution of ICT equipment and product waste. On the other hand, ICT's positive impacts on African women's lives can include transport improvement and travel substitution, e-commerce for online delivery, product dematerialisation and recycling, efficient production of durable equipment, energy monitoring and management applications, and green ICT.

Through production, design, usage, and disposal, ICT impacts the environment directly (first-order effect). This direct effect of ICT on the environment is influenced by both the producers and consumers of the ICT equipment. During the production and operation of the ICT hardware, the producer affects the environment directly, and the product design determines how the environment is affected beyond the company's boundaries (Yi & Thomas, 2007). Further, the consumer's purchase, mode of usage, and disposal largely determine the amount of energy consumed relative to its direct impact on the environment (Hilty, 2008). It is imperative to note that the impact of ICT on the environment extends to all groups of people, including African women.

However, the substitution of processes, optimisation of processes, induction of processes, and rebound effect cause indirect impact (second-order effect). Indirect effects are referred to as enabling effects and comprise ICT applications that reduce the environmental impacts of economic and social activities. They affect how other ICTs are produced, designed, and utilised to achieve a positive impact on the environment. Lastly, ICT can affect the behaviour of its users; this is known as the systematic effect

(third-order effect). This involves how the consumer adapts to the ICT and makes practical use of them. The success of green ICT applications thus depends essentially on the adjustment of the consumer lifestyle (The Smart Report, 2020), including that of African women.

While ICT has been a key driver of economic growth in African countries in recent years (Evans, 2019), studies estimated that ICT contributes about 2.8% of global GHG emissions (Higón et al., 2017). Despite this, African women have the potential to use ICT as a solution to the unmitigated 98% ratio of GHG emissions. The SMART 2020 report, developed by the International Climate Group, recommends that green ICT be deployed for enhancing and monitoring the environmental and human activities, including those led by African women, that generate carbon emissions to achieve optimal climate change mitigation. ICT has the potential to enhance energy sustainability both in the ICT sector and other energy-consuming and carbon-emitting sectors, as exemplified in green technologies, including electric vehicles (EVs), wind turbines, and solar modules (Evans & Mesagan, 2022).

The prospects for ICT-enabled energy transition for climate change mitigation for African women include:

6.1 Green Transport System

The green transport system depicts the application of green (no carbon) vehicles to reduce fossil fuel consumption and the transportation sector's carbon footprint, which disproportionately affects African women. Transportation is a major source of air pollution and greenhouse gas emissions in Africa, and individuals, including African women, can help reduce this harmful effect by adopting more sustainable transport practices like cycling, carpooling, and green vehicles. Manufacturers and the government can help achieve greener transport with the broader application of electrical energy in transport systems. Also relevant in this regard is the integration of road traffic through smart charging systems, navigating vehicles with ICT, vehicles-to-grid systems, and computerised monitoring and mobility systems. The electric vehicle (EV) is of particular potential as an ICT-enabled climate change mitigation innovation based on sophisticated software for managing information and electricity flow within a definitive transportation value chain. Other ICT-driven electrical applications include vehicle application assistance, electronic payment and billing systems, computerised fleet monitoring systems, and mobility and smart

charging services, which can also benefit African women by making transportation more accessible, efficient, and sustainable.

6.2 Self-Sufficient (Smart) Buildings

Globalisation and urbanisation have increased the need for smart cities and buildings (Komninos, 2008). Smart buildings, including those accessible to African women, are designed to generate energy without external contributions. ICT is expected to improve the efficiency of the building's lifecycle using green architecture and energy efficiency technologies. To achieve a considerable reduction in the carbon footprint attributable to rural-to-urban migration, the emphasis on improving the overall lifecycle of buildings, including those accessible to African women, is critical. Specifically, the energy intensity and surface area of buildings can be enhanced by incorporating intelligent solar power and tracking systems, light control systems, building optimisation software, and environmental sensors. Also, microgrids have been identified as an effective way of achieving smart buildings, including those accessible to African women, in developing countries (Hertzog, 2010). They are small power systems with a self-generating, transmitting, distribution, storage, and energy management system. The incorporation and implementation of green energy modelling software will facilitate greater production levels relative to the same surface area as a photovoltaic panel, contributing to the economic and social empowerment of African women.

6.3 De-carbonisation of Energy Supply and Usage

Developing countries, including many in Africa, are highly hydrocarbon dependent, which highlights the importance of implementing new and green measures to decarbonise energy generation and consumption. African women can also play a crucial role in promoting the use of renewable energy sources and reducing dependence on fossil fuels. Various components of renewable energy can be utilised to achieve this goal:

i. Solar energy is one of the most researched renewable energy sources, and initiatives such as the production of electricity through solar streetlamps are being deployed to reduce dependency on fossil fuels. Other examples of solar energy platforms include polypropylene, high vacuum tubes, and photovoltaic collectors.

ii. Wave energy can be generated by floating steel tubes on the ocean surface, converting the movement of the waves into electrical energy.
iii. Waste-to-energy technology, which generates electricity or heat from waste through combustion, is another way to decarbonise energy.
iv. Natural gas boilers emit fewer toxic gases, and release more water vapour and less carbon, resulting in higher thermal yields and less air pollution.

The application of ICT, such as smart grids that monitor power consumption in energy generation, can enhance energy efficiency during distribution and usage. Consequently, this will increase the use of renewable energy while reducing consumer preferences for conventional GHG-emitting energy sources. Some examples of these ICT applications include remote sensing and remote grids for monitoring and managing energy systems. Empowering African women to participate in and benefit from these initiatives is crucial for creating a more sustainable energy future in the region.

6.4 Land and Forestry Management

In the quest for industrialisation and urbanisation, developing countries have directly and indirectly caused harm to the environment. Deforestation and the intensive cultivation of crops on land are the second largest global anthropogenic source of GHG emissions (Pendrill et al, 2019). The persistence of such socio-economic lifestyle makes African women particularly vulnerable to forest degradation. Mitigation of harmful land use and deforestation can help reduce the amount of carbon released into the atmosphere, and this can be achieved through the following:

i. Recycling and waste management: The management of solid waste requires the commitment of both the government and individuals, including African women. The production and regulation of green technology, such as smart containers, food waste tracking systems, automated optical scanning technology to sort plastic waste, and the use of recyclable materials in production.
ii. Vertical gardens and farms: This can help reduce the high temperatures linked to climate change and contribute to saving energy that

could otherwise have been used for heating and air-conditioning purposes. Since vertical gardens do not require unnecessary watering routines, the application of the technology to farms can save considerable amounts of water and conserve fertile soil.

ICT in land and forest mitigation helps enhance data collection on forest conditions by monitoring deforestation, illegal logging and forest loss from road construction, farming, and animal grazing. It also enhances forest monitoring and resource management, thereby managing the understaffing challenges facing the forestry industry in developing countries. African women can benefit from the timely processing and storage of data in a database for better land planning and usage. Information on critical issues and opportunities is diffused through digital technologies. For example, Radio Frequency Identification (RFID) is one ICT software used for monitoring the forest, which is readable by hand-held computer devices that display icon images instead of text, thereby enabling non-experts, such as women, to interpret the data.

7 Conclusions and Implications

The collection of ideas and perspectives in this chapter encourages a shift in the adaptation, perception, and implementation of advanced digital technologies (ICT) in African countries, igniting the transformational reforms required for effective climate change mitigation for the women population. More than ever, Africa must take action, in terms of implementing effective scientific measures to minimise the effects of climate change and ensure food security in the short and long terms. New digital technology developments in phenomics and genetics, as well as the availability of computer resources for plant genomics, are emerging technologies that might be valuable for African women and other stakeholders. African scientists must build competence in areas such as computer literacy and artificial intelligence (AI) while addressing the issue of high costs and associated hazards.

Governments at all levels must support scientists, particularly African women scientists, with the requisite resources to engender valuable research findings that will be useful in climate change mitigation. One of the keys to adjusting to the effects of climate change, especially in Africa's most susceptible regions, is the creative potential offered by ICT (Heeks, 2010). Connecting successful ICT initiatives with people, especially

farmers, might be one method of providing information and agro-advice, particularly to African women. These could cover environmental and capacity development issues (Upadhyay & Bijalwan, 2015).

The digitalisation of agriculture in Africa might increase food security for the continent's rapidly expanding population and promote adaptive urbanisation. Digital urban farming, particularly through rooftop gardens, vertical and hydroponic farms, and greenhouses, can aid in climate change mitigation efforts. It can help lower carbon emissions from food transportation and improve "sinks" that store heat-trapping greenhouse gases. Adopting enhanced technologies based on best agronomical practices and technological innovation will boost crop output while decreasing GHG emissions (Lybbert & Sumner, 2012). Government policies and plans must be in place to subsidise digital technology and ensure that Africans, including African women, are not left out of the ICT revolution, which is important for climate change adaptation. ICT innovations suitable for a warm environment provide a chance to create resilience to the future effects of climate change on women in Africa.

Although a myriad of challenges still exists, ICT can help to reduce the bureaucratic hurdles that raise the costs and inefficiencies of doing business in Africa, enabling the fluid interaction and integration of producers and consumers, including African women, into the global marketplace. Increased demand, new business players, and value chain restructuring are all components of the rapid change, although their overall impact is still unevenly dispersed. In many African countries, digitalisation can significantly enhance value chains and agronomic systems, as well as increase resistance to labour shortages and environmental change. This can lead to various agricultural systems, including tools and computer systems, that could potentially benefit African women. For example, in advanced economies, a number of computer systems for dairy farm operations have been created as a result of information technology: the animal simulation model (e-Cow) forecasts dairy cows' herbage consumption, milk production, and changes in weight (Baudracco et al., 2012).

The ability to create advanced ICT and expand the use of currently available strategies is important to transitioning to a low-carbon economy. Creating an institutional and regulatory environment that encourages innovation and the use of advanced technology is necessary for such significant transformations (Adenle et al., 2015). Capacity building in Africa should reflect extensionist and stakeholder perspectives regarding climate

change mitigation (FAO, 2013). As stakeholders in climate change, African women must develop a thorough understanding of climate change threats, variability concerns, and functional adjustment strategies (Maka & O'Donovan, 2019). Furthermore, agricultural extension workers providing technical advice to farmers should be trained on contemporary policy initiatives and engage with relevant stakeholders, including African women, for innovative technology interventions (FAO, 2013). It is believed that productivity would increase with improved connectivity, facilitation, partnerships, and cohesive integration of technology. Research institutions, centres, and universities should be committed to developing more reliable green technologies and exploring how ICT can be effectively utilised to provide renewable energy solutions and innovations to achieve climate change mitigation and energy sustainability for African women. Additionally, more research is needed to examine a wider variety of digital technologies in Africa's quest for a greener environment.

In conclusion, the adoption of advanced digital technologies (ICT) in Africa has the potential to enhance climate change mitigation efforts and promote sustainable development, especially for African women. However, achieving this will require concerted efforts from governments, research institutions, extension workers, and other stakeholders to build capacity, promote innovation, and ensure inclusive participation in the digital revolution.

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Climate-Smart Technologies for Empowerment of Women Farmers in Africa

1 Introduction

Climate change is one of the most significant challenges facing humanity due to its detrimental effects. One of the United Nations' 2030 Sustainable Development Goals is to combat the global impacts of climate change. Changing climatic conditions affect over 100 million people globally, exacerbating the gender poverty gap across nations and continents (Ray, 2021). Developing nations and continents lacking relevant institutions and strategies to mitigate these fatal outcomes, such as Africa, are more vulnerable to the effects of climate change, resulting in increased death rates, disease outbreaks, and property loss from events such as floods, droughts, and devastating storms. According to the World Meteorological Organization's 2020 report on the state of the climate in Africa, the continent's climate is characterised by rising temperatures, rising sea levels, and extreme weather events, which increase the associated risks of global warming (WMO, 2020). Therefore, it is crucial for Africa to establish appropriate measures to mitigate the continuous depletion of the ozone layer, particularly to protect women, who are the most vulnerable population (Ray, 2021).

Abating poverty and hunger, and making efforts to combat climate change and its effects are three principal aims that the global community

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has been devoted to in achieving the 2030 Sustainable Development Goals. These three objectives are very crucial as the population is predicted to rise in later years. According to Lipper et al. (2014), an extra 2.4 billion people are estimated to be inhabiting developing economies in 2050 (especially the economies in sub-Saharan African countries and South Asian countries). Moreover, in these economies, agriculture is a vital source of livelihood, but over one-fifth of the global population is observed to be food insecure on average (Lipper et al., 2014). Efficient agricultural processes are, therefore, a significant factor that can be used to eradicate hunger, poverty, and malnutrition. However, climate change could be a hindrance to agricultural growth in certain regions, especially in developing economies (Asfaw & Branca, 2017).

Climate-smart agricultural practices have been adopted in African countries to address the problems of land degradation and desertification. These projects aim to improve food security, enhance timber production, and lower crops and livestock vulnerability to climate change (Barasa et al., 2021). Reforestation helps lower climate change risks by reducing wind speeds and consequently minimising the harm done to crops. For example, in Mali, Senegal, Ethiopia and Niger, farmers have undertaken extensive reforestation and greening efforts, resulting in significant environmental improvements, particularly in the Sahel region (Nyasimi et al., 2014). This outcome was achieved through improved feed and livestock manure management, as well as shifting to species that are resilient to illness and drought (World Bank et al., 2015).

These climate-smart technologies are beneficial to women, specifically regarding their contribution to agricultural productivity and food security, which have been widely recognised in developing nations (Khatri-Chetri et al., 2020). In recent decades, research and development efforts in the global south have emphasised cardinal issues affecting women in agriculture, such as increased access to factors of production, prominence in policymaking, and greater participation (Khatri-Chetri et al., 2020). Notably, several studies have established the nexus between gender, social, and economic dimensions in the agricultural sector (Khatri-Chetri et al., 2020; Peterman et al., 2014). However, the efficiency of CSA in terms of its advantages to both men and women can be impaired if the gender gap in the agriculture sector persists (Nelson & Huyer, 2016). This chapter, therefore, discusses the potential of climate-smart technology in improving women's empowerment in Africa and ultimately improving food security in the continent.

2 Climate Change as a Challenge to Agriculture in Africa

Climate change is a principal challenge for domestic agricultural sectors and connected international supply chain networks. The impacts of climate change are increasing globally, especially among producers in developing nations whose livelihoods are significantly affected by volatile climatic conditions. Its effects are also being observed in crop and livestock production, particularly in Africa, south of the Sahara, where the dramatic rise in temperatures and varying rainfall patterns are expected to lower crop yields (Bryan et al., 2016). According to Abegunde et al. (2019), temperatures in the continent are projected to increase at approximately 1.5°C, higher than the 1951–1980 temperatures, until 2050 and remain at that level until 2100 in the scenario of a low-emission setup. In the case of a high-emission setup, sub-Sahara African temperatures are expected to increase by 5°C higher than the 1951–1989 baseline by the end of the century (Abegunde et al., 2019). A decline in rainfall, as well as an increase in the frequency of floods and drought, is also expected to occur (Nyasimi et al., 2014).

Recent impacts of climate change, such as a tree density reduction in the western Sahel region and the receding of glaciers in East Africa and Asia, have also been observed, indicating the increasing potency of climate change (Field & Barros, 2014). The climate change effects on the global agricultural system are predicted to be accompanied by a population boom and a change in consumption patterns (Abegunde et al., 2019; Harvell, 2002). It is estimated that the global population figures will rise to as high as ten billion by 2050 (Serdeczny et al., 2016). This requires a significant agricultural transformation to guarantee adequate food supplies for rising demand.

A major portion of the expected rise in the global population by the end of the century is predicted to come from Africa. These projections also show that Africa will be highly impacted by the varying climate conditions and a transition in the agricultural system. Arable farmland is expected to reduce by 110 million hectares by 2080 in developing countries, while accessible land for crop production expansion in sub-Saharan Africa is expected to decrease due to moisture limitations and rising variability (Abegunde et al., 2019). Moreover, Africa has been observed as a region profoundly associated with climate change due to excessive dependence on rain-fed agricultural systems.

Food security and the mitigation of hunger are at the greatest risk because of different factors such as climate change uncertainties, land degradation, market fluctuations, and incremental population growth (Barasa et al., 2021). Several African countries have adopted strategic propositions for implementing climate-smart agricultural technologies to solve the challenges regarding agricultural productivity. It is envisaged that this will increase food productivity, build pliability to climate change, and reduce the impact of greenhouse gas emissions (Barasa et al., 2021).

The effects of both past and future climate change on cereal crop output in different parts of the world amount to a loss in crop output of up to 20% for wheat, 35% for rice, 60% for maize, 13% for barley, and 50% for sorghum depending on time, geographical location, and climate projections (Khatri-Chhetri et al., 2017). Climate change could affect agricultural output in the form of variations in crop cultivation appropriateness, the pervasiveness of diseases and pests, and a decreased input use efficiency (Khatri-Chhetri et al., 2017). Climate change is evolving as one of the main threats to overall development in Africa, especially within the agricultural sector (Nyasimi et al., 2014). Temperatures are expected to increase in several African regions (North Africa, West Africa, Southern Africa, and Central Africa), while rainfall is expected to drop in 2050 (with East Africa being the only exception). Increasing temperatures could adversely affect aquatic and coastal habitats, bringing about a reduction in crop farming, especially in maize (Nyasimi et al., 2014). These predictions have prompted a global transition to climate-smart agriculture (CSA), and its advantages have been recognised by various institutions, researchers, and policymakers (Barasa et al., 2021).

3 Climate Change as a Challenge to Women Smallholder Farmers in Africa

Leaders worldwide have pledged to reduce chronic malnutrition in children under five by 40% by 2025 (International Food Policy Research Institute, 2019), but progress has been slow due to limited impact of nutrition-specific interventions (Jones et al., 2019). In Africa, malnutrition remains a challenge, with a higher incidence of stunting and a serious malnutrition issue for the adult population (International Food Policy Research Institute, 2021). Agriculture has gained interest as a way to mitigate malnutrition risks, with initiatives like Leveraging Agriculture for

Nutrition in East Africa and Agriculture to Nutrition in place to explore the relationship between agriculture and nutrition and address political, knowledge, and resource challenges. Though efforts have been made to advance the agriculture-nutrition relationship in Africa, more effort is required on the spill-over effect of gender equality (SGD 5) in the agricultural sector and the effective mitigation of climate change risks.

In the literature, the empowerment of women and the development of agriculture are two of the underlying determinants of nutrition, especially child nutrition (Carlson et al., 2014). More importantly, women's empowerment is observed to interact with the agriculture-nutrition linkage in specific respects (Meinzen-Dick et al., 2012). Firstly, women's agricultural occupation could increase their bargaining influence within a household. Evidence implies that women are more inclined to spend income on nutrition enhancement (Gillespie et al., 2019). Consequently, the higher bargaining power of women could lead to a higher resource allocation for nutrition (Bryan et al., 2016). Higher bargaining power could also contribute to increased nutrition by enabling women to negotiate healthcare access for themselves and their children (Bryan et al., 2016).

Mitigating the impacts of climate change on the agricultural sector is focused on reducing the emission of greenhouse gases such as methane and nitrous oxide. The sustainable intensification of existing arable land is a fundamental way of achieving the reduction of greenhouse gases through the decrease of land cover change (Wollenberg et al., 2011). The negative impact of climate change shocks can also be reduced through adaptation efforts, which could vary from minimal to significant changes in the approach that can lead to a transformation in agricultural systems (Sani et al., 2016). This method requires creating an ecosystem that promotes resilience, specifically crops and livestock with greater tolerance for flood, drought, and heat (Sani et al., 2016).

