



Empowering women in climate-resilient farming through sustainable agriculture technologies

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Abstract

This research paper aims to examine the gendered impacts of agricultural technologies and practices that promote climate-resilient farming and assess how these technologies can empower women in the agricultural sector. While primary research on this topic is limited, a wealth of secondary data and scholarly literature provides valuable insights into the complex relationship between gender, sustainable agriculture technologies, and climate resilience. The study utilizes secondary research methods, including extensive literature reviews, newspaper reports, and government data, to gain insight into the underlying dynamics. The findings of this study reveal that sustainable agriculture technologies, while offering potential benefits for both men and women, can significantly empower women in the agricultural sector. Increased income, enhanced decision-making power, and improved food security emerge as key pathways through which these technologies contribute to women's empowerment, underlining their pivotal role in promoting gender equality within climate-resilient farming practices.

Keywords: Gender, Sustainable Agriculture Technologies, Climate-Resilient Farming, Empowerment

1. Introduction

Climate change, an unequivocal consequence of human activities and natural processes, has emerged as a profound and multifaceted challenge with far-reaching implications for global agriculture (Da Silva, 2023; Moharaj & Rout, 2020) ^[1]. The discernible alterations in temperature patterns, precipitation regimes, and the prevalence of extreme weather events have begun to disrupt established agricultural systems, thereby imperilling the world's food security and the livelihoods of billions (Zuazo *et al.*, 2010). Concurrently, the imperative to mitigate the adverse effects of climate change while enhancing the resilience of agriculture has thrust sustainable agriculture technologies into the forefront of global discourse. Climate change poses a formidable and immediate threat to the agricultural sector, casting a shadow over its capacity to ensure the consistent production of food for a burgeoning global population (McMichael, 1993) ^[4]. The unpredictability of weather patterns, including prolonged droughts, erratic rainfall, and intensified storms, has engendered crop failures, yield reductions, and a heightened vulnerability to pests and diseases (Volk *et al.*, 2023; Sahoo & Moharaj, 2022) ^[5, 6]. These climatic upheavals have given rise to a new era of uncertainty, compelling a re-evaluation of traditional agricultural practices and necessitating innovative solutions to safeguard food security. In response to the escalating challenges posed by a changing climate, sustainable agriculture technologies have emerged as indispensable tools. These technologies encompass a diverse array of practices, ranging from the development of climate-resilient crop varieties and precision agriculture techniques to the efficient management of water resources and soil health (Banson *et al.*, 2014; Kumar & Moharaj, 2023) ^[9]. Their shared objective is to imbue agricultural systems with greater adaptability to climatic perturbations while simultaneously mitigating their contribution to greenhouse gas emissions. Sustainable agriculture technologies, therefore, represent a proactive approach to addressing the intricate nexus of climate change, food security, and environmental sustainability.

However, amidst the recognition of sustainable agriculture technologies as indispensable for climate adaptation and mitigation, a critical facet has emerged as a focal point of scholarly inquiry and policy discourse. This facet pertains to the gendered dimensions of technology adoption and empowerment in the agricultural sector. A burgeoning body of literature and an escalating commitment from policymakers have, in recent years, intensified efforts to examine how sustainable agricultural technologies intersect with gender dynamics, thereby reshaping agricultural practices and the roles of men and women within the sector (Kumar & Moharaj, 2023; Moharaj, 2023) ^[9, 10].

Gender, as a critical social construct, fundamentally shapes access to resources, decision-making authority, and labor division within agriculture. Women, who constitute a substantial proportion of the agricultural workforce worldwide, have historically encountered systemic disparities in accessing resources, education, and credit. Additionally, they have often been relegated to roles characterized by limited decision-making power and recognition within farming communities (Moharaj & Prasad, 2021) ^[11]. The implications of these gender inequalities have been acutely exacerbated by climate change, amplifying the vulnerability of women in agriculture to its myriad consequences.