Certain strategies have been adopted by smallholder farmers in sub-Saharan Africa to address variability in climate. In areas with low precipitation, farmers substitute the farming of crops with high water requirements with the farming of crops with low water requirements (Abegunde et al., 2019). In regions with frequent flooding, farmers plant short-cycle crops and have varied planting times to evade periods of heavy rainfall. Furthermore, in Southern Africa, where there is severe water strain, farmers make use of water conservation mechanisms, including irrigation, wastewater reuse, and water harvesting (Makate et al., 2018; Mango et al.,

2018). It is evident that without these measures, agricultural activities will be characterised by higher risks due to climate change.

Small-scale farming by women plays a vital role in the provision of food and employment in several African countries (Abegunde et al., 2019). Many sub-Saharan African households are dependent on smallholder farming for food and income (Gollin, 2014). Although many female farmers conduct agricultural activities on uneven portions of land, they remain important to food production and are, thus, an important part of the African community. Despite the vast potential of smallholder farming by women, it faces certain barriers that lower its efficacy in abating the problems of poverty and insecurity. These farmers are highly vulnerable to varying climate conditions, making climate change one of the most profound threats that smallholder farmers face on the continent. These risks and poor agricultural practices have led to reduced soil fertility and, thus, low farm output (Ngwira et al., 2013).

4 Adoption of Climate-Smart Technologies in Africa

The threats associated with climate change and variability cannot be overemphasised, particularly in the agriculture sector, which is the mainstay of African economies, accounting for most livelihoods across the continent (WMO, 2020). These risks are becoming more severe as the environment is exposed to rising temperature levels. Decreased crop yield, disease damage, and flood impacts on food systems are major risks to agriculture (Barasa et al., 2021). Hence, the need to design an agricultural system that would increase food production at all levels despite climate changes. This necessitated the introduction of CSA as a sustainable approach that aids the transformation of agri-food systems towards green and climate-resilient practices (FAO, 2022). The three core objectives of CSA include sustainable improvement of agricultural production and incomes, adaptation and resilience development to climate change, and reduction and elimination of greenhouse gas emissions (FAO, 2022; Adesipo et al., 2020).

CSA refers to innovations that aim to help communities and countries adapt to and mitigate the effects of climate change while also achieving sustainable development and food security. CSA technologies include the use of conservation agriculture, agroforestry, intercropping, agroecology, small-scale irrigation, livestock diversity, soil/water conservation and

nutrient management, landscaping, mulching, minimising tillage and breeds, amongst others (Senyolo et al., 2018; Chandra et al., 2018). Notably, CSA is context specific depending on the socio-economic, environmental, and climate change factors prevalent in a geographical location (FAO, 2022). Extant literature indicates that these CSA technological practices have been tested in various African economies (Barasa et al., 2021).

For instance, an integrated soil fertility management framework, such as mixing organic and mineral fertilisers to improve maize yield, was used in Kenya (Paul et al., 2020), Nigeria (Hammed et al., 2019), and Uganda (Rware et al., 2020). There is also evidence from the use of soil conservation and multiple stress crop practices in Ethiopia (Makate et al., 2018), Ghana (Bashagaluke et al., 2019), Mozambique (Thierfelder et al., 2016), Nigeria (Oladimeji et al., 2020), South Africa (Ighodaro et al., 2020), and Zimbabwe (Setimela et al., 2018). The result was a huge increase in the variety of drought-resistant maize yields, which enhanced the overall income of small-scale farmers, as well as smallholder households (Barasa et al., 2021).

The World Bank views CSA as a viable means towards achieving sustainable development goals (SDGs) (World Bank, 2015a). To improve food security, most developing nations are seeking various ways to develop low-cost and dependable weather monitoring and forecasting systems that can be integrated with advanced smart technologies (e.g., remote sensing, IoT-based sensors, agricultural drones, and biosensors) (Adoghe et al., 2017; Tenzin et al., 2017). Regarding the adoption of CSA practices in Africa, FAO recommends its implementation through five action plans, which are (1) Expanding the evidence base for CSA; (2) Supporting enabling policy frameworks; (3) Strengthening national and local institutions; (4) Enhancing funding options; and (5) Implementing CSA practices at field level (FAO, 2022).

Overall, there is a slow adoption rate of CSA technologies in Africa; this is evidenced by a World Bank report indicating that only 26% (14) of all 54 countries in Africa possess a CSA country profile, despite its numerous benefits (Basara et al., 2021). The 14 countries are Kenya, Ethiopia, Benin, Cote d'Ivoire, Senegal, Tanzania, Rwanda, Lesotho, Mozambique, Malawi, Gambia, Zimbabwe, Zambia, and Uganda (Basara et al., 2021). Highlighting some of the early adopters, in Lesotho, for instance, there is the Lesotho Climate-Smart Agriculture Investment Plan (CSAIP) and the Machobane Farming system (MFS). The Lesotho CSAIP focuses on resilient landscape and commercialisation, such that the former is a

combination of a local farming system and modern scientific knowledge. MFS, on the other hand, involves the use of intercropping, crop rotation, and relay cropping to apply plant ashes and manure to conserve the moisture of the soil, thereby improving soil fertility to be highly resilient to climate change (World Bank, n.d.). To sustain these gains and further promote climate-smart agriculture CSA, the government of Lesotho, launched the Smallholder Agricultural Development Project (SADP), a comprehensive programme backed by the World Bank and the International Fund for Agricultural Development (IFAD). SADP aims to enhance climate resilience, drive commercialisation, and boost nutritional diversity, in line with the World Bank's global CSA scaling efforts and knowledge-sharing initiatives (World Bank, n.d.).

Further, there is the Malian CSAIP developed by the World Bank, which relies on an existing framework to create programmes, policies, strategic plans, and establishments, either at the local, national, or international levels. Mali set up actions necessary for the improvement of crop resilience (Basara et al., 2021). CSAIP (2015–2030) was also established in Kenya to meet the three pillars of a CSA approach: increased productivity, adaptation, and mitigation across production systems (Barasa et al., 2021).

The Kenya CSAIP (2015–2030) was developed to organise local and international CSA interventions aimed at addressing the socio-economic challenge. Some of the challenges faced include the fact that the majority (74%) of the Kenyan population were rural dwellers, with 11 million people actively engaged in primary production agriculture, and about 24% of the population not properly nourished (FAO, 2015; World Bank, 2015b). Interestingly, several initiatives in Kenya have attributes of CSA but are not referred to as CSA, and they are not recognised from the perspective of climate change (Osumba & Rioux, 2015). Nevertheless, incorporating CSA concepts into existing practices in Kenya will be less problematic due to the existence of an applicable framework (Barasa et al., 2021).

The adoption of CSA in Lesotho has led to a decrease in soil erosion and has enhanced biodiversity in the country (World Bank, n.d.). The CSAIP was also utilised in Mali to increase crop and livestock resistance to climate change impacts (Basara et al., 2021). Furthermore, Sustainable Rice Intensification (SRI) has been viewed as a climate-smart alternative in almost 20 African nations, with more than four million farmers benefiting from the initiative since 2013 (Zougmore et al., 2018). Climate Information Services is also a vital climate-smart option for farmers in Africa. Findings from Senegal and Ghana illustrate high potential in ameliorating the

adaptive capacity of small-scale farmers to climate change risks. Through collaboration between meteorological agencies, ICT service providers, and scientists, farmers can access authentic information and reliable forecasts. For instance, in Ghana, weather forecasts and audio messages on smart agricultural practices are sent to farmers in their preferred language (Zougmore et al., 2018). The benefits of the existing CSA projects show the potential of large-scale CSA adoption with regard to the improvement of the agricultural outlook and mitigation of climate change in Africa.

5 Gender and Climate-Smart Agriculture in Africa

A large percentage of the world's poor are women (WMO, 2020), who are also the most vulnerable victims of unpredictable weather events (World Health Organization-WHO, 2014). In Africa, where social infrastructure is most impoverished, the outcomes are more devastating. Malnutrition, malaria, displacement of homes and families, loss of material possessions, and death mostly affect women of low social status and economic means. This tragic reality will only worsen in the coming decades as millions become increasingly incapable of protecting themselves against natural disasters attributable to climate change.

The studies on climate change and gender infer that the methods by which gender connects with pliability and vulnerability to climate change are very specific and contextually driven, notwithstanding the appearance of certain behavioural commonalities (Bryan et al., 2016). The perception of climate change is an important requirement for taking action, as are the forms of response options. For instance, in Nigeria, men are observed to be more concerned with the effects of climate change on the output of legume and tuber crops, while women were seemingly more concerned about a reduction in the availability of seeds, fruits, and herbs from community woodlots (Bryan et al., 2016).

Researchers have identified the prominent factors affecting household-level reactions to climate change, such as access to information, access to rural services (e.g., credit), cognitive processes, and social capital (Bryan et al., 2016; Okurut & Ama, 2013). This stream of literature emphasises the gender of the head of the household, indicating that households headed by females have a lower chance of being able to adapt to climate change (Bryan et al., 2016). Consequently, it can be inferred that

climate-smart agriculture, as it relates to gender, has important implications for women's empowerment.

Despite these concerns, sex-disaggregated data on climate-smart agriculture in African countries such as Senegal, Kenya, and Uganda indicate that both men and women are adopting new agricultural techniques that are likely to boost their resilience to climate change effects (Hills et al., 2015). For instance, in north-western Kenya, climate change could bring about major effects on agricultural productivity and farmers' livelihoods. A project organised by the Food and Agricultural Organisation (FAO) in 2015 called Mitigation of Climate Change in Agriculture (MICCA) emphasised the empowerment of female and male dairy farmers (World Bank et al., 2015). Furthermore, through this project, women in the Kamotony region of Kenya were able to receive CSA training and establish a tree nursery. The revenue from the tree seedlings, garden flowers, and tea cuttings for planting gave them financial assistance to invest in dairy farming.

These new practices enabled the women to lower climate change risks and access funds, allowing them to make additional investments in their agricultural activities (World Bank et al., 2015). The additional credit also enables these women to pay their children's school fees without difficulty and make monthly contributions to the National Health Insurance Fund for their family members. Moreover, the success of CSA in the region has enabled women to embark on agroforestry, which would have been ordinarily difficult for gender and cultural reasons. Activities such as these require certain features to be successful. These include innovativeness, trust, collaboration, as well as effective decision-making (Bernier et al., 2015).

Information is also vital for acclimating to climate change; however, various studies indicate that women do not have adequate access to important sources and types of climate change information and suitable responses (Bernier et al., 2015). Moreover, due to the different roles of men and women in agriculture, men and women also have various predilections for information (Bryan et al., 2016). Information appears to be a major barrier to women's adoption of climate-smart practices. Findings of a study based in Kenya show that although the awareness of women on climate-smart agricultural practices was lower than that of men, women who were aware of these practices to an extent were as likely as men to employ these practices (Bernier et al., 2015). Access to credit and strong institutions also moderate the resilience of men and women against climate change risks (Bryan et al., 2016). An intra-household study based on four countries in West and East Africa and South Asia indicates that improvement in

women's access to credit and information increases the chance that they will employ new CSA practices (Bernier et al., 2015).

A sizeable number of investments in CSA do not consider the variations in resource entitlements of men and women, labour burdens, and other barriers in contemplation (Mutenje et al., 2019). For example, men tend to have expanded access to common property resources and credit (Perez et al., 2015). Men also have greater control over land than women, and land controlled by women is usually of poor quality and typified by insecure tenure (Perez et al., 2015). Many times, it is assumed that these initiatives will ultimately have the same effects on both men and women. Even the most inclusive or expansive CSA interventions may unknowingly discriminate against women when gender-differentiated barriers are ignored (Mutenje et al., 2019). If these constraints are not considered in the present and future CSA efforts, they will translate to more investment risks and reduce women farmers' ability to expand investment in CSA. Therefore, the gender gap could be worsened, and the susceptibility of communities to climate change could rise, and this could adversely impact food security.

However, small-scale farmers and stakeholders in the agricultural sector significantly depend on ICT, hence the utilisation of technologies in climate-smart agriculture activities (World Bank et al., 2015). ICT-based climate-smart technologies diffuse the information flows of agricultural development opportunities. This increases women's engagement in agricultural production decision-making, income use control, and community leadership (Huyer, 2012). Climate-smart technologies have an even greater impact when these technologies can reach marginalised groups of people and are tailored to their socio-cultural characteristics.

CSA approaches based on information technology such as mobile phones, radio, and social media have proven to be beneficial to women's participation in CSA activities and commodity value chains (World Bank et al., 2015). For instance, in Senegal, text messages in the local languages, radio, and public information broadcasting are the communication channels most useful to women smallholder farmers. In addition, a research study on how information technology could support agricultural enterprises owned and managed by women in Zambia and Kenya concludes that ICT tools vary in their accessibility and usage by women and men (World Bank et al., 2015). Therefore, Zambia is currently developing projects to improve women's ICT access. Apart from equity, the dissemination of information to farmers should be integrative (to enable farmers to act on received information), legitimate, and suited to farm-level decision-making (Tall et al., 2014).

6 Policy Implications for Women Empowerment in Africa

A major lesson of existing CSA initiatives is the recognition that women are active and valuable contributors to climate change adaptation processes (World Bank et al., 2015). Another lesson is that sustainable farming activities can be a viable source of employment for rural women, as they are important players in the green economy's socio-economic value chain (Barasa et al., 2021). Effective climate-smart projects empower women and add value to their agricultural participation. For instance, diversification of sources of income is possible as a result of agricultural processing and marketing. Nevertheless, more effort is required so women farmers are not excluded from the benefits of transformational changes in the agricultural sector.

Furthermore, the implementation of climate-smart technologies in agriculture is reassuring, especially at the country level, where the incorporation of agricultural practices and pertinent local innovations has the potential to realise the pillars of climate-smart agriculture (Sikora et al., 2017). This has been affirmed in sub-Saharan Africa, where climate-smart approaches are transitioning from investing in merely technology-oriented projects to system-centric processes that emphasise the intricacies of farming systems (Ngwira et al., 2013). Studies have indicated that when there is a singular focus on technologies while executing agricultural innovation, the factors that regulate the accessibility and productive effects of such technologies are ignored (Schut et al., 2016).

It is often argued that when addressing adaption to climate change issues, especially at a regional level, a collaborative approach between researchers, practitioners, and policymakers should be adopted. This approach should be motivated by an interdisciplinary research line-up consisting of team members from various social backgrounds and sectors that aim to solve complicated environmental issues. However, the achievement of such an approach depends on the level of understanding among the members and the extent to which these members fit their efforts into the application of knowledge. An example of a collaborative method to address climate change issues is the collaborative research initiative in Africa and Asia (CARIAA), which combines ecological, physical, and socio-economic dimensions in this methodology (Cochrane et al., 2017). This initiative utilised a hotspot approach, emphasising the glacier-fed

river basins as well as the semi-arid regions of Asia and Africa (Cochrane et al., 2017). This hotspot method is derived from the acknowledgement that climate change will not have the same impact on all persons (Abegunde et al., 2019).

7 Conclusion

Climate-smart agriculture (CSA) practices offer a holistic approach to addressing climate change issues for women smallholder farmers in developing nations, particularly in Africa. These practices include efficacious agricultural techniques aligned with the three main pillars of CSA, such as mulching, integrated crop-livestock management, conservation agriculture, and enhanced water management (Murray et al., 2016). For instance, water management techniques have been successfully adopted in the Sahel regions of West Africa, resulting in increased grain output by more than 200% compared to control fields in Niger and Burkina Faso (Zougmore et al., 2018).

However, while some African countries have adopted CSA, there is still significant room for improvement, with only 26% of African countries having established CSA country profiles (Barasa et al., 2021). Despite these challenges, there are success stories in countries such as Lesotho, where CSA has brought about higher productivity, increased incomes, improved food security, and nutritional diversity, especially for women farmers (World Bank, n.d.).

Although more work needs to be done for the full potential of CSA to be realised, some African countries such as Senegal, Kenya, and Lesotho have made significant progress in improving women farmers' livelihoods through the use of climate-smart technologies. Therefore, African economies should adopt Beuchelt and Badstue's (2013) framework of programme cycle procedures of planning and design, implementation, as well as monitoring and evaluation in CSA project implementation. Effective institutions and expanded food production activities, such as food processing, are also necessary for sound CSA practice, enhancing food security and promoting SDG 5: gender equality.

In conclusion, the adoption of climate-smart agriculture practices has the potential to improve the livelihoods of women farmers in Africa, enhance food security, and mitigate the negative impacts of climate change. While progress has been made in certain African countries, more efforts

are needed to ensure these practices are fully adopted across the continent. Governments and other stakeholders must work together to provide the necessary support, resources, and infrastructure to empower women farmers and promote sustainable agricultural practices to ensure an equitable future for all.

8 Limitations and Suggestions for Future Research Directions

This chapter has added to the literature by offering a broad discussion of climate-smart technologies for the empowerment of women farmers in Africa. Although the study is limited to simply discussing selected issues, it captures pertinent perspectives that can be applied in different country settings. Research on climate-smart technologies, which began in 2000, according to Gandah et al. (2000), grew at a minimal rate between the 2000s and the early 2010s, began to gain priority in 2014, and achieved considerable visibility in 2020 (Barasa et al., 2021). Climate-smart technologies have been investigated by researchers and have been applied to mitigate the risks associated with climate change in certain African countries (Abegunde et al., 2019; Barasa et al., 2021, Bryan et al., 2016). A rising number of studies have also begun to investigate the reasons for gender variations in observations of climate change, adaptive capacity, and utilisation of climate-smart practices. This is not limited to male and female heads of households but extends to decision-makers of both genders (Bernier et al., 2015; Perez et al., 2015).

The constraints women experience regarding CSA adoption, such as land tenure issues and inadequate information in Africa, necessitate the implementation of more rigorous studies to empirically understand these challenges to the effective adoption of climate-smart technologies. In addition, future research can delve into a deeper examination of the literature and current debates involving the emerging prospects of climate-smart technologies for women and other vulnerable populations. In this regard, there is a compelling need to proffer new questions about climate change not only in Africa but in other regions. Also, it is crucial to continue studying the relationship between gender and climate change and to conduct a broader and deeper theoretical analysis of the viewpoints presented here.

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Cleantech, Telehealth, and Other Emerging Technologies for Improving African Women's Adaptation to Climate Change

1 Introduction

Digital technologies have become ubiquitous in daily life, and this trend has been globally exemplified at an accelerated rate in recent decades. From portable devices such as smartphones and tablets to cutting-edge technologies like clean energy technologies, telehealth, education technology (Edtech), artificial intelligence (AI), and blockchain, these technologies offer numerous benefits, including the ability to communicate and exchange information, achieve personal goals, and address the pressing issue of climate change (Nkoumou Ngoa & Song, 2021; Cleantech Group, 2022). Notably, digital technologies are increasingly playing a critical role in addressing global challenges such as climate change. Clean technologies, such as solar and wind power, are reducing our reliance on fossil fuels and helping to mitigate the impact of climate change. Similarly, blockchain technology is utilised to create more sustainable supply chains, while AI is leveraged to optimise energy consumption and reduce carbon emissions.