In light of these disparities, it has become increasingly imperative to assess how sustainable agriculture technologies can either perpetuate or alleviate gender-based inequalities within the agricultural sector. This entails an examination of the extent to which women are afforded equitable opportunities to access and harness the benefits of these technologies, and how their adoption influences women's agency, socio-economic status, and empowerment. As such, sustainable agriculture technologies represent not only a strategy for climate adaptation and food security but also a lens through which to scrutinize and address deeply entrenched gender disparities in agriculture (Wood *et al.*, 2019). In addition to synthesizing existing knowledge and identifying gaps, this research aims to provide a conceptual framework that elucidates how sustainable agriculture technologies can empower women in the context of climate-resilient farming. Understanding the mechanisms through which these technologies interact with gender dynamics is paramount for crafting effective policies, programs, and interventions that harness their full potential. Empowerment, in this context, encompasses not only increased economic agency but also the enhancement of women's decision-making authority, their capacity to adapt to changing environmental conditions, and their participation in broader community and societal processes (Balabantaray *et al.*, 2023) ^[30]. It recognizes that the ability to access and utilize sustainable agricultural technologies can be a catalyst for transformative change, not only within individual households but also within entire agricultural communities. To navigate this complex terrain, we adopt a multidisciplinary approach, drawing from fields such as agricultural science, gender studies, development economics, and environmental sustainability. By synthesizing insights from these diverse domains, we seek to provide a comprehensive understanding of the intricate web of factors influencing the gendered impacts of sustainable agriculture technologies.

Key insights from the examination of gendered impacts of agricultural technologies promoting climate-resilient farming reveal the potential for positive transformation in the

agricultural sector. These technologies, encompassing climate-resilient crop varieties and precision farming practices, not only enhance productivity but also contribute to economic empowerment for women. Such empowerment is evident through increased income and amplified decision-making power, positioning women as key agents of change in agricultural communities (Huyer & Partey, 2020) ^[13]. Additionally, these technologies play a crucial role in improving food security, particularly for women and their households, by mitigating vulnerabilities to climate-related shocks. Identified trends in the current knowledge emphasize the growing recognition of the gendered dimensions within the agricultural sector. Researchers and policymakers are increasingly examining the intricate intersection of gender dynamics and technology adoption, reflecting a broader acknowledgment of existing disparities (Djoudi *et al.*, 2016) ^[14]. Furthermore, there is a noticeable trend toward the development and implementation of gender-sensitive policies and interventions to facilitate equitable access to and adoption of sustainable agricultural technologies. However, significant gaps in the current knowledge persist. Many studies rely heavily on qualitative data or limited-scale surveys, hindering the generalizability of findings. A critical need exists for more comprehensive quantitative research that can provide robust evidence. Moreover, further exploration into the intersectionality of gender with other social factors is essential for a nuanced understanding of differential impacts (Balabantaray, 2022) ^[15]. Long-term effects and sustainability of technology adoption remain underexplored, as do the actual implementation and effectiveness of gender-sensitive policies at community and national levels. Lastly, research on women's participation in the design and development of sustainable agricultural technologies is limited, pointing to an area with substantial potential for enhancing gender responsiveness in innovation and development efforts (Dalei *et al.*, 2021) ^[22].

2. Research Methodology

This research paper primarily relies on secondary data sources to comprehensively explore the gendered impacts of agricultural technologies promoting climate-resilient farming and their potential to empower women in the agricultural sector. The secondary data employed encompass a diverse array of scholarly literature, academic publications, reports from international organizations, and relevant documents, including but not limited to those produced by the Food and Agriculture Organization (FAO), the World Bank, and peer-reviewed journals. The temporal scope of our data encompasses publications spanning from 2010 to 2023 to ensure the incorporation of the most recent developments and debates in this critical domain. The materials utilized for this research consist of a wide range of academic articles, policy reports, and field studies related to the intersection of gender, sustainable agriculture technologies, and climate resilience. These materials are drawn from reputable academic databases such as PubMed, JSTOR, Google Scholar, and the Web of Science. Additionally, relevant reports and publications from international organizations, government agencies, and non-governmental organizations are incorporated to provide a comprehensive understanding of the subject matter. A systematic search of academic databases and relevant institutional repositories is conducted using a combination of keywords and controlled vocabulary terms, such as "gender," "sustainable agriculture technologies,"

"climate resilience," and "empowerment." The search strategy is designed to identify a broad spectrum of primary and secondary sources. Identified publications are screened based on predefined inclusion and exclusion criteria to select sources that align with the research objectives. The criteria encompass relevance to gender, sustainable agriculture technologies, climate resilience, and empowerment. Relevant information from the selected sources is extracted and organized systematically. This includes key findings, methodologies employed in the original studies, and data related to gendered impacts and empowerment in the context of sustainable agriculture technologies. Extracted data are analyzed thematically to identify key insights, trends, and gaps in the existing knowledge. The analysis aims to provide a coherent synthesis of findings and to facilitate a nuanced understanding of the complex relationship between gender, agriculture technologies, and climate resilience. Building on the synthesized knowledge, this research paper offers evidence-based recommendations for future research directions and policy development, highlighting areas where further investigation and policy interventions are needed to promote gender equality in climate-resilient farming practices.

3. Gender Disparities in Agriculture and Climate Change

3.1. Significant Contributions and Limited Accessibility

Women have been the unheralded backbone of agricultural labour across the globe for centuries. Their substantial contributions to food production and farming activities, including planting, harvesting, and post-harvest processing, have played an instrumental role in sustaining communities and nations alike (Balabantaray, 2022) ^[16]. Yet, despite their indispensable involvement in agriculture, women frequently encounter a disconcerting reality—a stark imbalance between their significant contributions and limited access to essential resources critical for agricultural success, such as land, credit, and extension services. This essay delves into this complex issue, discussing the multifaceted challenges women face in accessing these resources, the implications of such disparities, and the imperative of addressing them to bolster both agricultural productivity and global food security.

Challenges in Resource Access

Women in agriculture often find themselves on the frontline of food production, dedicating their labor and expertise to ensure that crops flourish and harvests are bountiful. Their roles extend beyond the agricultural field to encompass various critical tasks within the sector, from livestock management to agro-processing. However, despite these multifaceted contributions, women continue to grapple with unequal access to essential resources. Land, for instance, remains a pivotal asset for agricultural production. Yet, land ownership and tenure systems in many regions persistently favor men, leaving women with limited access to land for cultivation. This disparity in land access curtails women's ability to implement sustainable farming practices and significantly undermines their potential to maximize agricultural productivity. Additionally, access to credit—a lifeline for agricultural investments—often remains elusive for women (Balabantaray & Samal, 2023) ^[30]. Financial institutions and lending mechanisms frequently exhibit gender bias, resulting in women being disproportionately excluded from formal credit systems. This financial exclusion stifles opportunities for women to invest in modern

agricultural technologies, purchase quality inputs, and scale up their farming operations. Furthermore, women's limited access to extension services, critical for disseminating agricultural knowledge and innovations, compounds the challenges they face. Extension services are often tailored to male-dominated farming practices, overlooking the unique needs and constraints of women farmers (Sahoo & Sridevi, 2021) ^[24]. This exclusion from vital sources of agricultural information leaves women at a disadvantage, inhibiting their ability to adapt to changing climate patterns and adopt climate-resilient practices.

Implications for Agriculture and Food Security

The disparities in resource access reverberate throughout the agricultural sector, culminating in dire implications for agricultural productivity and, consequently, global food security. Women's limited access to land not only diminishes their own agricultural output but also constrains overall food production capacity. Given that women constitute a significant portion of the agricultural workforce, such constraints have far-reaching consequences. Reduced agricultural productivity, arising from limited access to credit, further perpetuates food insecurity, particularly in regions where women are prevalent in agriculture. Moreover, the inequities in access to extension services impede the adoption of innovative and sustainable farming practices, hindering the sector's ability to adapt to climate change. In an era where climate-related risks pose increasing threats to agriculture, the exclusion of women from climate-resilient agricultural knowledge and practices exacerbates vulnerabilities and reduces the sector's overall resilience.