However, access to these technologies remains unequal, with a significant proportion of the population, particularly women, being left behind (Fulufhelo & Shumani, 2020). Closing the gender gap in technology usage is crucial for promoting socio-economic empowerment for women.

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Despite some progress in recent years, with the global gender parity score increasing from 0.89 in 2018 to 0.92 in 2020, according to the ITU (2021), the stakeholders need to intensify efforts to achieve equal access to the opportunities presented by digital technologies.

The African continent faces significant challenges in closing the gender gap and ensuring equal access to advanced technologies, such as cleantech, telehealth, edtech, blockchain, and artificial intelligence. Despite some progress in reducing digital disparities, women in the world's poorest regions, such as Africa, still face limited access to information and communication technologies (ICT), which hinders the numerous possibilities in this regard. The gender divide is particularly significant in the least developed countries (LDCs), where only 19% of women have access to the internet, compared to 31% of men (ITU, 2021).

However, there have been promising developments in Africa as internet use in the region increased by 23 percent between 2019 and 2021 (ITU, 2021). This indicates that African countries are starting to recognise the crucial role that ICT plays in facilitating development. For women, these digital technologies hold enormous potential for empowerment. They can create direct employment opportunities, make labour markets more flexible, lower production costs, and provide new investment opportunities for women, as well as increase their participation in the cleantech industry (Nkoumou Ngoa & Song, 2021; Raja et al., 2013; Suhaida et al., 2013; Future Africa, 2020).

In essence, while digitalisation has enormous potential to improve people's lives and address the impacts of climate change, it is crucial to address issues of access and gender equality to fully realise its benefits. Given the potential of these technologies to empower women and mitigate the impacts of climate change, this chapter aims to explore the importance of using digital technologies to address the challenges posed by climate change to African women.

2 Cleantech, Women, and Climate Change

The impacts of climate change, such as alterations in precipitation, sea level rise, and global warming, require immediate and sustained action to mitigate and adapt to their consequences (Cumming et al., 2016). The cleantech industry is one solution to the challenges posed by climate change, as it is primarily focused on developing clean technology

(Cleantech Group, 2022). The four main sectors of cleantech are minerals, water, transportation, and energy; this includes projects like biofuel, green transportation, recycling, green energy, and renewable energy (Cumming et al., 2017). The industry also encompasses energy storage, air and environment, and nuclear energy (Cumming et al., 2016).

Women are already playing a crucial role in the transition to clean energy and promoting responsible production and consumption practices, including a culture of circularity, in various countries as producers, consumers, and designers (Dolun et al., 2021). Women can also drive change through their influence on consumer spending, promoting responsible practices across different levels of the value chain. However, there is still a need for greater gender inclusion in the cleantech sector. The Green Climate Fund has committed to promoting gender equality and women's empowerment through its gender policy, which seeks to increase inclusivity in decision-making and governance structures within its funded projects (Acanjo, 2020).

In East Africa, over $100 million has been invested in training women to become solar technicians and supporting female-led microfinance groups focused on renewable energy (Acanjo, 2020). Additionally, female entrepreneurs are leading the way in developing energy-efficient solutions, such as Ugwem Eneyo's firm SHYFT, which provides smart energy technology to consumers in Nigeria to manage distributed energy sources (Future Africa, 2020). These efforts to increase women's participation in the cleantech industry are crucial for mitigating the effects of climate change and promoting environmental sustainability.

Access to clean technologies is crucial for both well-being and gender equality, particularly in the context of climate change. Climate change exacerbates the existing disparities in energy access, particularly for women disproportionately affected by its impacts (OECD, 2020). Addressing the issue of gender disparity in energy is vital to achieving Sustainable Development Goal (SDG) 7, which is clean and affordable energy for all. Women have the potential to play a crucial role in mitigating climate change by becoming active consumers and producers of clean energy. The more off-grid energy solutions become available, the more women can participate in the energy transition as consumers and entrepreneurs.

Women are increasingly entering the renewable energy and cleantech industries, providing innovative solutions to address climate change challenges. Cleantech cooperatives offer women opportunities to participate in the entire value chain, from production to consumption. For example,

the Solar Mamas programme, present in many African and Latin American countries, uses sign language and colour coding to educate women on generating energy and installing lighting systems (UN, 2021). Another initiative, Solar Sister, focuses on cultivating women's entrepreneurship skills to increase access to off-grid energy solutions and clean cooking in underprivileged communities in sub-Saharan Africa (UN, 2021). These programmes not only empower women as cleantech entrepreneurs and consumers but also support their development as leaders and agents for a transition towards cleaner and smarter societies (UN, 2021). They provide education and training in clean energy solutions and cultivate entrepreneurship skills to increase access to off-grid energy and clean cooking in underprivileged communities in sub-Saharan Africa.

3 Telehealth, Women, and Climate Change

Telehealth is a critical tool for delivering healthcare services and lowers the constraints associated with traditional face-to-face meetings. It encompasses various technologies and methods for connecting patients with healthcare providers to enhance personalisation, effectiveness, and security in health information sharing. Telehealth can provide timely and appropriate health interventions to specific patients through channels such as live videos, mobile health, store-and-forward, and remote patient monitoring (Sundstrom et al., 2019). Additionally, it is important to note that climate change is a significant factor that affects healthcare delivery globally. For example, extreme weather events caused by climate change can disrupt transportation systems, making it challenging for patients to access healthcare services promptly. Telehealth can help mitigate the impacts of climate change by providing an alternative means of accessing healthcare services and improving the resilience of healthcare delivery systems.

Women have unique health needs due to biological and cultural factors and are major beneficiaries of healthcare services (Koc et al., 2022). Telehealth offers personalised healthcare services that could particularly benefit African women. For example, telehealth has improved access to contraception services for women in disadvantaged communities or rural areas (Sundstrom et al., 2019). Furthermore, telemedicine, telepsychiatry, and online therapy have been shown to reduce the fear of cancer relapse, depression, anxiety, sleep disorders, and distress (Koc et al., 2022). Telehealth services are also linked to healthier dietary habits and monitoring and evaluation of the health of mothers and children (Ruiz et al.,

2020). Due to the COVID-19 pandemic, telehealth has become more crucial for providing safe and effective healthcare (Fryer et al., 2020). The implementation of virtual healthcare reduces the risk of COVID-19 exposure and promotes social distancing by reducing in-person consultations (Fryer et al., 2020; Drury & Lazuardi, 2021).

It is also important to note that climate change affects African women's health in many ways. For instance, natural disasters and extreme weather events caused by climate change can disrupt healthcare delivery systems, making it difficult for women to access healthcare services. Climate change also increases the risk of vector-borne diseases, which can have a disproportionate impact on women, particularly in African regions where they have limited access to healthcare services. In this context, telehealth can play an important role in improving access to healthcare services for African women despite climate change-related disruptions. Telehealth has the potential to support the current health systems and ameliorate the situation for women, such as with the telehealth application named ePartograph in Zimbabwe, which is designed to monitor the process of childbirth. Despite the progress that telehealth is making in Africa, it is important to consider the multi-dimensional impacts of climate change and take such into consideration regarding the development and implementation of domestic telehealth solutions.

Telehealth can generate benefits geared towards the empowerment of women and simultaneously contribute to address specific global climate change concerns. According to the World Financial Review (2021), telehealth offers three major benefits: convenience, healthcare, and personnel who can attend to a larger number of patients, which reduces the need for patients to travel and thus reduces their carbon footprint. This innovation is cost-effective, as the remote monitoring dimension increases patient engagement. In effect, there is a gradual de-emphasis on physical visits, which lowers greenhouse gas emissions attributable to transportation. Telehealth provides women patients with the opportunity to schedule a suitable time to converse with their healthcare provider and avoid scheduling blunders, common clinical roadblocks, and staffing challenges, helping to reduce waste and lower emissions associated with healthcare.

A study by Kruse et al. (2020) highlights the convenience of telemedicine, which enables patients to access healthcare in a seamless manner that minimises conflict with established work schedules. This initiative can provide healthcare services to female patients in both rural and urban settings, helping to reduce the need for travel and lowering their carbon footprint.

The use of telehealth is associated with an increase in positive health outcomes more frequent consultations, reducing the need for additional, unnecessary visits and lowering greenhouse gas emissions.

4 Edtech, Women, and Climate Change

Edtech refers to systems designed to enhance classroom learning and improve students' academic performance (Frankenfield, 2020). Technology in the education system has experienced two major waves of utilisation. The first wave is the introduction of hardware into the classroom. The second wave entails the integration of software to coordinate and ensure the proper use of the hardware (Williamson, 2021). These software solutions are known as edtech. Most of these are cloud based and make use of various algorithms to enable students to achieve learning goals (Frankenfield, 2020; Williamson, 2021). Proponents of edtech accentuate the enhancement capabilities of technology and software, thus enabling the teacher to transition into more of a facilitator role. Due to time constraints, it can be difficult for teachers to educate based on a curriculum, be at pace with slower learners, and still keep the class engaged in their studies. Edtech can improve students' academic performance by automating the assessment of learning ability and adjusting difficulty levels (Bettinger et al., 2020; Frankenfield, 2020).

It is important to note that education systems must also consider the pressing issue of climate change in the design and implementation of edtech solutions. Climate change will impact every aspect of our lives, and students need to be equipped with the knowledge and skills to tackle this global challenge. Hence, edtech solutions should aim to incorporate education on climate change and sustainable development.

Global spending on edtech as a percentage of total spending on education is still relatively small (estimated at 4% as of 2021), and it is predicted to rise to 10% in the next decade (Bouhaj, 2021). The edtech sector in Africa is also expected to grow to about $57 billion in 2030. This is a massive improvement from the $3 billion spent currently on edtech, but it will only be a small proportion (below 10%) of global edtech expenditure (Bouhaj, 2021). Different edtech companies in Africa have emerged, such as uLesson, Valenture Institute, and Fuzu, which shows how quickly the sector is developing in the continent. However, the sector is still relatively small compared to other continents and regions (Bettinger et al., 2020).

Organisations such as African Women in EdTech (AWE) aim to build a learning community that will mentor African women working in or pursuing careers in the edtech sector (Wake, 2022). This organisation has four main focus areas: resilience, recovery, teachers, and equity (Wake, 2022). Resilience entails enabling African countries to develop effective hybrid educational systems. Recovery deals with how countries can recover learning loss and personalise education with digital technology. Teachers focus on changing roles and gaining new skills to fully leverage edtech systems. Lastly, equity focuses on how nations can influence open technology systems to widen access to quality educational content and learning experiences, including education on climate change.

According to UNESCO (2020), not up to 40% of nations provide equal education access to boys and girls, contributing to the gender gap in education and perpetuating inequalities. The traditional modes of teaching are evolving into online learning, which offers a pragmatic solution to the gender gap in education and can play a role in addressing climate change. Online learning eliminates the need for physical transportation to and from school, reducing greenhouse gas emissions from transportation and promoting sustainable practices. Edtech has enormous potential as a catalyst for women's political, educational, and socio-economic empowerment, and the promotion of gender equality. According to Doshi (2018), edtech can bring about the empowerment of women by providing access to a wide range of options for quality education; elimination of gender bias; employment through the use of technology; sharing of opinions, ideas, and knowledge; as well as access to vital information covering topics such as health, agriculture, politics, and the economy.

M-learning can also facilitate women's education through the use of a mobile phone, eliminating the need for physical textbooks and reducing paper waste, contributing to a more sustainable future. Women learners can have access to information through both formal and informal means, making it possible for anyone anywhere in the world to learn without being confined within the walls of a classroom, reducing the need for transportation, and thus reducing greenhouse gas emissions.

5 Blockchain, Women, and Climate

Blockchain is a novel form of technology whose potentials remain largely untapped and are still being harnessed (Makala & Anand, 2018; Thylin & Duarte, 2019; Evans & Oni, 2022). Generally, blockchain is a distributed

ledger technology that allows for a complex range of technological interactions between persons without the validation and confirmation procedures provided by trusted intermediaries (Audia, 2018; Thylin & Duarte, 2019). Blockchain technology also provides users with the ability to generate and maintain undisputable and secure personal records (Skogvang, 2018). The ledger of records, or blocks, that constitute a blockchain and the information shared are secure so that the same transaction history is accessible to everyone in the blockchain network. Blockchain has been utilised for various purposes, such as digital finance, cross-border transfers, grant management, micro-insurance, and organisational governance (Coppi & Fast, 2019).

Despite the vast applications of blockchain, financial asset transfer is usually discussed as an area in which blockchains can play a vital role (Thylin & Duarte, 2019; Coppi & Fast, 2019). Women in the least developed and some developing countries are bearing the brunt of conservative lending activities, with small women-owned firms experiencing difficulties obtaining credit needed for business expansion (Lawal et al., 2016). However, despite the technology and bitcoin industry being stereotyped as a "boys club," a growing number of women are entering the industry and growing to different levels of influence (Kamath, 2018).

The marginalisation that many women have faced in Africa for centuries through economic exclusion, gender-based violence, limited involvement in politics, and unequal access to education has enabled blockchains to appeal to a variety of African women (Msoh, 2020). For them, these technologies represent the hope that African women can be free from financial constraints and limited opportunities. For example, Kenya's Roselyn Gicira leads blockchain innovation and its use in the country and is also the chairperson of the Blockchain Association of Kenya. In addition, through the Kenya Women in Blockchain Chapter, Gicira aims to integrate more women into the blockchain industry (Msoh, 2020). In Nigeria, Doris Ojuedeire has made efforts to promote blockchain technology and also include women in other African countries (Msoh, 2020). Industry leaders such as these are making tremendous efforts to increase the inclusion of women in the blockchain industry.

However, with the pressing issue of climate change, it is crucial to consider how blockchain technology can be utilised to mitigate its impact. Blockchain-based solutions can be used to track the supply chain of goods, promoting transparency and accountability in the reduction of greenhouse gas emissions and the promotion of environmentally friendly practices

(Thylin & Duarte, 2019). Moreover, blockchain can also help create a carbon credit marketplace, where organisations can offset their carbon footprint by purchasing carbon credits from environmentally friendly projects (Makala & Anand, 2018). Hence, the blockchain industry must strive to be not just inclusive of women but also environmentally responsible, as it plays a vital role in addressing the challenge of climate change.

Access to productive resources, including financial services, is critical in reducing gender inequality and addressing climate change (Hammond & Brown, 2018). Blockchain technology has the potential to advance finance and identification services and contribute to gender equality. For example, the SPENN case in East Africa offers a digital wallet that allows users to receive, save, spend, and transfer funds securely and efficiently, enabling women to have greater control over their finances (Lopez et al., 2019).

Moreover, blockchain technology can empower women by providing secure and cost-effective means of storing personal records, contracts, and payments (Sharma, 2018). Women in developing countries often face challenges in accessing financial services, such as high maintenance costs or minimum account requirements, but with blockchain, opening a cryptocurrency wallet comes with zero costs (Sharma, 2018). Storing contracts on the blockchain eliminates the possibility of document falsification, and facilitating payments through the technology is convenient, especially for those without bank accounts. By enabling secure financial transactions and access to personal records, blockchain technology can help women overcome some of the financial barriers they face and contribute to their empowerment, ultimately supporting the fight against climate change.

6 Artificial Intelligence and Women

Artificial intelligence (AI) is increasingly affecting the choices and behaviour of people in everyday life (Leavy, 2018). AI, which is defined as machines that imitate cognitive functions, is one of the most important applications of modern technology (Mesko & Gorog, 2020; Evans & Oni, 2022). Some new developments in AI involve machines with learning capabilities, allowing them to generate programmes and insights based on their ability to process large amounts of data (Samuel et al., 2018). It is also a tool for social good and a contributor to mitigating climate change, as UNESCO (2020) outlined ways in which AI would help achieve the Sustainable Development Goals (SDGs), including reducing the impact of human activities on the environment, predicting natural disasters, and

protecting endangered species. These applications of AI have implications for addressing climate change (SDG 13).

To realise the benefits AI has to offer, including its impact on addressing climate change, gender equality is vital. However, the field of AI is largely male dominated, with only 12% of AI researchers globally being women (Toews, 2020). In recent years, AI has faced criticism for exhibiting gender and racial biases in systems such as facial recognition and loan, job, and other evaluations (Daugherty et al., 2018; Samuel et al., 2018). To ensure gender equality in AI, it is necessary to employ more women in important roles such as development and coding and to make AI systems more inclusive (UNESCO, 2020).

However, several brilliant African women are at the forefront of AI technology and are working to reduce these biases. Joy Buolamwini's work on algorithmic bias has raised awareness of facial recognition systems and aims to achieve women's inclusion in AI through her non-profit organisation (Toews, 2020). Other African women in IT, such as Lily Botsyoe, assert that AI technologies can also empower women in Africa by helping communities overcome a shortage of healthcare personnel and increasing production through automated technologies (Toews, 2020). Inclusivity in AI is crucial not only for gender equality but also regarding the potential to address the negative impacts of climate change and delivery of the SDGs.

Artificial intelligence (AI) has the capability, similar to blockchain, to promote women's empowerment while also contributing to the fight against climate change. AI can play a crucial role in reducing greenhouse gas emissions, optimising energy usage, and enhancing renewable energy deployment. For example, AI algorithms can be used to control energy usage in buildings and homes, making them more energy efficient and reducing their carbon footprint. Additionally, AI can be applied to the transportation sector to improve the efficiency of vehicles and reduce carbon emissions from the transportation sector.

One way of promoting women's empowerment through AI is in the area of employment. According to Rubin et al. (2021), artificial intelligence can assist in eliminating gender bias from the recruitment process and also reconcile the issue of gender pay gaps. This can be done using the Natural Language Processing (NLP) engine, where the potential employee and employers are matched based on skills, experience, and the number of accomplished projects. However, it is also important to ensure that the development and deployment of AI systems are inclusive and consider the

perspectives and needs of all genders, including women, to ensure that they are not disadvantaged or excluded. Moreover, artificial intelligence can empower women to obtain relevant self-help information, through the use of interactive communication as well as autonomous applications (Women in AI & Vinnova, 2020). In this case, an AI-based system can assist women in comprehending more effectively and making better decisions related to climate change, such as reducing their carbon footprint and adopting more environmentally friendly practices. The potential for women's empowerment in Africa through artificial intelligence is high, and it is essential to harness this potential in the fight against climate change.

7 Conclusion and Implications for the Future

The integration of emerging digital technologies into the lives of women can play a key role in mitigating the impact of climate change. For example, telehealth can provide women with access to medical services eliminating the need for long-distance travel, which helps to considerably lower transportation carbon footprint. Similarly, clean technology and education technology can empower women with the tools and knowledge to live sustainably and support the shift towards a low-carbon economy. Additionally, blockchain and artificial intelligence can help reduce waste by promoting transparency in supply chains and improving energy efficiency across various industries.

Furthermore, women tend to have a stronger sense of empathy and responsibility towards society, including environmental protection. Therefore, empowering and including women in the fields of clean technology, telehealth, education technology, blockchain, and artificial intelligence can bring a unique and valuable perspective to the fight against climate change. Additionally, advanced digital literacy, combined with women's strong social skills, can lead to innovative solutions that address environmental challenges and drive sustainable development.

To ensure women can participate fully in these efforts, it is crucial to address gender gaps in access to digital technologies and STEM education. Affordable access to clean technology, telehealth, education technology, blockchain, and artificial intelligence should be prioritised in policymaking, and women should be encouraged to study STEM-related fields to increase their employment opportunities in the IT industry and their ability to contribute to the global conversations on the myriad of climate change issues.

Overall, promoting gender equality and addressing climate change are interdependent, and gender-responsive policies and investments that aim to include women in the digital revolution and the low-carbon transition are crucial to achieving both Sustainable Development Goals 5 (Gender equality and women empowerment) and 13. Providing access to these technologies for women is not just a matter of social justice, but also a critical component of a sustainable future for all. Policy efforts to eliminate gender gaps in clean technology, telehealth, education technology, blockchain, and artificial intelligence can not only create job opportunities for African women but also allow them to access global markets and reduce their economic vulnerability, as well as play a vital role in combating the critical challenge of climate change.

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PART III

The Way Forward

African Indigenous Knowledge and Climate Change Mitigation: Towards an Afro-Sensed Perspective

1 Introduction

Recent trends in climate change are characterised by increased GHG emissions, global warming, and varied effects on natural and human habitats. According to the World Meteorological Organization (WMO), carbon dioxide, methane, and nitrous oxide concentrations in the atmosphere were 150%, 262%, and 123%, respectively, above preindustrial levels in 2021 (WMO, 2022). The densely populated continent of Africa has a history of protracted and severe disasters, especially droughts. For instance, four years of below-average rainfall have led to a devastating drought in the Horn of Africa (Weforum, 2022). It has also affected more than 18 million people suffering from extreme famine in Ethiopia, Somalia, and Kenya (US government's Humanitarian Information Unit, in Weforum, 2022). Although there are other contributory factors, significant land degradation in the area has increased the vulnerability of the prevailing environmental precarity. According to Nyong et al. (2007), global economic activity may have had a substantial role in the recent environmental changes in Africa, resulting in instability and uncertainties on multiple levels.

The Intergovernmental Panel on Climate Change (IPCC, 2014) stated that phenomena linked to this shift, such as severe storms, cyclones, floods, and plagues, have prompted the international community to focus on

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mitigation and adaptation as the primary policy solutions (Robinson & Herbert, 2001; Adger et al., 2003; Pielke, 2005; Bizikova, 2012; IPCC, 2014). Studies (e.g., Makhado et al., 2011; IPCC, 2014) highlight some of these effects as being the outcomes of environmental degradation rather than climate change. However, Trisos et al. (2022) argue that mitigation entails developing strategies to minimise both production and concentrations of greenhouse gases (GHGs), whereas adaptation involves reacting to the effects of climate change. This is why national climate mitigation programmes throughout Africa might benefit from indigenous knowledge sources to achieve cost-effective, participative, and long-term outcomes.

African indigenous knowledge is culture specific and encompasses a body of wisdom, methods, approaches, skills, practices, norms, and ideologies (IPCC, 2019; Adeola, 2020; IPCC, 2022; Leal Filho et al., 2022; Adeola, 2023a and b). It is a foundational element of social, cultural, political, economic, scientific, and technical identity that has the potential to contribute towards the attainment of sustainable development. This accounts for why African indigenous knowledge has been identified as a vital resource for the mitigation of climate change in Africa (Trisos et al., 2022). For instance, more than 30% of the world's native languages are spoken in Africa, which is a repository of relevant information on biodiversity, soil systems, and water (Trisos et al., 2022). It is a dynamic and necessary asset to the conservation of indigenous history and culture (Ayal et al., 2015; Magni, 2017). According to Leal Filho et al. (2022), African indigenous knowledge influences life's decisions and the associated short- and long-term implications.

Although the collective wisdom and innovation of stakeholders and communities affected by climate change are noteworthy, African governments have continued to relegate the role of indigenous knowledge in national climate change mitigation policies, despite the IPCC acknowledging its significance (Parry et al., 2007). According to the literature (e.g., Labode et al., 2012; Orlove et al., 2010), African indigenous knowledge is rooted in cultural worldviews and experiences that close knowledge gaps and validate existing understanding, guiding the interactions between the community and its environment (Trisos et al., 2022).

The issue of climate change is widespread, and the complexity of its varied effects makes it a perennial subject of research (Trisos et al., 2022). The local knowledge, perspectives, observations, and responses of individuals experiencing changes in the climate can provide some valuable insights into climate change mitigation. Therefore, this chapter explores

the role of African indigenous knowledge in climate change mitigation, disaster risk reduction (DRR), climate-smart agricultural innovations, the role of Ubuntu, and finally, the integration of indigenous and scientific knowledge into climate adaptation in Africa. The chapter echoes the need for an Afro-sensed perspective in climate change mitigation.

2 Indigenous Knowledge and Disaster Risk Reduction in Africa

Disaster risk reduction (DRR) involves the deliberate and organized development and implementation of strategies, methods, and initiatives aimed at diminishing vulnerabilities, mitigating risks, and limiting the far-reaching impacts of disasters within a society (Amadhila et al., 2013; Hagelsteen & Becker, 2013). DRR is multidisciplinary in strategy and acknowledges the significance of connections between risks and the larger environment (O'Brien al., 2006). For instance, risk, vulnerability, and capacity evaluations are among the DRR strategies. These tactics emphasise a community's capacity to lower its own risk of catastrophe and build strong communities while preventing vulnerability from rising due to development or other externally driven activities (O'Brien et al., 2006; UNDP, 2004). However, indigenous tactics should be connected to suitable mitigation policies and local government actions (Fraser et al., 2006). This will guarantee the longevity of any mitigation strategy and make it possible to acquire external knowledge that can help reduce susceptibility.

On the other hand, indigenous knowledge is the institutionalised local knowledge that has been developed and handed down from one generation to the next, typically by word of mouth (Osunade, 1994). According to the United Nations Educational, Scientific, and Cultural Organization (UNESCO), indigenous knowledge is "the understandings, skills, and philosophies produced by communities with long histories of engagement with their natural environments." Similarly, the World Intellectual Property Organisation defined traditional knowledge as "knowledge, know-how, skills and practices that are developed, sustained and passed on from generation to generation within a community, often forming part of its cultural or spiritual identity." (World Intellectual Property Organisation, N.A.). Indigenous knowledge has made a substantial contribution to global agricultural advancements, including the domestication of crops and livestock, the preservation of group-consisting resources, the

development of animal traction, and the trade of plant and animal species (Mettrick, 1993). This implies that scaling climate-smart solutions in smallholder agriculture may require significant contributions from indigenous knowledge.

Studies (e.g., Elias et al., 2009; Gyampoh et al., 2009; McPherson et al., 2016) have noted that indigenous populations across the world have often demonstrated in-depth local ecological knowledge regarding disasters, especially biodiversity and other values that may be exploited for better impact conservation. According to Chianese (2016), indigenous knowledge is the information and understanding that has been gathered over generations, verified and modified over time, and directs indigenous cultures in their relationships with their natural ecosystem. The study further revealed that communities use indigenous wisdom to manage the effects of catastrophes caused by climate change (Chianese, 2016; Elias et al., 2009).

Native knowledge has been integral in advancing scientific understanding, empowering local populations, and complementing other processes, especially regarding saving the environment (Munsaka & Dube, 2018). Mwaura (2008) contends that indigenous knowledge may enable individuals to take the initiative in the management of disasters. For instance, mixed cropping readily qualifies as indigenous knowledge and is useful in enhancing crop yield, thus minimising the effect of selected crop failures.

Indigenous knowledge portends considerable benefits to endangered communities contributing significantly to climate risk reduction and environmental preservation (Munsaka & Dube, 2018). Maferetlhane (2013) also advocates that disaster risk reduction can greatly benefit from local or indigenous knowledge. For instance, local growers in some African countries have created several adaptation strategies that have enabled them to ameliorate sensitivity to climatic extremes and unpredictability. Establishing an early warning system for functional prognosis or forecasting is a key step in lowering the susceptibility to a meteorological hazard in Africa (Ajibade & Shokemi, 2003).

Although indigenous people are universally recognised as the most susceptible to the effects of disasters (Thomas et al., 2005; UNFAO, 2011), applicable adaptability and mitigation initiatives have not been effectively integrated. The degree to which indigenous knowledge has been used in disaster risk reduction in Africa has received little attention (Munsaka & Dube, 2018). Indigenous peoples' knowledge and experience often remain dormant in processes targeted at reducing vulnerability or

increasing adaptability to new conditions. Studies (e.g., Jones et al., 2018) have also argued the need to explore local knowledge at the community level as such will help affected communities prevent, mitigate, and recover from disasters.

Furthermore, advocates of indigenous knowledge systems, such as disaster risk reduction researchers, have frequently argued that indigenous knowledge is central to the preservation of human life and property from the harmful repercussions of catastrophes (Walshe & Nunn, 2012; Hiwasaki et al., 2014). Evidence has also shown that nations that have been successful at handling catastrophes have also made use of the native expertise of the local populations that have been impacted by catastrophes (Iloka, 2016; Rahman et al., 2016). Therefore, indigenous people's techniques and expertise might serve as a crucial foundation for current efforts to address the broader issues posed by climate change in Africa (Belfer et al., 2017; Fairhead et al., 2017). This aligns with the fact that local people have developed some capacities that can deliver sustainable and effective disaster risk outcomes (Iloka, 2016).

Kelman et al. (2012) have noted that environmental hazards pose a greater risk to humans due to shifting social, economic, cultural, political, and environmental circumstances. This is unconnected to the fact that developmental initiatives in Africa are known to have been conceived, sponsored, managed by outside interests, and delivered to rural areas with varied expectations. Due to the low regard for subsisting local culture, a considerable number of programmes had low participation and limited success ratio (Nyong et al., 2007). It is critical to note that to properly link development and catastrophes, novel laws and strategies are non-negotiable (Tran et al., 2009). A significant change in disaster risk reduction approaches can bring to the fore the potential of indigenous knowledge in reducing vulnerability (Mercer et al., 2010). The local expertise may offer crucial insights into the procedures for observing, adapting to, and cushioning the effects of climate change (Chianese, 2016). Thus, policymakers and practitioners must consider indigenous knowledge in official disaster management protocol.

3 Indigenous Knowledge in Climate-Smart Agricultural Innovations Among African Farmers

Sub-Saharan Africa's rural livelihoods are gravely threatened by climate change (Tume et al., 2019). Notably, the unpredictability of climate change constitutes an existential hazard to global agricultural productivity and food security (IPCC, 2014). African farmers are exposed to climate risk because of increased temperatures, changes in precipitation patterns or trends, and the recurrence of unusual climate events like floods and intense weather conditions (Amare & Gacheno, 2021). Therefore, it stands to reason that African farmers' ability to withstand climate change practically depends on local institutions and indigenous knowledge and is instrumental to scaling climate-smart agricultural innovations (Agrawal, 2010).

As the impact of climate change deepens, it is vital to explore a variety of climate-smart innovations. Climate-smart agriculture is an initiative that has been extensively promoted to alter agriculture prospects given the expanding climate change challenges (Hansen, 2018; Nkonya et al., 2018). According to Lipper et al. (2014), climate-smart agriculture is a strategy designed to change agricultural systems and improve food security owing to changing environmental conditions. In essence, the strategy provides situation-specific, flexible, and socially acceptable solutions. Specifically, the climate-smart agriculture strategy is based on three fundamental principles: (i) boosting agricultural output sustainably, enabling equitable increases in farm income, nutrition security, and development; (ii) enhancing the robustness of agricultural and food ecosystems; and (iii) lowering net emissions of carbon dioxide from farming production (McCarthy & Brubaker, 2014; Lipper et al., 2014).

Climate-smart agriculture has been depicted as a class of agriculture capable of conserving environmental resources whilst delivering the food requirements of the global population (FAO, 2018). The goal of climate-smart agriculture is to re-engineer agricultural systems and enhance food security despite changing climatic conditions and offer contextually appropriate as well as adaptable solutions (Lipper et al., 2014). For instance, resilient crops and livestock, optimal water management techniques (such as mulching and rotations), and other identifiable techniques qualify as climate-smart agriculture. Specifically, in the SSA region, studies (e.g., Westermann et al., 2015; Arslan et al., 2018; FAO, 2018; Makate, 2019)

underscore the low or poor adoption of climate-smart agriculture methods. Low adoption rates are primarily connected to the dearth of data or lack of success stories; lack of donor reliance, insufficient institutional support, and ineffective climate-smart agriculture policies and plans are some of the challenges affecting agriculture production scaling.

This situation necessitated external assistance to increase farmers' capacity to accept new technologies. All external efforts in climate change adaptation for rural populations require the involvement of local institutions (Agrawal et al., 2018). McCarthy et al. (2011) state that a substantial obstacle to the acceptance and scalability of climate-smart products is the expense of sourcing such important information. Therefore, the need for climate-smart information services is critical because they educate farmers about current climatic patterns and the many adaptation options available to them. Local institutions, such as agricultural cooperatives, community organisations, community-financing schemes, and women's savings groups, have been noted to be essential in mobilising resources for climate change management (Ajayi, 2019). The primary flaw of various local institutions, like community finance programmes, is the limited resources that can be mobilised in poor communities.

Additionally, local institutions help create beneficial networks that can be relevant for accelerating the adoption of climate-smart solutions (Ajayi et al., 2018). Effective networks will ensure that farmers have access to markets for their inputs and outputs and are informed about new developments. These extension approaches rely on farmer social networks to increase technology uptake and dissemination in subsistence farming. Improving the function of local institutional players can ensure equity in the distribution of information regardless of farmers' socio-economic condition (i.e., wealth or gender). The growth of farmers' knowledge, expertise, and ability in relation to climate-smart technologies and related services can be facilitated through local institutions (FAO, 2018). Churches, traditional leadership, schools, and other social organisations may improve climate change management efforts by pushing for political will and assistance from political stakeholders (Ajayi et al., 2018).

Indigenous knowledge conservation is crucial to the advantages of an ecosystems-based strategy for climate adaptation (UNFCCC, 2011). This is because it helps to co-create farmer-led knowledge on a coping mechanism for climate change. There is a rising interest in incorporating climate change and indigenous knowledge into initiatives such as climate-smart agriculture to boost local engagement and provide ecologically sustainable

ways to develop (Mafongoya & Ajayi, 2017). African farmers have established extensive local knowledge about nature in their region, which they utilise to cope with and solve the challenges of climate-related issues (Tume et al., 2019). Rural communities provide valuable local knowledge relevant to assessing and adapting to climate change (Jiri et al., 2015). According to Mafongoya and Ajayi (2017), indigenous knowledge is seen as social capital for the underprivileged and essential for ensuring a culture's survival.

Policymakers and other interested parties who want to increase the adoption of CSA technologies must be aware that rural communities and indigenous knowledge play an important role in climate change in a variety of creative ways. Therefore, designing, planning, and executing policies, projects, and programmes aimed at accelerating the adoption of innovations (e.g., smart agriculture) must incorporate local institutions and indigenous knowledge (Kristjanson et al., 2017).

4 Ubuntu and Climate Change

The incidence of climate change is a global phenomenon, and Africa is one of the continents that bears a significant weight of these changes (Alege et al., 2017). Africa has experienced two multibillion-dollar tropical cyclones, among the largest in history. Severe storms and flooding are climate-related challenges which are also rising. Less developed continents are disproportionately affected by the issues of climate change, particularly in areas where low-tech farming practices predominate (Kates, 2000).

Since the year 2000, when Tropical Cyclone Eline ravaged a 2000-kilometre area of southern Africa from east to west, there has been an upsurge in climate-change-induced catastrophes necessitating indigenous knowledge or people-oriented climate solutions to be adopted (Chatiza, 2019). Community resilience is the capacity of people, communities, and organisations to absorb traumas, recover from them, and then constructively remodel their social structures and ways of life in the face of ongoing change and uncertainty (Patel et al., 2017; Chatiza, 2019). Community-based disaster risk reduction (CBDRR) offers a chance to integrate local indigenous expertise on disaster risk reduction into more general risk reduction efforts. The broader idea of resilience, which communities must employ to rebuild their lives, includes disaster resilience, underpinned by the Ubuntu value system.

Ubuntu is a way of thinking and behaving that has maintained African communities for many generations (Munyaka & Motlhabi, 2009). Africa's Ubuntu value system emphasises the capacity for compassion, which can be described as a pervasive sense of caring and community, harmony and hospitality, respect and responsiveness displayed by individuals and communities towards one another. The term "ubuntu" originates from Nguni languages like Zulu, Xhosa, and Ndebele. Other African languages, particularly those in Southern, Eastern, and Central Africa, have adopted phonetic versions of the word (Mabovula, 2011). Several scholars agree that communities, philosophies, and faiths, from liberalism to Buddhism, share many of the same principles and practices as Ubuntu. Others assert that Ubuntu is "specific to the Bantu languages from whence it comes" and that it is "unique to Africa" (Kamwangamalu, 1999, p. 37). According to Mabovula (2011), Ubuntu is understood to signify empathy, love, community, collaboration, respect, humanism, and humaneness.

As Mlondo (2022) noted, the Zulu/Ndebele saying "Umuntu nguMuntungabantu" may be translated as "a person can only be a person via others" (Mlondo, 2022). Metz and Gaie (2010) suggest that sub-Saharan morality is relational in that the only way to grow one's humanity is to have healthy relationships with others. Another interpretation is that "we" and "I" are the outcomes of one another. According to one theory, a single person "symbolises a multiplicity of personas matching the variety of links in which the questioning individual stands" (p. 23). Ubuntu teaches that the highest moral duty is to grow as people, and that growing as a person necessitates a deeper sense of connection with others. Other Western moral philosophies describe healthy interaction with others in ways that are exclusively communal (Metz & Gaie, 2010).

In many African societies, Ubuntu/Hunhu refers to shared humanity and the responsibility that results from interconnectivity (Mapaure, 2011). For the indigenous populations of sub-Saharan Africa, life satisfaction is only worthwhile when it benefits mankind as a whole. By being prepared and utilising local resources, communities can survive and recover from calamities (Saurombe & Shava, 2021). Local knowledge application, ingrained in the Ubuntu/Hunhu concept, is a crucial tactic (Baumwoll, 2008). According to Mupedziswa et al. (2019), the notion of community as an organising element for life has become one of the groups' resilience strategies. For instance, locals go above and beyond in Zimbabwe to save those stranded due to landslides and other disasters.

Ubuntu/Hunhu is an indigenous philosophical perspective of African people that connotes and symbolises human beings' communal obligation to share life for the common good (Godfrey & Manasa, 2012). Thus, it is a vital force that supports and upholds the harmony of cosmic, natural, spiritual, and human elements. It is a cosmological theory that promotes adaptable views of the universe (Bondai & Kaputa, 2016). In the proverb, "a person is a person via other individuals," the term "person" alludes to the personhood, self-hood, and humanity that a person should aim for when interacting with "others" (humans, non-humans, and nature).

Ubuntu may be attained through moral relationships with others. The 'Homo economicus' drive to fulfil self-interest through the amassing of material prosperity is a factor in the planet's impending demise. Anthropocentric activity is one of the primary drivers of climate change. This paradigm change should be from the *"I in Me"* to the *"We in We"* as embedded in the Ubuntu philosophy, which embraces communitarianism and regard for the environment and future generations.