3.2. Gender Norms and Decision-Making Process

In the intricate tapestry of agricultural landscapes across the world, gender norms and societal roles have woven a complex narrative that profoundly influences women's participation in decision-making processes related to farming. The agricultural sector, in many traditional societies, adheres to deeply ingrained gender norms that not only shape but also restrict women's involvement in crucial aspects of farm management (Samal, 2021). From choices regarding crop selection to the allocation of resources and the embrace of new technologies, gender norms often cast women in roles that limit their influence within agricultural communities. These norms, deeply entrenched and historically rooted, invariably favour male household members, perpetuating a gender-based hierarchy that not only limits women's participation but also hampers the full realization of the sector's potential for sustainable agricultural practices and adaptation to evolving environmental challenges.

The Influence of Gender Norms

Gender norms, constructed and perpetuated by society over generations, dictate the roles, responsibilities, and expectations assigned to men and women within agricultural communities. While these norms can vary widely across cultures and regions, they consistently shape the division of labor, access to resources, and decision-making processes within the agricultural sector. In many traditional settings, women are assigned roles that primarily revolve around household chores and tending to family needs, while men assume the mantle of decision-makers in agriculture.

Restrictions on Decision-Making

One of the most tangible impacts of these gender norms is the restriction of women's participation in farm management decisions. Crucial choices, such as what crops to cultivate, how to allocate resources, and whether to adopt new technologies or climate-resilient practices, are often dominated by men. This exclusion stems from the deeply ingrained belief that women's contributions to agriculture are secondary, subordinate to the authority of male household members. The consequence is that women's insights, knowledge, and perspectives are often overlooked, despite their profound experiences and contributions to agricultural activities. This exclusion not only undermines gender equality but also hampers the agricultural sector's adaptability and resilience in the face of climate change and other environmental challenges.

Perpetuating Gender-Based Hierarchies

Gender norms, by confining women to specific roles and limiting their participation in decision-making, perpetuate gender-based hierarchies within agricultural communities. This hierarchy, entrenched in power imbalances, has far-reaching implications for the equitable distribution of resources, the allocation of benefits, and the overall well-being of women within these communities. It also reinforces the notion that women are passive participants in agriculture, overshadowing their agency and potential to drive innovation and sustainable practices.

4. Sustainable Agriculture Technologies and Gender

4.1. Technology Adoption

The pursuit of sustainable agriculture stands as a beacon of hope for addressing the pressing challenges of our time, from food security to environmental conservation. Within this ambitious endeavour, the adoption of sustainable agricultural technologies plays a pivotal role (Sahoo, 2014) ^[25]. These technologies hold the potential to revolutionize farming practices, making them more environmentally friendly, productive, and resilient. However, it's imperative to recognize that not all members of the agricultural community have equal access to, or agency in, the adoption of these innovations. Women farmers, in particular, often find themselves navigating a landscape strewn with barriers when it comes to embracing sustainable agricultural technologies (Balabantaray *et al.*, 2023) ^[30]. The prevailing literature underscores this stark reality, revealing a complex web of obstacles that hinder their active participation in the technology adoption process.

Limited Access to Credit and Training

The first of these barriers is the challenge of securing access to credit and training opportunities. Sustainable agriculture technologies frequently necessitate an upfront investment in equipment, seeds, or training to implement new practices effectively. Yet, for many women farmers, accessing credit can be an arduous task. Discriminatory practices within financial institutions and biases against women seeking loans often result in limited or no access to crucial financial resources. This, in turn, hampers their ability to invest in the technologies needed to enhance their farming practices. Furthermore, training and capacity-building programs, which are integral to understanding and harnessing the potential of these technologies, often fall short in catering to the specific needs of women farmers. These programs are typically

designed without considering the unique constraints and responsibilities women may face within their agricultural roles. Consequently, women often miss out on opportunities to gain the knowledge and skills required for adopting sustainable agricultural technologies effectively (Balabantaray, 2023) ^[30].