5 Integrating Indigenous and Scientific Knowledge into Climate Adaptation in Africa

Climate change is not a new concept for indigenous cultures since they have been coping with it and adapting to it for a very long time (Etchart, 2017). Climate change adaptation is critical for long-term sustainability and progress, notably during periods of extreme weather. According to Odekunle and Adejuwon (2007), indigenous knowledge is a collection of information that a group of people has accumulated through many generations of living in proximity to the natural environment. It is an example of a dynamic knowledge base that has helped most rural communities thrive by adjusting to widely different and continually changing climatic conditions (Odekunle & Adejuwon, 2007). Local people, especially farmers, are adept at foreseeing the seasons and the changes that will occur within them (Elia et al., 2014). Although indigenous knowledge may be a tool for adjusting to everyday climate and weather fluctuations (Gwenzi et al., 2016), forecasting confidence has recently declined due to increased rainfall unpredictability due to climate change.

It is pertinent to note that rural people, most importantly farmers who rely on their ancestors' wisdom, have a tough time adjusting to the consequences of weather fluctuations due to climate change (Gwenzi et al.,

2016). This is because the result of daily and challenging seasonal forecasts is uncommon in traditional knowledge. Furthermore, indigenous knowledge can forecast when to sow and harvest different crops but cannot forecast rainfall amounts. It may not provide solutions to climate change adaptation or practical solutions that people can use daily (Elia et al., 2014). As a result, farmers are often unable to make informed decisions on agriculture, nor are they able to identify or foresee problems with the soil.

From a different point of view, when used effectively, scientific knowledge has been shown to help farmers make judgements on issues like the best tillage practices, crop kinds, planting times, possible markets, and trends (Leary et al., 2007). African farmers, especially those in rural areas, believe that scientific knowledge is particularly crucial since indigenous knowledge is hindered by outside pressures (Elia et al., 2014). However, there are many obstacles preventing people from fully utilising scientific knowledge for seasonal climate and weather prediction. Some of these obstacles were identified by Leary et al. (2007) among rural people in West Africa. They consist of the predictions of certain geographical and temporal resolutions, which were shown to be inadequate for short-term judgements. Additionally, the projections' accuracy, which according to Leary et al. (2007) is now around 75%, is inadequate. According to Elia (2014), scientific knowledge is presented by utilising ideas and data to support claims. As a result, the local people believe that scientific knowledge is excessively specialised and hence difficult to comprehend.

Rural farmers who rely on their ancestors' wisdom have a tough time adjusting to the consequences of the changing weather (Sraku-Lartey, 2014). It is important to realise that although indigenous and modern knowledge has very distinct beliefs and approaches, they may complement one another extremely well. Integrating the two worlds of knowledge will allow farmers to employ sustainable farming approaches that rely on what is already in use as well as what science can offer. Studies (e.g., Elia et al., 2014) assert that proper management of indigenous knowledge is necessary for integration, which is critical for growth and coping with climate change.

Indigenous knowledge may be shared across organisations and communities by building a platform for it. According to Tengö et al. (2014), discovery through various scientific approaches and a blend of indigenous knowledge is the safest method for the creation of more successful and

sustainable solutions to climate change, especially in Africa. It is important to realise that although indigenous and scientific knowledge has distinct beliefs and approaches, they are complementary (Sraku-Lartey, 2014). Rural farmers can adopt sustainable farming practices by combining what is being used with what science can provide by integrating the two domains of knowledge (Sraku-Lartey, 2014). Integration is critical for development as well as climate change adaptation, and indigenous knowledge must be both leveraged and effectively managed by creating a suitable framework. If the capabilities of the knowledge holders and organisations in charge of weather forecasts are evaluated and strengthened, the integration of various forms of knowledge is bound to function more successfully (Elia et al., 2014).

Although the adoption of both indigenous and scientific knowledge to assist communities in adapting to climate change has received little investigation (De Caux et al., 2014), connecting multiple knowledge networks has the potential to significantly support climate change adaptation and preservation goals at various levels while providing global advantages (Makondo & Thomas, 2018).

Furthermore, mixing indigenous and scientific knowledge can help local farmers adapt to climate change and make more informed choices (Basdew et al., 2017). The true objective of all human knowledge is to ensure the survival and perpetuation of the human species on Earth. Indigenous knowledge develops and is learned through the cohabitation and development of people and their immediate environment. According to Basdew et al. (2017), African traditional knowledge may be used to adapt to climate change by adding components of it to present and different climate-based weather forecasting systems. Relegating or losing it equates to altering the course of human growth in any given civilisation because, more frequently than not, acquired knowledge systems impose demands on the ecosystem that are excessive compared to its ability to meet them. However, it is believed that by fusing indigenous knowledge with scientific methods and expertise, its usefulness and viability may be substantially increased (Basdew et al., 2017). Considering that many African people, especially farmers, are unable to acquire adequate information due to a shortage of computers and internet access, integration calls for the inclusion of the populace, and their accumulated traditional knowledge and abilities in the scientific sphere, for adequate climate change mitigation.

6 Gender and Indigenous Skills for Climate Change Mitigation and Adaptation in Africa

Women's unique and indigenous mitigation and adaptation skills and abilities should be acknowledged in adopting an Afro-sensed perspective. Several studies show that women possess specific skills and strong resource management capabilities in climate change mitigation and adaptation. For instance, in Ghana, a study argued for the practical and ethical necessity of including women's needs, perspectives, and expertise in climate change negotiations by demonstrating that women had special knowledge to contribute to adaptation efforts (Glazebrook, 2011). Notably, women possess special skills in soil identification of various crops, adapting to unpredicted rainfall and soil damage and mitigating climate change effects through crop rotation (Glazebrook, 2011). In Rwanda, the disruption of rainfall has led women to rotate crops and assess how plants react (Oxfam, 2011). A study in Ghana documented differences in adaptation strategies in response to flooding—women tended to prefer post-harvest technology over men's preference for light infrastructure projects (Codjoe et al. cited in Connolly-Boutin and Smit (2016)).

Gender differences can also be seen in various studies relating to farming decisions (Dah-gbeto & Villamor, 2016; Jost et al., 2016; Saenz & Thompson, 2017). In a survey on gender-specific responses to climate variability in a semi-arid ecosystem in northern Benin, it was found that participating women-only groups perform better in avoiding patch degradation than men-only groups (Dah-gbeto and Villamor (2016)). These findings suggest that considering gender differences in farming decisions and practices can lead to more sustainable and effective outcomes for ecosystems and communities. Additionally, incorporating a gender-sensitive approach in policies and programmes relating to agriculture and the environment can lead to more equitable and impactful results (Jost et al., 2016). It is crucial to continue to examine and understand the role of gender in agriculture and environmental decision-making in order to create effective and sustainable solutions.

Women are more active than men in environmental protection as they are more willing to acknowledge ecological problems and risks. These attitudes and environmental behaviours are confirmed in literature (Goldsmith et al., 2013; Zelezny et al., 2000) as women are more concerned about climate change (Sundblad et al., 2007) and are generally regarded as more pro-environmental relative to men (Goldsmith et al., 2013; DíazReviriego

et al., 2016). However, it's important to consider that these findings may not be applicable to all individuals, and cultural and societal factors may also play a role in shaping these attitudes and behaviours (Goldsmith et al., 2013). Additionally, it is crucial to continue to analyse and understand the reasons behind these differences in order to develop targeted and effective strategies for environmental protection.

Regarding social inclusion, given their nurturing nature and as natural caregivers, women appear to thrive better than men. In Rwanda, a study on gender inclusion in the social business focused on providing solar lighting to poor rural households showed that female sales agents, compared to their male counterparts, sold significantly more units on average and significantly increased access to the underserved or vulnerable in communities (Barron et al., 2019). An article by Baskin (2022) argued that Nigerian women possess distinct skills, knowledge, and understanding of how to mitigate the impacts of climate change, including biodiversity management and farming techniques, making them more sustainable caretakers of land than men.

Finally, examining gender-specific responses to climate change can enhance efforts to improve adaptability and resilience to climate change in Africa (Dah-gbeto & Villamor, 2016). This is particularly important when applying indigenous knowledge to climate change adaptation and mitigation in Africa and designing adaptive community interventions. Taking a gender-sensitive approach in considering the impacts and responses to climate change can lead to more equitable and sustainable outcomes. This includes incorporating the unique perspectives and experiences of both men and women in decision-making processes and programmes related to climate change adaptation and mitigation (Dah-gbeto & Villamor, 2016). By doing so, we can ensure that these efforts are effective, inclusive, and benefit all members of the communities affected by climate change.

7 Conclusion and Implications

This chapter explores African indigenous knowledge and how it could be used for climate change mitigation. It gives an Afro-sensed perspective on climate change mitigation and shows how indigenous knowledge may be employed to make Africa a green economy. The chapter also addresses the need to explore local insights into managing disasters and other climate change issues. This is achieved by appraising how the indigenous Ubuntu value system, which places great emphasis on the worth of society and the

individual (munthu), promotes a green economy in Africa. The features of the Ubuntu concept in the areas of compassion, care, collaboration, team spirit, sympathy, dignity, political decision-making procedures, and respect for nature are beneficial practices that may aid in enhancing the greener economy in Africa. The goal is to retain the unique repository of cultural knowledge while embracing the innovation of modern science to achieve the mitigation of climate change.

Worldwide, people are becoming more and more susceptible to climate-related dangers. This chapter covers some of the most pressing environmental issues now plaguing modern African civilisation, with a focus on the environmental difficulties currently being experienced. This susceptibility is not distributed evenly since individuals in less developed nations, such as Africa, experience a greater number of losses. Africa has natural advantages that may be used for climate change adaptation, such as abundant and secure means of subsistence. Ubuntu stresses the significance of "community, cooperation, compassion, and sharing." Thus, a plea is in order for a global paradigm shift away from a market-based, individualistic approach and towards the environmental ethics of the Ubuntu philosophy.

The efficiency of indigenous knowledge systems should be considered when developing climate change mitigation programmes in Africa's drought-prone regions. Although many decision-makers continue to doubt the validity of indigenous knowledge, viewing it as an insufficient foundation for sustainable harvesting, the proper incorporation of indigenous mitigation strategies into national climate plans will promote the quest for a green environment in Africa.

Moreover, with regard to climate fluctuation and change, Africa is rich in time-tested and context-specific indigenous and local knowledge (ILK). Since ILKs are ingrained in the culture, the population accepts them as a means of protecting their lives and properties from climate-related dangers, including illness, violence, and drought, as well as ensuring food security. Although ILK has the potential to close the information gap in contemporary scientific knowledge, it has encountered significant difficulties because of a dearth of knowledge transfer and documentation. Therefore, proper channelling of ILK can work with scientific knowledge to increase the understanding of the region's mitigation of climate change's slow-onset consequences.

Finally, African government's over-reliance on Western knowledge formats for disaster risk reduction (DRR) undermines the knowledge and confidence of locals in communicating effective mitigation solutions that

have worked for them on a broader scale. To address this, respective governments should prioritise the sharing and employment of African indigenous knowledge in all forms of community engagement and policymaking. By gaining a greater understanding of local operations, the government can improve interaction with locals, broaden knowledge capital, and enhance policy formulation for climate change mitigation. Furthermore, gender-specific skills should be taken into account when applying indigenous knowledge to climate change adaptation and mitigation in Africa and designing adaptive interventions for communities. In particular, women should be recognised as agents of positive change for enhanced climate action, so they can be empowered to actively participate in decision-making processes, advocate for policies that promote sustainability, and implement climate solutions in their communities. This is also in the spirit of Ubuntu.

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Green Reskilling of African Women for Climate Action

1 Introduction

The unlocking of Africa's most underutilised and untapped resources can be achieved by addressing widespread gender disparities in the areas of economy, training, governance, and leadership (Fernández et al., 2021; Mojapelo & Faku, 2019). Women comprise at least nearly half of the agriculture-based economic workforce in many African countries (ILO, 2014; Campaign, 2014). Despite their contributions, women in agriculture face challenges such as the lack of formal agreements and guaranteed wages, leading to disparities in wages and resource access (Mojapelo & Faku, 2019). The gender wage gap results in many women being employed in low-wage, low-productivity jobs, either as self-employed individuals or as household contributors to the household income (Fernández et al., 2021). Transitioning to a green economy and empowering women requires green competencies and a precision mindset (Maclean et al., 2018). As women become more empowered, Africa's significant resources will be unleashed (Nhamo & Mukonza, 2020). Gender equality and women's empowerment are critical components of greening economies for long-term poverty alleviation and economic growth (Nhamo & Mukonza, 2020). It is crucial to incorporate the inclusivity of women in the development of a green economy that promotes people's welfare and equitable development through the creation of quality green jobs (Babugura, 2020).

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Understanding the concept of a green economy is essential to grasp the importance of gender and women's empowerment in the context of green jobs and green skills. The United Nations Environment Programme (UNEP) describes a green economy as *"one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities"* (Environment for Europe Ministerial Conference (2011)). A "green economy" does not supplant sustainable development, but an increasing number of people appreciate that attaining sustainability hinges on making the correct economic decisions. The model of the green economy is driven by resource efficiency that encompasses skilled and technical human competencies and capacities (Pavlova, 2018). In more precise terms, "resource efficiency" refers to the ability to enhance output while using fewer resources—whether material or non-material. Green economies must meet this efficiency requirement, but more fall short in certain instances owing to variations in resource utilisation as exemplified in many countries.

Green economy transition and resource efficiency can be achieved by reskilling women, ensuring ecosystems remain stable and functional (ecosystem resilience). Also of relevance in this regard is discovering ways to optimise resources in the production and consumption of goods whilst mitigating associated environmental impacts. Africa holds a vital female labour workforce that could triple its productivity through enhanced green reskilling. This perspective is captured in the works of Potokri (2022), who argues that women in Africa must develop sustainable skills in the wake of the fourth industrial revolution (4IR) or face the danger of being isolated in the emerging world of work. Climate change unlocks opportunities for women in key sectors of the African economy through sectoral, green-based jobs. Green-centric sectors, such as agriculture, manufacturing, energy, production, and processing, necessitate skills domiciled in technical green competencies.

The effects of climate change on Africa's women labour market are still largely unresolved, notwithstanding the demand for information generation and dissemination and the escalating body of research and reports from governmental, corporate, and non-profit organisations on gender-related issues (Glazebrook et al., 2020; Martinez-Fernandez et al., 2010). There has been a rise in interest in "green growth paradigm" theories as an alternative model of economic growth, especially in the wake of the climate crisis (Unay-Gailhard & Bojnec, 2019). Therefore, this study

elucidates the following: green growth as a concept, green skills and green jobs, sectoral green jobs and women's empowerment, green economy transformational training, and green competencies and climate action. The study further identifies potential opportunities that gender and green economy paradigms offer to counter proliferating climate change consequences. Thus, the study shows the importance of reskilling women with green skills that will create opportunities in the era of climate change in Africa.

2 Green Growth and Gender Inclusivity Concept in Africa

The concept of green growth has picked up pace globally as an approach to ameliorating consequential ecological impacts. In 2012, at the Rio+20 Summit, the concept of "inclusive green growth" was first introduced as part of ecological civilisation (Sun et al., 2020); Similarly, the World Bank (2012) defines green growth as "*a system that is efficient in its use of natural resources, clean in that it minimises pollution and environmental impacts, and resilient in that it accounts for natural hazards.*" It is imperative to solve the worldwide environmental issues that affect society. However, ecological and environmental conservation is concerned with the well-being and growth of humans. For the sake of protecting the environment, preservationists worry about waste, degradation, and the loss of habitat. The green growth model attempts to bring together industrialised and developing countries' interests in green growth and equitable development subject to the identifiable categories of African countries (Bouma & Berkhout, 2015).

The effective utilisation of Africa's resources should incorporate green growth principles to address the persistent gender divide in resource access. Despite progress made since the adoption of the Beijing Declaration, Africa continues to have high levels of gender disparity and poverty (Ezenwa-Onuaku, 2020). The success of green economy initiatives in various African countries shows its potential for rural areas, but the challenge lies in how to effectively integrate the green growth paradigm into rural Africa, where many women require these products (Ngondjeb et al., 2020). It is essential that green growth initiatives take into consideration the specific needs and challenges faced by rural women, and design programmes and policies that empower and uplift them.

Crafting visionary green strategies and policies as a premise for gender and green growth inclusivity in Africa is paramount. These policies should reflect the roles of both genders and identify aspects where women's empowerment through participation and engagement in green growth initiatives takes precedence. Ideally, there needs to be a balance between rigidity and adaptability in green growth plans, as well as between practicality and enforcement (Kararach et al., 2018). Overall, these gender discrepancies should highlight the need for a sustainable and equitable green economic model for both genders. Social policies and community-based initiatives are crucial social drivers, particularly for rural communities that host marginalised groups, including women. Green fiscal interventions could help combat rising rates of involuntary joblessness by committing to reskilling women in the green sectoral business cycles and labour supply interaction.

3 Green Skills and Green Jobs for Women Empowerment in Africa

Pre-existing societal inequities, including gender inequality, are predicted to be exacerbated by climate change in the global south, where gender policies are still on the back burner (Ahmed et al., 2022). However, green skills that enshrine inclusivity could cushion such gender disparities in the emerging economies of sub-Saharan Africa. Accelerating the shift to a greener era, a greener process is being promoted by both advanced and emerging countries and thereby increasing focus on ecologically sustainable growth models associated with a more manageable carbon footprint. Women's education, skill building, and the cultivation of talent are all levers that can hasten and strengthen this transformation process to a green economy (Maclean et al., 2018).

There is an increasing demand for green skills, but many firms are not communicating this reality. Rather, men and women are being segregated in the workplace, and as such, the demand-driven skills matrix may not unfold appropriately. Organisations lack sufficient knowledge of the green skills they need and the effects of the green economy in the domains of Science, Technology, Engineering, and Mathematics (the STEM skills) (Kwauk & Casey, 2022). Since their business models are predicated on future-focused environmentally friendly market dynamics, it is highly probable that they will incorporate green capabilities. Certain low-carbon

industries, such as carbon sequestration, nuclear power, and renewable energy, have already analysed the future demand for employee skills and balanced women's inclusion. However, other green industries are not getting the same level of research attention.

The reskilling of women in Africa should consider key foundations of green economy skill base models that include skills supporting climate resilience, skills on the management of natural assets, skills that support resource efficiency, and skills that support the low-carbon industry (Table 1). In terms of global economics, the green economy represents a paradigm shift (Karimi et al., 2022). Africa's focus must be adjusted significantly for this to happen. Accepting this shift is challenging, but it is essential if we are to meet the Global 2030 Agenda for Sustainable Development Goals. Therefore, it is crucial to prioritise empowering women by nesting gender equality as a global goal both in skill and technically enabled mindsets in African economies (Table 2).

3.1 Green Jobs

Green jobs and related work activities aim to protect the environment and specifically combat climate change, through energy and raw material conservation, promotion of renewable energies, waste/pollution reduction, and biodiversity and ecosystem protection (Dell'Anna, 2021). Decent labour, offered by green-based industry models, ensures access to basic social services, a living wage, safe and fair working conditions, recognition of gender and employees' rights, and input into choices that directly influence women. "Skills for green jobs" are commonly understood to include all the abilities required to carry out the duties associated with green jobs and those that can be utilised to improve the environmental friendliness of any given occupation (Gregg, 2017). This depiction encompasses eco-friendly practices but also brown sectors (which include activities like mining, oil drilling, and material manufacturing).

Green jobs are also an essential weapon in the fight against unemployment, such that green activities are a priority for legislators in many nations and areas throughout the world (Rutkowska-Podołowska et al., 2016). These activities have the potential to be implemented in virtually every sector of the economy, contributing to sustainable development and ultimately greening the economy. Green jobs for African women being offered in select industries are compatible with the female gender needs. Green employment opportunities in sub-Saharan Africa will be created

Table 1 Green and gender-inclusive skills

Green and gender-inclusive skills	
• Natural assets management skills	*All commercial activities rely on the availability of natural resources. To keep them safe and under control, both men and women need skills like:* a) Accounting for the natural environment b) Acquiring knowledge on environmental impact evaluations c) Ecosystem service planning, management and development, environmental law interpretation, and target setting d) Ability to create and implement systems for managing natural resources
• Low-carbon industry support skills	*Generation of energy and industries with high-energy needs are the primary focus of low-carbon industry. Skills consist of:* a) Professionals in the fields of science and engineering who have experience working with nuclear power plants or renewable energy sources (including wind and marine) b) Technicians that have the education or experience necessary to upgrade homes and businesses for greater energy efficiency c) Capacity to produce and implement systems, products, and practices that reduce carbon emissions d) Reduction of carbon emissions through actions taken by operators (e.g., driving in a fuel-efficient manner)
• Climate-resilient skills	*Ability to adjust to climatic fluctuations is crucial in industry and commerce. Hence, skills required include:* a) Expertise in the relevant scientific and technical areas, such as climate change projection modelling and interpretation b) Monitoring and evaluation skills interlaced with Climate Early Warning Systems (EWS) that predict future scenarios towards climate resilience c) Competence in developing and implementing strategies, plans, and projects to increase climate resilience d) Taking measures at the operator level to increase climate resilience (e.g., installing water conservation measures in existing buildings)
• Resource-efficient skills	*General or basic green skills are necessary for all firms. These include:* a) Accountancy services for businesses and organisations that focus on carbon and environmental matters b) Skills to develop and integrate technologies, product designs, and boosting resource efficiency of notably lean manufacturing c) Project management abilities with excellent awareness of resource efficiency d) Maximising resource efficiency through actions taken at the operator level (e.g., minimising waste during production)

Adapted from HM Government (2011)

Table 2 Digital green skills

Green digital skills	*Explanation*	*Source*
Green digital and marketing skills	Green marketing, also known as "eco-marketing" or "environmental marketing," is the promotion of goods and services with an emphasis on their positive impact on the natural environment. People have access to relevant, actionable information, such as highly localised content in videos, human mediation to reinforce messages, capacity training to increase service delivery, and near real-time data gathering and analysis to inform modifications	(Revive Digital, 2018); Cluley et al., 2020
Digital green monitoring and inspection skills	Green monitoring skills are distinct from engineering and science in that green monitoring deals with the technical and regulatory aspects of running a corporation. Systemic changes, such as those necessitated by the shift to a low-carbon, resource-efficient economy, will lead to the development of not only new products and services, but also new production methods and business models. Having digital green abilities in monitoring and evaluation allows one to use digital media to create indicators to measure performance, such as monitoring through video capture and screening. The use of digital media enables the transmission of performance data and the monitoring of work progress. Furthermore, web-based analytics dashboards make it feasible to track development and performance.	(Auktor, 2020)
Digital green agricultural skills	Multiple solutions are available in the agriculture and food sectors as a result of digital advancements and technologies. Using mobile technology, remote sensing services, and computer abilities, for example, will help enhance access to information inputs and the market. Every aspect of the agri-food chain is being influenced by digitalisation. The utilisation of digital agriculture abilities has the potential to provide economic benefits through higher production, resource usage efficiency, climate change adaption, and environmental benefits.	(Trendov et al., 2019)
Digital green communication skills	With these abilities, one can, for example, build dialogue spaces that support green ideas in farming and marketing. Communication integrates several media, such as radio, television, and videos, to help people share and enjoy green sharing. Furthermore, having these skills allows for the development and implementation of digital green communication plans.	(Digital Green, 2022)

(*continued*)

Table 2 (continued)

Green digital skills	*Explanation*	*Source*
Digital green design skills	A designer can work and make eco-friendly web designs that encourage green practices. Green designs can also be used to combat climate change. The green digital skills also encourage green and sustainable web hosting, such as carbon offsetting, powering data centres directly with renewable energy, etc.	(Castel-Branco, 2022)
Green mobile technological skills	Green mobile technologies help Africa's farmers face climate change. The agricultural industry in Africa can better adapt to climate change if more people have access to digital technology, particularly mobile-based technologies.	(Mushi et al., 2022)

across a variety of industries, with the highest number being added by the energy, construction, and agricultural sectors. In recent times, the number of women joining the agricultural workforce in Africa has grown. Green job development is projected to increase in the majority of African countries, where women are disproportionately represented.

In addition to more traditional technical and generic abilities, green expertise has been acknowledged as a crucial knowledge base. Companies are seeking employees with the generic and technical skills as well as the green capabilities essential for structural reform in the environmental, social, and economic spheres. Technical and generic skill versatility is a requisite for transitioning to green jobs across all sectors. Economic reorganisation and employment changes result from the transition to a green economy and green job creation. As the nature of work evolves and changes, so do the skill sets that employers consider integral to the performance. To guarantee that layoffs are minimised and impacted individuals obtain retraining, it is essential to assist businesses in adapting to change and provide current and potential employees with suitable skills. Therefore, it is essential to be proactive in positioning for future skill requirements.

4 Green Economy and Transformation Gender Mainstreaming in Africa

The world's ecosystems and rural settlements or communities are threatened by unprecedented levels of climate change, refugee crisis, pandemics, and ecological degradation. This has a disproportionate impact on the

poor, especially the most marginalised members of this population. Global Agenda 2030 SDG 5 aims to achieve gender equality and empower all women and girls by the year 2030. According to the United Nations (UNDP, n.d.), women are often the most acutely affected by the repercussions of climate change. This is due to a combination of reasons, the most prominent being discrimination and language hurdles. Also, because of their vital reproductive roles, women are primarily reliant on climate-vulnerable means of subsistence. The World Bank (2012) notes that social programmes that specifically target women have greater returns on investment and more rapid reductions in poverty, contrary to the alternatives that isolate women.

The transition to a green economy, which aims to balance economic growth with environmental protection, presents both challenges and opportunities (Ngare et al., 2022; Kasztelan, 2017). While a green economy can lead to investment, growth, and job creation in relevant industries, it also requires developing new skills and adapting existing workers to the changing job market. The greatest challenge lies in ensuring that the workforce has the necessary skills to participate in the green growth model and perform tasks related to the creation of transformative green jobs. However, with adequate training and a focus on gender for transformative change, the benefits of a green economy can be fully realised.

Creating sustainable and gender-inclusive green jobs requires a focus not only on specific gender-based skills but also on a profitable economic model. According to Pollin (2019), on green work and decent work studies, economies should emulate sustainability embedded in transformative skills:

> *The idea that building a green economy should be a source of job creation should be intuitive, even though it is frequently portrayed as a job killer. This is because building the green economy necessarily entails building — it means large-scale new investments to dramatically raise energy efficiency standards and equally dramatically expand the renewable energy supply. Spending money on virtually anything will create jobs. The only relevant question should then be how many jobs get created through building a green economy, and correspondingly, how many jobs will be lost through the contraction and eventual dissolution of the fossil fuel infrastructure.* (Pollin, 2019)

Women are viewed as agents of change in emerging global economies with immense potential to upscale Africa's labour pool (Rosca et al., 2020). However, to capitalise on these women's potential, reskilling and

upskilling are required in major climate-sensitive sectors in Africa (energy, forestry, agriculture, and water), which account for the majority of GHG (greenhouse gas) emissions. Therefore, the green economy perspective holds that achieving gender parity and empowering women and girls are necessary conditions for ending global inequality. In the same vein, Principle 20 of the Rio Declaration (United Nations, 1992, p. 6) affirms the importance of women in environmental management and development. Moreover, since future generations will also need resources, women need to take an active role in achieving green growth-driven sustainable development in Africa (Nhamo & Mukonza, 2020).

Taking climate action necessitates green mindsets and gender-empowered initiatives that take into account women's participation and inclusivity in developing countries (Acosta et al., 2020). For instance, the gender responsiveness tool has been increasingly well received in the global south to leverage climate change financing initiatives like the Green Climate Fund (GCF) and Adaptation Fund. Women are empowered with green financing training to unlock resource potential in sub-Saharan Africa (SSA). The Green Climate Fund (GCF) prioritises the needs of women and girls with regard to funding for climate change mitigation projects and implements the UNFCCC's (United Nations Framework Convention on Climate Change) objectives. Gender mainstreaming in climate change plans and practices at the domestic level has been reinforced by the preference of most national transformation initiatives to access climate change finance from GCF (Ampaire et al., 2020).

5 Constraints in Green Reskilling of Women for Climate Action in Africa

Gender mainstreaming and climate change action through a transformative reskilling approach in Africa is constrained by the following:

Green economy is a novel, vast, unclearly defined, and unstructured sector—The United Nations Environmental Programme's (UNEP) description of "green economy" is perhaps the most generally used and accepted that incorporates resource efficiency, reduction of carbon emissions, and enhanced energy efficiency models. According to the UNEP,

> a green economy is defined as low carbon, resource efficient and socially inclusive. In a green economy, growth in employment and income is driven by public and private investment into such economic activities, infrastruc-

> ture and assets that allow reduced carbon emissions and pollution, enhanced energy and resource efficiency, and prevention of the loss of biodiversity and ecosystem services. (UNEP, n.d.)

However, green economy is still a new notion that relates to a combination of existing and growing industries, issues, ideas, and concepts (European Union, 2016). Most assessments concentrate on one or a few of these themes, with a disproportionate number focusing on energy, mobility, industry, and the utilisation of natural capital, with less emphasis on gender dimensions or dynamics. However, very few enquiries adopt a more comprehensive approach, spanning multiple concepts. This explains why there are presently no effective national green economy evaluations and relatively sparse research efforts in the aspect of green resource utilisation.

Lack of coherent framework on women's green reskilling to advance the green economy—Recent studies are generated in response to a pressing need or a policy dilemma concerning this narrow niche of the green economy and gender, a process known as "bottom-up" assessment. Because of the breadth and depth of the notion, it is uncommon to find assessments that are part of a coherent "top-down" integrated framework on women's inclusion through reskilling and upskilling.

6 Conclusion

Green employment refers to positions in a specific subset of businesses that deliver environmental advantages. Policymakers would achieve their objectives if they considered the broader issue of how policies address environmental externalities, such as how anthropogenic climate change can affect employment rather than domiciled gender shifts. This multiplier approach has an impact on job creation, particularly because of how gender segregation impacts policy and hence employment creation. While green growth strategies are rarely explored, they may have unforeseen repercussions for employment costs and workers' productivity. Job markets operate differently across economic systems, and this should be taken into account, particularly in African countries where economic prospects are contested, and unskilled women outnumber the skilled ones. Under these conditions, both green economic growth and job creation are achievable. However, this raises challenges, particularly for African countries whose industrial expansion plans have relied on access to low-cost

carbon-based energy sources, which undermine climate action. Changes in the structure of the economy should be followed by proactive labour market reforms on gender and women's green reskilling.

Africa's plan to recover from economic setbacks includes retraining its workforce to meet the demands of the future workplace. Therefore, African governments should increase their initiatives to retrain and reskill the labour force on a consistently incremental basis. This could help cushion the effect on African citizens exiting defunct sectors with unreliable economic productivity output. The need to ensure that women in different regions in Africa have equal opportunities to pursue green careers is incontrovertible. Also, gender-inclusive policies are instrumental for a gender-responsive green economy thereby eliminating the structural hurdles faced by women to participate in the green employment market. Consequently, it is opined that there should be concerted efforts at removing all forms of gender bias structures across the legal and corporate processes whilst addressing all manifestations and effects of exclusionary societal norms.

7 Recommendations

To eliminate gender discrimination in the workplace and ensure equal opportunities for women to access green jobs, a combination of education programmes, mentorship by female role models, and support systems for both genders in male-dominated domains is recommended. It is critical to rapidly advance towards a shared conceptualisation of the green economy in terms of gender, workforce, and learning industrial processes. Immediate and long-term actions are required to ensure that the green economy transition does not disproportionately impact women.

To ensure that women have an equal share of green job opportunities, both the public and private sectors in Africa must establish gender-inclusive policies and programmes. Reskilling and upskilling of African women through sustainable and structural retooling are recommended for a transformative green economy. This will require targeted training and capacity-building programmes addressing women's needs and challenges.

In conclusion, recognising and addressing gender disparities in the green economy is essential to achieving a truly sustainable and just transition. Taking concrete steps towards gender equality and empowerment can create a more inclusive and resilient green economy while also unlocking the full potential of women as drivers of economic growth, agents of positive change for the environment, and key actors in climate action. By

empowering women with the knowledge, skills, and resources they need to participate fully in the green economy, we can create a more sustainable and resilient future for all.

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Gender Equality, Climate Action, and Technological Innovation for Sustainable Development in Africa: Conclusion and Recommendations

1 Introduction

African countries are too often unprepared to shelter and care for their people during natural disasters. Disaster management policies and procedures needed to mitigate the threats associated with climate change must incorporate a gendered approach that considers the immediate and long-term effects on women, a vulnerable population in developing countries. Studies have shown that women in Africa bear the burden of traditional domestic responsibilities and typically require assistance during disasters as they seek birthing shelters, infant/childcare facilities, and care for elderly family members (Adeola, 2020, Adeola, 2021; Adeola et al., 2021; Blau et al., 2022).

Even though the role gender plays in climate-related outcomes is widely acknowledged as a crucial area of investigation, the scant number of pertinent articles shows that further empirical study on the subject is necessary. Extant literature reveals the effects of changing weather patterns, particularly on the effect of inadequate water supply for Africa's farmers who rely on rainfed farming (Henriksson et al., 2021; Nyasimi et al., 2018). Similarly, public policy-level interventions aimed at increasing the use of communication strategies and technological innovations to combat

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climate change challenges should pay special attention to Africa's women farmers.

This chapter summarises the authors' ideas presented in this book and provides gender-responsive solutions to climate change impacts while also highlighting future research directions. Table 1 summarises the ideas from Chaps. 2, 3, 4, 5, 6, 7, 8, 9 for ease of reference. The book takes into account the critical role of gender and technological innovations and tools in mitigating and adapting to climate change in Africa. Although Africa has been identified by international organisations as the continent most vulnerable to climate disasters, there is evidence in this book that Africa has the human and natural resources to combat climate change if the necessary policies are adopted.

Climate decisions and actions have predominantly been inclusive of men, with limited participation of women. This book, through chapters on gender and climate issues in Africa (Chap. 2), gender vulnerability to climate change (Chap. 3), and climate change and gender difference (Chap. 4), unravels the deleterious effect of climate change on women and the girl child during natural disasters. The authors of this book propose that women have invaluable contributions that must not be neglected in the quest for a sustainable Africa. By empowering women with sustainable practices through technological adoption, it is projected that Africa will become a protagonist and not a victim of climate change.

African women need to be given the due audience, attention, responsibility, and roles they deserve in an effort to combat climate change. To this end, this chapter first provides a synopsis of the discussions in the book as seen in Table 1; makes recommendations for gender-responsive solutions to climate change impact; outlines strategies to make climate information services more gender-responsive in Africa; and discusses contemporary themes, issues, and climate-responsive pathways. Finally, the chapter highlights future research directions to achieve the climate-safe Africa we want.

2 Gender-Responsive Solutions to Climate Change Impact in Africa

Climate change can be expected to escalate gender-related weaknesses and overlapping levels of abuse against women. Gender-responsive remedies to address climate vulnerability and hazards are not widely understood; therefore, lacking gender-responsive directives have not been implemented equally. Meaningful strategies for mediating the effects of climate change in

Table 1 Summary of chapters in the book

Parts	*Chapter*	*Title*	*Summary*
Part A: Gender and Climate Change	Chap. 1	Gender Equality, Climate Action, and Technological Innovation for Sustainable Development in Africa: *A Background*	• African leaders are advised to design adaptive interventions acceptable to both women and men by leveraging the GAP framework to develop an inclusive climate action plan. Technological innovations must be introduced to capture climate change risks and suggest mitigations and adaptative opportunities. Both adaptive and mitigating actions must incorporate women to ensure diverse and informed representation.
	Chap. 2	Gender and Climate Issues in Africa: *Regional Challenges, Insights, and Recommendations*	• Regional governments are encouraged to adopt the Gender Action Plan for climate change to identify gender-specific opportunities and establish blueprints for action. • Regional governments must address discriminatory and biased policies against women. • Sex-disaggregated data and research must be conducted to determine gender gaps in climate actions.
	Chap. 3	Explaining Gendered Vulnerability to Climate Change: *The contextual conditions*	• Gender-differentiated consequences of climate-induced shocks also reflect gender disparity in access to healthcare and education, in decisions about marriage and having children, in the experience of or likelihood of violence, and in the range of economic prospects. These factors highlight the importance of considering context conditions in decisions about climate change mitigation, adaptation, and decision-making.
	Chap. 4	Climate Change and Gender Gaps in Africa's Agricultural Sector	• Support for mitigation actions can be more rewarding if advocates effectively leverage women's traditional strengths, increasing the success rate of adaptation approaches. This chapter recommends that priority be given to women's land ownership, participation in crisis prevention and response, as well as reconciliation initiatives.

(*continued*)

Table 1 (continued)

Parts	*Chapter*	*Title*	*Summary*
Part B: Technology and Climate Change	Chap. 5	Leveraging ICT for Climate Change Adaptation in Africa: A Focus on Women	• The digitalisation of agriculture in Africa has great potential to increase food security for the continent's rapidly expanding population and promote adaptive urbanisation while also aiding in climate change mitigation efforts. Therefore, it is crucial to create and implement advanced ICT and expand the use of currently available strategies, which is essential for transitioning to a low-carbon economy. • To achieve this, there is a need to establish an institutional and regulatory environment that encourages innovation and the use of advanced technology. Additionally, the needs of women, who are important stakeholders in the agricultural sector, should be taken into account. Given their significant contributions, women should be empowered to play a crucial role and be recognised as agents of positive change in the sector.
	Chap. 6	Climate-Smart Technologies for Empowerment of Women Farmers in Africa	• Climate-smart agricultural practices can be adopted by women in African countries to address the problems of land degradation and desertification. These practices could also be extended to food security, enhancement of timber production, and lowering the vulnerability of crops and livestock to climate change.
	Chap. 7	Cleantech, Telehealth, and Other Emerging Technologies for Improving African Women's Adaptation to Climate Change	• Improving access to ICT and encouraging women to pursue STEM (Science, Technology, Engineering, and Mathematics) should be a key policy focus for African countries. This is essential for the success of climate action, as women play a critical role as key stakeholders in addressing climate change.