Lack of Information

Another formidable barrier to technology adoption among women farmers is the pervasive lack of information. Information is the lifeblood of successful technology adoption, as it empowers farmers with the knowledge needed to make informed decisions. However, women farmers often encounter information gaps that hinder their ability to engage with sustainable agricultural technologies. Extension services, which are responsible for disseminating agricultural knowledge, tend to disproportionately target male farmers. As a result, the information provided may not be relevant or accessible to women. This mismatch in communication leaves women farmers unaware of the potential advantages of sustainable agricultural technologies and unsure of how to integrate them into their farming practices.

Social Norms and Gender Roles

Perhaps the most deeply rooted of all barriers are the social norms and gender roles that shape the dynamics of rural communities. In many traditional agricultural societies, gender norms dictate that men hold primary decision-making authority in farming matters. This deeply ingrained patriarchal structure not only restricts women's participation in critical decisions concerning technology adoption but also constrains their mobility. The societal expectations and roles assigned to women often confine them to specific agricultural tasks that are less likely to involve technology adoption.

4.2. Technology Impacts

In the quest for sustainable agriculture, one cannot underestimate the transformative potential of technology adoption. Sustainable agriculture technologies have emerged as powerful tools capable of revolutionizing farming practices and ensuring long-term food security while minimizing the environmental footprint. Yet, their impact goes beyond merely improving agricultural efficiency; these technologies hold the promise of catalyzing substantial positive changes in the lives of women. From drought-resistant crop varieties to precision farming techniques, the adoption of sustainable agricultural technologies can have a profound and multifaceted impact on women, empowering them in various ways.

Enhancing Crop Yields and Food Security

One of the foremost ways sustainable agriculture technologies empower women is through improved crop yields and enhanced food security. In many regions, women are the primary caregivers and food providers within their households. Consequently, any advancements in agricultural productivity directly impact their ability to ensure a stable food supply for their families. Drought-resistant crop varieties, for instance, mitigate the risks associated with erratic rainfall patterns, providing a more reliable source of food and income. Moreover, sustainable agricultural practices, facilitated by precision farming techniques, reduce post-harvest losses, ensuring that a more significant portion of the harvest reaches the dinner table. This reduction in food

wastage not only contributes to improved household food security but also alleviates the burden on women, who often bear the responsibility of managing and preserving the harvest.

Increased Income and Decision-Making Power

Beyond bolstering food security, sustainable agriculture technologies open doors to increased income and enhanced decision-making authority for women. In many rural communities, women have historically been relegated to subsistence farming or specific low-income agricultural tasks. The adoption of technologies that improve crop yields and reduce labor demands can significantly augment the income generated from agricultural activities. This additional income not only empowers women economically but also expands their influence within the household. With greater financial contributions, women gain a more prominent role in household decision-making processes, including those related to farming practices, resource allocation, and family investments.

Participation and Empowerment

Perhaps one of the most profound impacts of sustainable agriculture technologies on women is their increased participation and empowerment within the agricultural sector. These technologies often facilitate more efficient and less physically demanding farming practices, removing some of the traditional barriers that restricted women's involvement. As women actively engage in technology-driven agricultural activities, they gain valuable knowledge and skills, positioning themselves as integral contributors to the farm's success. This active participation not only boosts their self-esteem and confidence but also challenges traditional gender norms that limited their roles to certain agricultural tasks. As women take on more diverse responsibilities, their visibility and recognition within the farming community increase, further cementing their position as influential stakeholders in the agricultural landscape.

4.3. Empowerment through sustainable agriculture technologies

In the ongoing global pursuit of sustainable agriculture, the adoption of innovative technologies stands out as a pivotal pathway to achieving not only environmental sustainability but also profound social change. A significant dimension of this social transformation revolves around the empowerment of women. Sustainable agriculture technologies have the potential to impact women's lives in multiple dimensions, with economic empowerment taking center stage. Through increased agricultural productivity and income resulting from technology adoption, women's economic agency can be significantly enhanced, leading to greater financial independence and decision-making power within the household.