(*continued*)

Table 1 (continued)

Parts	*Chapter*	*Title*	*Summary*
Part C: The Way Forward	Chap. 8	African Indigenous Knowledge and Climate Change Mitigation: Towards an Afro-Sensed Perspective	• The features of the Ubuntu concept in the areas of compassion, care, collaboration, team spirit, sympathy, dignity, political decision-making procedures, and respect for nature are beneficial practices that may aid in enhancing the greener economy in Africa. The goal is to retain the unique repository of cultural knowledge while embracing the innovation of modern science to achieve the mitigation of climate change. Notably, the role of African women in promoting sustainable development and addressing climate change challenges was also emphasised.
	Chap. 9	Green Reskilling of African Women for Climate Action	• Africa's plan to recover from economic setbacks includes retraining its workforce to meet the demands of the future workplace. Therefore, African governments should increase their initiatives to retrain and reskill the labour force on a consistently incremental basis.

Africa must take into consideration economic, social, and cultural realities, all of which are informed by gender issues. African nations are called upon to design adaptive interventions acceptable to both women and men; conduct gender analyses to identify climate-related risks; and adopt vulnerability-reduction initiatives, particularly for women in rural areas.

Attention to the ten critical focus areas that follow would lessen women's susceptibility, increase their resilience and capabilities to respond to climate change, and facilitate SDG 13.

2.1 Gender-Sensitive Legal Rights and Institutional Support

The legal rights of African women to own property and resources must be established and enforced to guarantee equality in reaction to climate change or climate-related disasters. According to Awiti (2022), although some sub-Saharan nations have acknowledged women's land ownership for their constitutions and implemented appropriate legislative and institutional changes, there are still obstacles that prevent women from having access to or control of land and other productive assets. It is important to give meaningful legal attention to gender-sensitive issues, especially given the current uncertainties in climate change in Africa.

2.2 Women's Representation and Participation in Decision-Making

Women's equitable and meaningful engagement in the environment and policymaking processes continues to be severely hampered by the absence of information, statistics, and quantification of their involvement in these activities. Women face impediments to political participation owing to intrinsic patriarchal structures at the national and local levels, even when robust national gender legislation is in place. This inequality is exacerbated by women's lack of participation in the decision-making process on issues of climate change mitigation through policy planning and implementation (United Nations Climate Change, n.d.a). It has been shown that adopting a variety of supportive measures, such as adopting flexible meeting schedules that do not interfere with women's household responsibilities and acknowledging possible safety issues, can boost women's involvement in decision-making (Ihalainen et al., 2021).

Removing entrance obstacles and enhancing involvement will positively affect women's representation and participation rate in decision-making. According to Howard (2019), investment in workforce participation and capacity development will help increase women's economic power. Groups charged with decision-making regarding climate adaptation and mitigation programmes must unfailingly incorporate women to ensure adequate and diverse representation so women will be empowered to make policies that directly impact their gender and children (Adeola, 2020).

Women have a critical role to play in mitigating climate change. Therefore, their representation and participation in climate-related decision-making is expedient. African women could become important

agents of change at the local level because of their knowledge and experience in domestic activities that promote sustainable climate action (UN Women, 2022). Women's participation in climate decision-making leads to more stringent climate policies that result in lower emissions, improved natural resource management, better resource governance, and conservation outcomes at the local level (UN Women, 2022).

2.3 Facilitating the Participation of Women in Agricultural Value Chains

Women in Africa are frequently excluded from participation and investment in agricultural value chains, particularly in processing, marketing, and management; gender conventions; and lack of monetary capital, the long-term advantages of initiatives involving the agricultural value chain are in jeopardy. Climate change increases the severity, frequency, and range of threats (Nyasimi & Huyer, 2017). Gender-sensitive financial institutions in Africa are in a position to boost women's productivity and quality by supporting their participation in agri-business value chains.

Men and women frequently pursue distinct, though often congruent, agricultural careers and rely on various technologies and production management systems. It is critical to consider how these distinctions, often influenced by societal norms and decisions, can merge in a way that encourages men and women to adapt environmentally friendly farming methods and raise awareness of the relevance of gender equality to enhance agricultural output (Nelson & Huyer, 2016).

2.4 Enabling Diversification of Livelihoods for Women

Diversification of livelihoods is encouraged for African women in an ever-changing climate. According to Njuki et al. (2022), successful adaptation initiatives will depend on projects that empower women to add value to their agricultural production and broaden their sources of income. To this end, in addition to combating erratic agricultural productivity, diversification into revenue-generating enterprises offers the potential for women's financial security (Nyasimi & Huyer, 2017). Youth migration plays a role in this diversification: As youth venture into service sectors, access to education improves, especially in rural regions, which opens up skilled employment options. Similarly, business assistance grants for agriculture-based entrepreneurship development offer several home-based income choices.

2.5 Data by Gender and Relevant Gender Indicators

Data and gender analysis are the most valuable methods for identifying differential impacts and conducting risk assessments (Frenova, 2022). The ability to provide timely, accurate data is, at best, limited for many sub-Saharan African nations. Sex-disaggregated data has to be required by any laws or regulations that control the gathering, evaluation, and distribution of official statistics. Collection and analysis of data based on gender-related effects will expedite the formulation of decision-makers planning agendas, especially as they shape the national budget.

2.6 Gender-Responsive Financial Services

Women cannot adjust to or build resistance to climate change without adequate financial resources (Danso-Abbeam et al., 2021). The broader impact of financial inclusion on women's economic empowerment is limited by social and cultural restrictions and the social standing of women. Additionally, insurance against climate-related disasters is a crucial risk management tactic that may boost resilience, safeguard assets, and save lives. However, because impoverished women are predominantly present in economically vulnerable communities, financial support programmes should include a comprehensive spectrum of products. According to Ng'weno et al. (2018), adjustable financial solutions that match personal experiences show greater potential for effect at scale than a one-size-fits-all strategy. To determine how best to target and personalise financial products to meet women's specific needs, personal data must be collected. Resolving equality disparities in property ownership and employment would augment policies intended to increase women's access to financial services and the collateral needed to borrow from formal banking institutions.

2.7 Gender-Responsive Adaptation and Mitigation Technologies

Diverse socio-economic characteristics such as gender, age, and crop farming knowledge, as well as organisational elements such as access to extension services and climate change knowledge, all affect recipients' adoption of climate change mitigation and adaptation measures. Mutenje et al. (2019) demonstrated that women's purchasing power, drought shock, and access to CSA technology positively increased the likelihood of investing in CSA technology mixes. Locally led climate action can empower women to

achieve a higher quality of life and benefit vulnerable populations; hence it should be encouraged at community and sub-sovereign levels.

The Commonwealth Secretariat, in their best practice guide on gender integration in the Nationally Determined Contributions (NDCs) published in October 2022, recommended a skill empowerment strategy for gender-just integration for all women, irrespective of sector or state of vulnerability, in an effort to promote an inclusive integration of women into climate mitigation and adaptation plans (Commonwealth Secretariat, 2022). NDCs (see Chap. 1) are climate action plans to cut emissions and adapt to climate impacts. Each party to the Paris Agreement is required to establish an NDC that should be updated every five years (UN Climate Action, n.d.).

Henriksson et al. (2021), in a study of smallholder sugarcane farmers in Southern Malawi, found that women have more difficulty accessing and utilising weather and climate information than men. Such impediments are a result of illiteracy, cultural norms, unfamiliarity with digital technology, and language hurdles. For instance, Senegalese women prefer receiving communications in their native tongues via SMS apps, local radio, prediction boards, and broadcasts at gathering sites like mosques (Tall et al., 2014). Men in Ghana's Upper West Region were more receptive than women to adopting climate information services, given their greater access to financial resources (Partey et al., 2020).

Creation of a grassroots network of female broadcasters would be a valuable strategy to encourage women's access to meteorological, climatological, and agro-advisories as a means to lower the causal factors of disasters (Huyer et al., 2021). When access to climate information for women is prioritised, the use of mobile phone technology and other climate information services will help to narrow the gender awareness gap on Climate-Smart Agriculture (CSA) in Africa (Mittal, 2016).

2.8 Promoting Labour-Saving and Productivity-Enhancing Technologies

It is a fact that African women and girls who carry water and fuel wood, often at great distances, undoubtedly have long-term detrimental health challenges and are exposed to discrimination and physical harm (Nyasimi & Huyer, 2017). In the same vein, women's work in agriculture and the home is frequently labour intensive and time consuming, which limits the time they have for activities like education or diversifying their income

sources; it is, therefore, critical to promote and make affordable labour-saving technologies that help women reduce their workload, increase their productivity in a changing climate, and give them more free time (Huyer, 2016; Jost et al., 2016; Murray et al., 2016).

2.9 Promoting an Assets-Based Approach to the Gendered Impacts of Climate Change

Mediating the consequences of hazardous climate change on women depends on their having access to assets and finance (Ngigi & Birner, 2013). These resources include natural capital (e.g., soil fertility, water, and trees); human capital (e.g., knowledge, abilities, drive, time management, well-being, and nutrition); financial capital (e.g., credit and savings); social capital (e.g., cultural standards, legal frameworks, and institutional structures); and physical capital (e.g., technology and infrastructure). According to Awiti (2022), gender disparities in agri-business and other sectors are a measure of these assets or capital.

There is evidence that women, especially those in rural areas, continue to experience gender disparities, especially in access to resources like land, animals, agricultural inputs, and services. For instance, according to the Food and Agriculture Organization of the United Nations (FAO, 2010), on average, women in sub-Saharan Africa possess 15% of the land, a percentage that conceals significant national differences. Gilbert (2002) found that male farmers in Malawi used more fertiliser and devoted more acreage to commercial crops than female farmers. Compared to males, African females are less likely to embrace new crop types and management strategies (Kristjanson et al., 2017).

Understanding the risks of climate change requires the use of an asset-based way of building gender-responsive treatments. Men and women have differing baseline wealth endowments, which results in fundamentally unequal risk or adaptability outcomes. Women in most rural African countries, on average, have less knowledge, information, and time (human capital) than males to address climate-related hazards (Simpson et al., 2021). Women confront significant challenges in diversifying into different livelihood alternatives if they do not have fair access to land, financing, knowledge, and agricultural technology. Therefore, any attempt to create and implement gender-responsive global warming remedies must employ a holistic, asset-based strategy to identify dominant causative pathways and provide appropriate governmental and institutional choices to address interconnected asset or capital dis-endowments.

2.10 Commitment to the Crafting of a National-Level Gender Action Plan (GAP)

As mentioned in Chap. 1, African countries should commit to crafting a national-level Gender Action Plan (GAP) that focuses on the priority areas identified in the enhanced GAP adopted by UNFCCC in December 2019 during COP25 in Madrid, Spain (UNFCCC Gender Action Plan, 2019). According to the UN Women report, from a gender perspective—the adoption of the enhanced five-year Lima Work Programme (United Nations Climate Change, n.d.b) and an updated Gender Action Plan (GAP 2.0) (UN Women, n.d.) represent a key outcome of COP25. Parties to the GAP initiative commit to the promotion of gender equality in policies regarding climate action (gender-responsive climate action) and promotion of women's rights. Five priority areas were identified in the GAP agreement:

1. Capacity-building, knowledge management, and communication
2. Gender balance, participation, and women's leadership
3. Coherence
4. Gender-responsive implementation and means of implementation
5. Monitoring and reporting

The development of a national-level GAP will encourage cooperation among the countries' relevant organisations and authorities as the activities associated with the identified GAP priority areas advance gender equality at multiple levels.

3 Strategies to Make Climate Information Services More Gender-Responsive in Africa

Climate information services can be vital to rural farmers' sustenance management, but they can also promote gender inequities if they do not acknowledge and adequately address women's needs. According to Gumucio et al. (2020), proper gender-responsive climate information services will strive to address these issues. Five options are recommended to achieve gender-responsive climate services, especially as they relate to African women.

3.1 ICT-Based Communication Channels Suited to Women's Needs

Several studies (e.g., Gumucio et al., 2020; Huyer, 2016; Jost et al., 2016) report that access to and ownership of ICTs and communication facilities may be restricted for women. Gumucio et al. (2020) found that women with limited funds frequently find it difficult to afford radios and cell phones, and consequently men understand ICT forms more accurately than women. Barriers to ICT ownership handicap women who then have limited access to routine meteorological data and warnings. Interventions aimed at promoting ICT use are fundamental to accessing communication resources.

Women's access to media-based services may be constrained by household responsibilities. Therefore, understanding women's preferred communication resources is important when ICT and media are used to distribute climate change information. This calls for utilising local information sources and formats that are accessible to women. It is also useful to discover significant community relationships as women who possess mobile phones can share information obtained with other female family members and acquaintances. An ongoing example in this regard is the project in Rwanda called "Weather patterns services for agriculture," which uses background research on how men and women manage their assets and access communication channels to create ICT or mainstream press communication tools that let farmers access climate data (Nsengiyumva et al., 2018).

3.2 Women's Groups and Other Information-Sharing Channels for Communication

Studies have shown that most African women have limited access to climate risk mitigation strategies linked to weather patterns and meteorological alerts due to organisational biases and perceived barriers to official group activities. It has been reported that women's participation in organisations that share climate information may be constrained by sociocultural structures and conventions around inter-gender relationships, physical space, and mobility (Gumucio et al., 2020). Cultural beliefs in some African countries prevent women from engaging in social activities and services that offer knowledge and/or training. The inclusion of women's organisations' connections to climate information and remote advisory dissemination might aid in addressing this issue.

In some locales, there are some socio-cultural circumstances that prevent a male agricultural extension officer's interaction with a woman without a male family member's approval or presence. Therefore, it is pertinent and also a matter of necessity to incorporate women's organisations as communication channels as an effective method to respond to these discriminatory standards. The Village Knowledge Centre (VKC) (Rengalakshmi et al., 2018) and the Agro-meteorological Advisory Service (AAS) (Gumucio et al., 2020) are examples of local information sources that have helped to sustain women's information services in Indian villages. According to Huyer et al. (2015), Participatory Action Research (PAR) methodologies can be helpful in identifying group processes and information-sharing media suited to women's access constraints.

3.3 Local/Civil Society Organisations to Address Women's Socio-cultural Constraints to Access

Considering the existing norms in some parts of Africa, changes in gender relations at the home and community levels may be necessary to increase equitable rights for male-dominated groups and surroundings. African women have, over time, been side-lined in decision-making related to major climate change mitigation issues, even though studies have shown that women more often experience the negative side of climate change. This is a result of some socio-cultural norms that constrain women's access to important agricultural inputs such as land. It is, therefore, important to note that improving women's access to typically male organisations and public domain activities necessitates changes in often deep-seated socio-cultural institutions and practices that must be considered when designing interventions.

To overcome some norms that constrain women's access to climate information, local and civil society groups are encouraged to increase their involvement in community-wide initiatives affecting gender practices and duties. According to Thompson-Hall et al. (2016), partnerships with regional stakeholders committed to gender awareness will be critical in creating culturally conscious climate information services. For instance, exposure to agricultural production information for women and ethnocultural minority producers in South-east Asia resulted in more equitable gender-based power relations at family and community levels (CARE International, 2010). Collaborative interventions among local civil society

groups with expertise in social change processes and evolving gender roles and behaviours are in a position to resolve constraints to access to climate information services.

3.4 Provision of Women's Climate Information Needs

Given that gender inequalities exist in obtaining meteorological information to inform decision-making, women are more likely than men to experience and struggle to adapt to the adverse effects of climate change (Henriksson et al., 2021). Men have greater access to information than women and other underrepresented groups throughout the majority of Africa, and this is also true for weather and climatic services (Nyasimi et al., 2018). Carr and Onzere (2018) note that gender relations define both the access to power resources and power to make decisions, including the response to weather and climatic information that can be helpful to both men and women. Discriminatory practices related to gender, age, and other socio-economic factors contribute to unsuccessful climate information distribution in Africa.

Considering the already wide gender gap affecting access to climate information in Africa, it is important to acknowledge that the type of climate information that will be most helpful to women and men will vary depending on gendered work roles and obligations, life stage, and ethnicity, all of which influence women's information requirements and preferences. Therefore, assessing and meeting the information requirements of women will be relevant to the cultural boundaries and must be incorporated into the design of communication strategies.

3.5 Integration of Climate Services with Rural Development Efforts to Address Women's Resource Constraints

Key challenges to the uptake of agricultural systems, especially as they relate to women in Africa, include inadequate funding, limited agricultural inputs, and insecure land rights (e.g., Goh, 2012). Furthermore, restricted availability to and participation in agricultural decision-making can considerably hinder women's ability to fully access and utilise climatic knowledge (Gumucio et al., 2020). Carr and Onzere (2018) noted that focusing on the delivery of climate-related information alone will create considerable hurdles for disadvantaged populations that must respond to that

information. Climate information services will be actionable for farmers when programmes or policies create pathways that can be fully utilised to blend climate services with rural development efforts.

4 Contemporary Themes, Issues, and Climate-Responsive Pathways

Understanding and responding to climate change in Africa requires the identification of contemporary themes and issues that will guide climate-responsive pathways. This section discusses critical issues and pathways:

4.1 Climate Action by Regional Communities

Africa's regional groups are driven by both geopolitical competition and climate imperatives. Considering that some countries in a region may lack the capacity to act alone to address climate change and SDG 13, the need to advance joint strategies and tools across regional levels is crucial, even more so regarding adaptation and mitigation. Already, some initiatives are under way across the African continent, focusing on understanding how multilateral groups can address climate action and green innovation. In Africa, there are at least eight regional economic communities (RECs) and overlapping country memberships (Hale, 2022). Reinforcement of these links among regional communities can contribute to scaling climate action. For example, the EAC-SADC-COMESA tripartite represents three regional economic communities' blocs currently addressing the impact of climate change and seeking to establish effective adaptation and mitigation actions to improve economic and social resilience (COMESA, 2022).

Even though the African Continental Free Trade Area (AfCFTA) (Briel, 2023), is not inclusive of any treaty commitments on climate change, there is still time to leverage the new agreement to scale climate action. For example, there is a significant possibility to fortify the link between the AfCFTA and the climate action goals of Africa's Agenda 2063. National AfCFTA plans can align with national climate policies (also known as nationally determined contributions [NDCs]) in the form of trade measures to foster climate action by labelling and certification schemes, classifying climate goods and services, and exempting climate measures from non-tariff barriers (Hale, 2022; Van der Ven & Signé, 2021). In addition, the AfCFTA Secretariat can explore State Parties' interests by the addition of a Protocol on the Environment and Sustainable Development. In doing

so, State Parties would be able to address environmental concerns of particular relevance to building an inclusive and sustainable Africa.

Standards play a crucial role in the design of market products (Hale, 2022). Major standard-setting bodies such as the International Standards Organization (ISO) and other national bodies are currently aligning their standards to climate change goals (Hale, 2022). With the London Declaration of 2021, which defines ISO's commitment to achieving the climate agenda by 2050 and combat climate change through standards, the ISO has begun aligning its standards with climate targets. For African countries and regional groups, early participation in standard-setting would position African traders at an advantage to conform with the evolving climate-related standards and regulations in foreign export markets. For example, to prevent carbon leakage, the European Union adopted a resolution in 2021 to implement a Carbon Border Adjustment Mechanism as a part of the European Green Deal. Unfortunately, many African countries are slow in transitioning towards low-carbon economies; rather, they rely more on the exports of carbon-intensive products. To ensure that carbon border measures do not undermine the industrial development in Africa, the regional communities must push for carbon border measures paired with major infrastructural investment initiatives such as the US's Build Back Better World, the EU's Global Gateway, and the Belt and Road Initiative.

Since finance is an essential element of exports and imports (e.g., insurance and credit schemes), institutions such as Export Credit Agencies (ECAs) can play a crucial role in financing trade. The African Export and Import Bank (Afreximbank) at the continental level, in collaboration with national ECAs, can support these ECAs in integrating climate policy action into their operations. Through the African Green Innovation Framework and the constitution of a high-level panel, African countries have recognised the need for green innovation (Hale, 2022). While the African Green Innovation Framework includes policy commitments on climate action, there is a growing need to speed up implementation. The launch of the African Green Hydrogen Alliance is an important step towards a viable energy solution for industrial production. There are other sectoral initiatives on cutting-edge technologies that fit well with Africa's industrialisation aspirations (Hale, 2022). Such initiatives can be coordinated with others, such as the Glasgow Breakthrough Agenda (established at the UN climate change negotiations in 2021), which aims "to make clean technologies and sustainable solutions the most affordable, accessible and attractive option in each emitting sector globally before 2030"

(Hale, 2022). A Green Innovation Fund based on revenue streams redirected from developed countries' carbon border taxes would be invaluable to support these initiatives.

Climate finance can support regional communities in addressing climate change. Developed countries must be encouraged to deliver on climate finance (US$100 billion a year) pledges made in 2009 to address the needs of African countries in terms of meaningful mitigation actions (Savage, 2022). Approximately US$250 billion is required annually to transform Africa to greener technologies and adapt to climate change. Funding in 2020, however, was just US$29.5 billion (Savage, 2022). The EAC-SADC-COMESA tripartite climate initiative is financed via a multi-donor arrangement, including key development partners: the European Union, the Government of Norway, and the UK's Department for International Development through COMESA. At the regional level, more of such development partners are needed to strengthen the capacity of the regional communities to advance and implement climate change actions. In addition, these efforts can support the development and enactment of climate change bills/policies, as well as the identification and cascade of pertinent national best practices and success stories and subsequently sharing them amongst partner states.

In 2022, the African Union released the continent's first collective climate response framework: AU's Climate Change and Resilient Development Strategy and Action Plan (2022–2032) (Briel, 2022). Formed to promote an African-led and African-owned climate response, the AU's ten-year strategic plan document is a key first step for mapping out a regional harmonised response to climate change to foster Africa's adaptive capacity and unlock transformative climate-resilient development. However, making the strategy a reality across the continent will require a wide range of stakeholders to overcome their resource, capacity, and institutional constraints of moving from planning to implementation (Briel, 2022). Moreover, the vision must garner impetus from member states, other regional communities, and non-state actors. The strategy's identified climate-related intervention target will only be realisable with specific resource mobilisation and implementation mechanisms. Moving from design to execution will require a strong focus on implementation that factors in the diversity of complementary institutions, plans, and actions across all levels. Gender consideration remains important even as regional governments make their plans.

4.2 *Climate Justice and Gender-Centric Policies*

"Africa is being devastated by a climate crisis it didn't cause. COP 27 must help". Amina J. Mohammed, Deputy Secretary-General of the United Nations

As leaders gathered in Egypt for COP27 in November 2022 to discuss climate change, the issue of climate justice was on the front burner. Gender issues must be nested within policy and implementation priorities centred towards climate justice, particularly as Africa canvasses for it, as *there is no climate justice without gender justice*. Women's rights activists at the Bali Conference of December 2007 used the slogan "No climate justice without gender justice" as their rallying cry (Terry, 2009). This voice is expected to grow louder in the coming years as women's groups and advocates for gender equality engage in climate change discussions. Earlier, Bali Principle of Climate Justice, published in 2002 by the International Climate Justice Network, was included as one of its core principles (No. 22)—"Climate Justice affirms the need for solutions that address women's rights" (Corpwatch, 2002). Climate justice is highly contested and premised on historical injustices that have negated climate protection actions and would require reparation for victims, women included.

Importantly, in all discussions of climate justice, the future should be considered, and a gendered perspective should be incorporated. How can we redress the mistakes of the past? However, gender equality concerns are difficult to introduce when climate change is framed as a problem requiring primarily technical and economic solutions (Maguire, 2019). High transaction costs in the prevailing carbon trading system make it inaccessible to low-income people. Markets are intrinsically gender-inequitable, as many advocates for gender equality have pointed out, due to the unequal distribution of land, credit, and information between men and women. The focus on markets to reduce greenhouse gas emissions discriminates against women (Terry, 2009). However, to ensure that the UNFCCC's market mechanisms and other practical fixes (such as commoditising voluntary carbon and debt-for-nature swaps) would drastically reduce greenhouse gas emissions, we must consider the conceivably catastrophic effects of unchecked climate change on the rights of women. To tackle climate change and environmental injustice related to gender, emphasis can be placed on working with existing mechanisms, such as advocating for Clean Development Mechanisms (CDM) projects to be aimed directly at improving poor women's access to alternative energy services.

4.3 Climate Adaptation and Gender

Climate adaptation mechanisms are methods for dealing with actual and/or predicted outcomes of climate change. Adapting to a changing climate can be a preventative, responsive, or proactive strategy. Adaptation to climate change has coincided with a flurry of new environmental initiatives across Africa (Epule et al., 2017). Households need short-term and immediate assistance from climate adaptation mechanisms if they are to thrive during climatic shocks. While adapting to climate change is a viable option for rural residents—and there are many positive strategies for preparing for a changing climate—there are also potential drawbacks that must be considered (Enríquez-de-Salamanca et al., 2017).

In recent years, there has been considerable emphasis on adaptation strategies critical to ensuring that vulnerable populations can deal with various intensities and types of climate change. Research findings have provided insights into the biophysical and economic factors as well as unique social characteristics that shape attitudes and reactions. Gender inequalities and other forms of societal differentiation and stratification have been shown to impede adaptive capacity and decision-making (Adzawla et al., 2019). It is well established that women suffer disproportionately more from climate change-related consequences than men. Cultural beliefs, social biases, and political discrimination all make it difficult for women to advance in the workplace (Eastin, 2018). As a group, women are more vulnerable to the negative effects of climate change due to their disproportionately high poverty rates.

When discussing climate change and its effects on agriculture, global and local issues are inextricably linked and frequently presented as causes and consequences (Acosta et al., 2021; Faiyetole & Adesina, 2017). Agricultural and forestry practices and land-use changes account for roughly a quarter of all man-made greenhouse gas emissions (IPCC, 2019). However, due to the location-specific nature of climate change's effects on agriculture, localised solutions are regarded as critical for effective adaptation and mitigation strategies (UNDP, 2019). Given that women's roles are highly contextual, socially determined, and constantly evolving over time, a greater emphasis on community is regarded as equally important. To avoid developing adaptive technologies that are inappropriate for the context or that may perpetuate pre-existing gender inequalities, valuing local knowledge is critical to decision-making regarding climate change adaptation (Huyer, 2016).

Making decisions about adapting to climate change is typically folded into ongoing local government planning and implementation rather than functioning as an independent body. Whether it is its own decision-making process or a part of a larger developmental framework, local climate adaptation can be broken down into five distinct but interconnected stages, as proposed by Edvardsson and Hansson (2013). In addition, each of the five steps of local adaptation requires a focus on gender equity:

1) Recognise risks, vulnerabilities, and opportunities.
2) Establish adaptation objectives and criteria.
3) Identify adaptation options.
4) Assess adaptation options (including identification of conflicts and synergies).
5) Implement, monitor, and evaluate.

Empirical evidence suggests that the effects of climate change will be felt more acutely by women than by men. Although more pronounced in developing nations, this gender-based vulnerability is not absent in developed countries. Policy interventions in the form of adaptations can mitigate a portion of the dangers brought on by climate change; however, if they are not carefully crafted, adaptation measures may contribute to maintaining conventional gender inequalities and increasing women's susceptibility to climate change. A gender-sensitive approach to adaptation planning is needed to prevent this kind of maladaptation, and this can be demonstrated by expanding upon existing adaptation policy frameworks.

4.4 Climate Finance Insufficiency

Africa needs about US$2.8tn by 2030 to help keep global warming below 1.5 Celsius and mitigate its effects (Mohammed, 2022). However, the entire continent received only about US$30 billion of the global climate finance funds allocated in 2020 (Mohammed, 2022), underscoring a significant resource gap (Mohammed, 2022). For various stakeholder groups to access, administer, and mobilise climate finance efficiently, it is essential first to determine the extent to which developing economies require climate finance. The availability of adequate financial resources is essential for achieving economic transformation towards a low-carbon, climate-resilient future. The Paris Agreement states explicitly that "financial flows shall be aligned with a pathway towards low greenhouse gas emissions."

Bhandary et al. (2021) allude to the reality that the insufficiency of quantifiable incentives, the refusal of most for-profit firms to internalise environmental externalities, low or unquantifiable returns to corporate social responsibility practices, preconceptions of high risks of low-carbon technological advances on the portion of the banking industry and other mainstream financiers, a discrepancy between long-term payback periods and the riskiness of investments, and a lack of political will are all factors that have worked against the mobilisation of private finance to address climate change finance at the global north and south divides where Africa is negated to such climate financing discrepancies.

Despite making relatively small contributions to the global warming crisis, the world's least developed countries are among the most susceptible to its effects. An ever-expanding network of multilateral institutions, bilateral governments, and non-governmental organisations provides climate finance (Hirsch, 2021). In sub-Saharan Africa, women, like their male counterparts, are affected by climate change extremes affecting their well-being and efforts towards climate resilience, yet they are systematically excluded from access to climate-related funding available to men (Martín Casas & Remalia Sanogo, 2022). Gendering climate change financing explicitly negates the female gender to further climate consequences.

Four barriers to accessing climate finance have been identified through Africa's Green Climate Fund:

1. Complex accreditation processes: One of the most frequently cited obstacles to gaining access to climate finance is the lengthy and difficult accreditation process for the Green Climate Fund (GCF). As an example, due to the GCF's stringent fiduciary principles, environmental and social safeguards that are tailored to the private sector, and other legal and formal requirements, small climate organisations (CSOs) in developing countries face a disproportionate disadvantage in the accreditation process (GCF, 2020). The GCF accreditation process is not only difficult but also time consuming, and the likelihood of a proposal being funded is low.
2. Requirements and gender considerations: Eligibility inequities, such as asset ownership, business skills, information access, and membership in cooperatives, make it harder for women and women's groups to access climate financing (Atmadja et al., 2020). Though most

global climate funds now include gender policies or gender action plans, these are often insufficient. Mechanisms have yet to show substantially improved engagement and sustainable participation from women's organisations at the grassroots level (Cooper Hall et al., 2019). Women's organisations still bear the brunt of adapting to the requirements and frameworks of funding systems. Gender parity must be systematically incorporated into all facets and levels of a fund. Governance is needed to incorporate public participation mechanisms (including women's representative groups) to set funding priorities and design, implement, monitor, and evaluate projects (Schalatek, 2020).

3. Political, technical, and financial factors: Because of the GCF's emphasis on country ownership, country "support," and no-objection approaches, climate organisations with a local presence must have the full endorsement of the central government before they can submit an application for funding (Hirsch, 2021). This requires mutual trust between the government and these groups; unfortunately, this is not a given in many developing nations. However, accessing some GCF funding is challenging due to the technical requirements, lengthy application process, and associated costs. Given their limited resources, locally based climate organisations appear to be disproportionately affected by a lack of clarity in the discussions as well as the assumed preference of the GCF to provide concessional loans rather than grants, combined with a great leverage effect on private finance.
4. Fund design and metrics of success: Many funds prioritise large-scale projects over local services because of their investment strategies. Traditional financing intermediaries (such as multilateral development banks) are less able to finance small-scale projects directly because of the high transaction costs. Despite the availability of a variety of innovative financial instruments, few have been used, suggesting a low tolerance for risk. Local management capacity is often a limiting factor (Price, 2021). CSO's engagement with multilateral climate funds can be complicated by a number of factors, including the GCF's complex language and modalities, limited access to GCF information and knowledge, and a lack of capacity support or resources to engage with the fund.

5 Research Opportunities and Knowledge Gaps

It is worth noting that there are numerous scholarships available to support the study of the gendered effects of climate change all over the world, particularly in sub-Saharan Africa. More research is required to fully understand the diverse consequences of global warming and the requirements of small-scale farmers around the globe for adjustment and recovery. This is particularly important within the context of gender dynamics.

This book identifies significant evidence gaps and potential focus points for responding to the gender-related effects of climate change in Africa. It also identifies research possibilities for the establishment of local climate services that cater to gender-based connectivity and usage concerns. More detailed knowledge of household-level gender disparities and interactions will be necessary in order to prioritise and package gender-responsive policies and activities in Africa. Increased analysis of gender inequalities will be critical to learning how climate services will contribute to an entrepreneurial ecosystem for women's rights. The following knowledge gaps were identified in the course of the study.

5.1 Gender-Differentiated Demand and Benefits

There is a glaring disparity between the ways that women and men profit from using climate services. These disparities can be attributed to cultural, socio-economic, and institutional factors intertwined with changes in weather patterns (Shackleton et al., 2015). Although extant literature (e.g., CARE International, 2010) indicates that women and men farmers' needs for knowledge vary in relevance to their decision-making and risk mitigation, further research into gender-differentiated demands will be necessary to provide a more thorough understanding of gender-based challenges, particularly as they impact access. There is a need for more research into how men and women are affected by or respond to the adverse effects of climate change in Africa. Such research will aid in predicting the consequences of science-based interventions, rights to productive assets, and decision-making authority in the household.

5.2 The Impact of Climate Services on Women's Involvement in Decision-Making

Women, especially those in Africa, can overcome climate change challenges if periodic weather-related projections are available to help in the

creation of risk-reduction measures that can be adjusted to fluctuations. Like their male counterparts, female farmers can make educated agricultural decisions when they have access to and a clear understanding of meteorological and climatic information (Clifford et al., 2020). When males are no longer the exclusive decision-makers, women will benefit from their greater participation in farming decision-making and will be perceived as more than just farm labourers (Rengalakshmi et al., 2018). Going forward, more detailed effect analyses of variations in women's and men's involvement in farming and family choice as a result of access to climate information products will be critical to understanding how climate services may support women's empowerment.

Since gender roles in the home are ever changing, that is, when men no longer make all of the families' decisions, the systems of norms and conduct in households in the crop, livestock, and pastoral societies require greater attention. Research is needed to understand the impact of climate change on the distribution of productive assets and rights to female family members.

5.3 Success Stories of Interventions That Enhance Women's Capacity to Act on Climate Information

There are few studies into the influence of women's access to climate-related knowledge and how they utilise it in decision-making. Documentation of potential enabling variables and processes would contribute to a knowledge base on access inequities as well as initiatives and processes that have improved women's access to climate information (Gumucio et al., 2020). A related question is whether women confront more severe, gender-based structural barriers to acting on climate information.

5.4 Combination of Communication Processes Best Suited for Women

A review of research on women's access to and usage of ICT will aid in the identification of more gender-responsive channels of communication, although previous studies have highlighted the challenges to the effective use of ICT by men and women. Other channels may be more suitable to facilitate women's interpretation and application of complicated kinds of information, even though ICTs may be useful for specific types and

timelines of information. Women may value the chance to talk with information mediators such as village meteorological office officials and local non-governmental organisations (NGOs) in person.

5.5 Gender Interaction with Other Socio-economic Factors to Shape Information Needs

According to Nyasimi et al. (2018), factors such as levels of capital assets, schooling, travel, and property ownership contribute to shaping access preferences and information needs. Other studies (e.g., Carr & Owusu-Daaku, 2016; Cherotich et al., 2012; Roncoli et al., 2009) found that the interaction between gender and socio-economic characteristics like age, status, and race can significantly impact the roles that women and men play in family decision-making. Differentiating between inherent features of women and male farmers can help determine their information requirements and preferred methods of delivery.

5.6 Local Knowledge Within Decision-Making Processes

Since local knowledge plays a vital role in decision-making at every stage of life, this book has urged greater research into how gender interactions with other socio-economic variables inform evidence-based targeting of policies and interventions of gender-related access to climate information. It is important for future research studies to be influenced by a thorough and receptive grasp of how the important variable of local attitudes and practices regarding gender roles informs decision-making processes.

5.7 Social Justice and Equity Risk of Climate Change

Since it is important to understand how socio-economic, political, and cultural systems interact with the biophysical process to originate, maintain, and spread gender-differentiated effects, there is an urgent need for research that focuses on social justice and equity risk of climate change, especially to women in Africa.

Finally, it must be emphasised that business schools have a crucial role to play in preparing leaders to make an impact in solving Africa's climate-related problems and ensuring commitment to preserving natural resources and the biodiversity business sector, acknowledging the climate emergency, and ensuring a green and clean transition. Interestingly, in the last

quarter of 2022, six leading business schools in Africa launched Business Schools for Climate Leadership Africa (BS4CL Africa) to build a collaborative framework for climate action capable of transforming business education curricula to match the needs and adapt to the realities of Africa (University World News, 2022). Participating schools include the School of Business at the American University in Cairo, Egypt; ESCA Ecole de Management (ESCA School of Management) in Morocco; the Lagos Business School in Nigeria; the School of Tourism and Hospitality at Strathmore University, Kenya; and the Gordon Institute of Business Science and the Stellenbosch Business School, both in South Africa (University World News, 2022). The initiative is supported by the Association of African Business Schools (AABS), the United Nations Framework Convention on Climate Change (UNFCCC), and Principles for Responsible Management Education (PRME) at the United Nations Global Compact and the PRME chapter in Africa. We believe it is a step in the right direction and are hopeful that gender and climate change will be a priority as the initiative takes shape.

6 Conclusion

Despite scholarship devoted to the gender gap in farming and global warming, gender parity can still be regarded as less inclusive in agricultural and green policies. Given the contemporary environmental hazards prevalent in Africa today, implementing policies and keeping track of gender results with sex-disaggregated data should be emphasised, and women's peculiarities acknowledged. It is, therefore, important to create and implement policies that take into account women's efforts in order to close the gender disparity gap in Africa.

In almost all developing nations, especially in Africa, unstable land tenure, industrial equipment, limited finance, and restricted agricultural inputs have been identified as key impediments to women farmers' ability to adopt proven ecological principles and forest management. Therefore, the experiences, knowledge, and realities of both women and men should be included in any potential mitigating measures. Climate change impacts and related adaptation measures are not gender-neutral because susceptibility is typically dictated by socio-economic conditions, livelihoods, capabilities, and access to information. It is essential that capacity-building knowledge is made available to all users—men and women, boys and girls—as ways and means, including technologies, are established to improve resilience.

Women may find it challenging to use adaptation methods in the face of climate change due to persistently ingrained traditional gender norms. Without an awareness of how new climate-smart techniques and processes may impact gender roles and tasks in families and communities, the deployment of climate-smart technologies may fail to assist women and may even reinforce existing inequities. The use of collaborative methods that encourage change in the interests of women and marginalised groups is essential for stemming the effects of gender norms and community power dynamics.

Therefore, policies that advocate meaningful strategies for addressing gender issues tied to the effects of climate change must take into consideration economic, social, and cultural realities within Africa. Nations are challenged to design adaptive interventions acceptable to both women and men; conduct gender analysis to identify specific climate vulnerabilities; adopt vulnerability-reduction initiatives, particularly for women in rural areas; and consider how technological innovation can address the negative impact of climate change. Finally, groups charged with decision-making regarding climate adaptation and mitigation programmes must unfailingly incorporate women to ensure adequate and diverse representation, thereby empowering women to make policies that directly impact their gender and children.

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