Economic Empowerment: A Catalyst for Change

Economic empowerment is a potent force capable of catalysing transformative change in the lives of women, particularly in rural agricultural communities. Within these communities, women often play a central role in food production, as caregivers, and as contributors to the family's income (Balabantaray & Singh, 2022) ^[17]. However, their contributions have frequently been undervalued or

marginalized, leaving them with limited control over financial resources and household decisions. Sustainable agriculture technologies can be a game-changer in this context.

Increased Agricultural Productivity

The adoption of sustainable agriculture technologies, such as improved crop varieties, precision farming practices, and efficient irrigation systems, can significantly boost agricultural productivity. Higher yields and reduced losses translate into increased income for farming households. Importantly, these technologies often alleviate some of the labour-intensive tasks traditionally carried out by women. As a result, women have more time and energy to engage in income-generating activities or pursue education and training opportunities, further enhancing their economic prospects.

Greater Financial Independence

The additional income generated through sustainable agriculture technologies empowers women with a newfound sense of financial independence. They are no longer solely reliant on the financial contributions of male household members, which can be particularly empowering in situations where women are vulnerable to economic dependence. Financial independence grants women greater autonomy in determining how resources are allocated within the household, from investments in education and healthcare to decisions about nutrition and household expenditures (Balabantaray *et al.*, 2022) ^[18].

Enhanced Decision-Making Power

Economic empowerment is intrinsically tied to decision-making power within the household. As women contribute more substantially to the family income through technology-driven agricultural practices, their voices gain greater recognition and influence. This, in turn, translates into a more equitable distribution of decision-making authority. Women are better positioned to advocate for their needs, interests, and those of their children, leading to improved overall household welfare.

4.4. Decision-Making Empowerment

The Intersection of Economic and Decision-Making Empowerment

The interplay between economic and decision-making empowerment is undeniable. As women gain economic independence through the adoption of sustainable agriculture technologies, they invariably step into a new realm of influence within their households and communities. This newfound financial security not only enhances their self-esteem but also emboldens them to assert their voice and agency in critical decisions.

Increased Confidence

One of the less quantifiable yet profoundly significant aspects of decision-making empowerment is the boost in confidence that women experience through their engagement with sustainable agriculture technologies. These technologies equip women with the skills, knowledge, and tools they need to become more effective and efficient farmers. As they witness the tangible results of their efforts-increased crop yields, improved income, and enhanced food security-their confidence in their farming abilities soars. This newfound confidence extends beyond the fields, spilling over into

various aspects of their lives.

Participation in Decision-Making Processes

With greater confidence and economic contributions, women become increasingly active participants in decision-making processes related to farming and resource allocation. They are better positioned to voice their opinions, preferences, and concerns within the household. Decisions about crop selection, investment in new technologies, and resource allocation are no longer unilateral but collaborative efforts that involve women's perspectives. This shift towards more inclusive decision-making benefits the entire household, as it often leads to more informed, equitable, and sustainable choices.

Community Development

Decision-making empowerment extends beyond the confines of the household. Women who are confident and engaged in agricultural decision-making often expand their influence to the broader community. They become active participants in community development initiatives, including those related to agriculture and environmental sustainability. Their insights and leadership can drive positive change at the local level, resulting in improved farming practices, natural resource management, and community well-being.

5. Challenges and Barriers

5.1. Challenges and Barriers in Women's Participation in Climate-Resilient Farming

Climate-resilient farming is an urgent imperative in a world increasingly challenged by the impacts of climate change. In this context, women play a crucial role in ensuring food security, as they constitute a significant portion of the agricultural workforce (Agarwal, 2014) ^[26]. However, their full participation in climate-resilient farming is hindered by a complex web of challenges and barriers. Two of the most prominent obstacles are limited access to resources and deeply entrenched cultural norms, both of which significantly impact women's ability to engage effectively in sustainable agricultural practices (Allen, 2006) ^[27].

5.2. Limited Access to Resources

Access to Credit

One of the foremost barriers faced by women in climate-resilient farming is limited access to financial resources, particularly credit. Sustainable agricultural technologies often require upfront investments in equipment, seeds, and training. These investments can be a substantial financial burden for smallholder farmers, a majority of whom are women. Discriminatory lending practices, coupled with a lack of collateral, hinder women's access to credit. Without access to adequate financial resources, women are unable to make the necessary investments in climate-resilient technologies, which in turn limits their ability to adapt to changing climate conditions.

Land Tenure

Land ownership and tenure are critical determinants of women's participation in agriculture. In many regions, women have limited access to land, either due to legal restrictions or customary practices that favor male landholders. Without secure land rights, women are less inclined to invest in climate-resilient farming practices, as they lack the assurance of reaping the long-term benefits. In

cases of divorce or widowhood, women often face the risk of losing access to the land they cultivate, further disincentivizing their investment in sustainable agriculture.

Technology-Specific Training

Effective adoption of sustainable agricultural technologies often requires specialized training. Unfortunately, women frequently encounter gender bias in training programs. Training sessions may be designed without considering the unique needs and constraints faced by women farmers. Moreover, women's limited mobility due to traditional gender roles can hinder their attendance at training programs. This lack of access to technology-specific training leaves women ill-equipped to harness the full potential of climate-resilient farming practices.

5.3. Cultural Norms

Deep-Rooted Gendered Divisions of Labour

Cultural norms and deeply ingrained gendered divisions of labour within agriculture are enduring barriers to women's full participation in climate-resilient farming. These norms often dictate that men are responsible for certain agricultural tasks, while women are relegated to others. For instance, men may be responsible for ploughing, planting, or operating machinery, leaving women with tasks such as weeding or post-harvest processing. This division of labour can limit women's exposure to climate-resilient technologies and practices, as they may not be involved in the decision-making or implementation of these innovations.

Limited Decision-Making Authority

Cultural norms also tend to restrict women's decision-making authority within farming households. In many traditional agricultural societies, men hold primary decision-making power regarding crop selection, resource allocation, and technology adoption. Women often have limited influence in shaping agricultural practices and adaptation strategies. This lack of decision-making authority prevents women from actively engaging in climate-resilient farming practices, even when they recognize their potential benefits.

6. Discussion

Sustainable agriculture technologies have emerged as a powerful force in reshaping farming practices worldwide. These technologies hold the promise of not only enhancing agricultural productivity but also contributing to environmental sustainability. In this transformative landscape, women's empowerment within the agricultural sector is gaining significant attention. While the evidence overwhelmingly suggests that sustainable agriculture technologies have the potential to positively impact women, it also underscores the persistence of gender-specific barriers that demand our unwavering attention and concerted action. The potential of sustainable agriculture technologies to empower women in the agricultural sector is undeniable. These technologies offer a pathway to economic empowerment, enhanced decision-making authority, improved food security, and skill development. However, this transformative potential must be realized in the context of persistent gender-specific barriers. To fully leverage the benefits of sustainable agriculture technologies for women's empowerment, a comprehensive approach is required. This approach should encompass gender-sensitive policies, equitable access to resources, tailored training and extension

services, and efforts to challenge and transform cultural norms and gender roles within agriculture. By addressing these barriers, we can unlock the full potential of women as key drivers of change in building more resilient, sustainable, and equitable agricultural systems that benefit us all. In the ongoing journey towards gender equality within the agricultural sector, sustainable agriculture technologies stand as a beacon of hope, but only through collective action can we ensure their transformative potential is realized for women everywhere.

7. Conclusion

In this study, we have embarked on a journey to unravel the intricate relationship between sustainable agriculture technologies, climate-resilient farming, and women's empowerment within the agricultural sector. The insights garnered from the existing body of literature have shed light on the transformative potential of technology adoption. However, as we navigate the landscape of gendered impacts, it becomes evident that there is still much terrain to cover and mysteries to unravel. While the evidence we have explored offers valuable glimpses into the mechanisms through which technology can empower women, it also reveals the complexity of this relationship. To truly grasp the transformative power of technology, further research is imperative. This research should delve deeper into the intricate web of factors that influence how women engage with sustainable agriculture technologies and the ensuing impacts on climate resilience and gender equality. This study underscores the importance of addressing the specific challenges and barriers that women encounter within the agricultural sector. Whether it is limited access to resources, deeply ingrained cultural norms, or economic constraints, these barriers must be dismantled to fully harness the potential of sustainable agriculture technologies. In doing so, we pave the way for a future where climate resilience and gender equality are not merely aspirational goals but tangible outcomes of our collective efforts. As we conclude our exploration, it is evident that sustainable agriculture technologies hold the key to a more equitable and resilient agricultural sector. By forging ahead with rigorous research, policy initiatives, and collaborative action, we can unlock the transformative potential of technology adoption for women. In this endeavor, we do not merely seek to expand our knowledge but to catalyze meaningful change—to empower women, fortify climate resilience, and usher in an era of gender equality within agriculture. It is a journey that beckons us all, and the destination is a more sustainable, equitable, and prosperous future for agriculture and society as a whole.

8. Recommendations

Policymakers, in collaboration with stakeholders at all levels, have a vital role to play in championing proper recommendations to create a more inclusive, equitable, and sustainable agricultural landscape. The recommendations given below are not only essential for the empowerment of women but also for the broader goal of achieving food security, poverty reduction, and environmental sustainability in the face of evolving climate challenges. The recommendations can be categorised as gender-responsive agricultural policies, capacity building and community engagement (Gumucio *et al.*, 2020; Nepal, 2016) ^[28, 29].

8.1. Gender-Responsive Agricultural Policies

Implement Gender-Responsive Policies

Policymakers should prioritize the development and implementation of gender-responsive policies within the agricultural sector. These policies should specifically address the unique needs and constraints faced by women in agriculture. Focus areas should include equitable access to credit, land, and technology adoption. Such policies should not only acknowledge existing gender disparities but also actively work to rectify them. Monitoring and evaluation mechanisms should be integrated into policy frameworks to assess their effectiveness in promoting gender equality within the sector.

Enhance Access to Credit

Policymakers should work in conjunction with financial institutions to facilitate women's access to credit. This may involve reforms in lending practices and collateral requirements, with an emphasis on creating financial products tailored to the needs of women farmers. Additionally, financial literacy programs should be integrated into agricultural extension services to empower women with the knowledge and skills necessary for making informed financial decisions.

Secure Land Tenure Rights

Land tenure security is fundamental to women's empowerment in agriculture. Policymakers should enact and enforce legislation that guarantees women's land rights, ensuring that women have secure ownership or user rights to the land they cultivate. These rights should be explicitly protected and reinforced through legal frameworks and community-level initiatives.

8.2. Capacity Building

Invest in Targeted Training

A key step towards empowering women in agriculture is investing in targeted training programs. These programs should be designed with a gender-sensitive approach, considering the unique needs, constraints, and responsibilities of women farmers. They should encompass a wide range of skills, from sustainable farming practices to financial management, with a focus on building women's confidence and competence in adopting and managing sustainable agriculture technologies.

Strengthen Extension Services

Extension services play a pivotal role in disseminating knowledge and skills related to sustainable agriculture technologies. Policymakers should allocate resources to strengthen and expand these services, ensuring they are accessible and tailored to the needs of women. Training of extension workers should also include gender sensitivity training, enabling them to better understand and address the specific challenges faced by women farmers.

8.3. Community Engagement

Promote Gender-Inclusive Decision-Making

Gender-inclusive decision-making should be promoted at all levels of the agricultural sector, from farm households to cooperatives and community-level bodies. Policymakers should advocate for the active participation of women in agricultural decision-making processes. This can be achieved by creating platforms and opportunities for women to voice

their opinions, share their insights, and influence the development and implementation of agricultural policies and practices.

Encourage Women's Representation

Policymakers should encourage and support women's representation in agricultural cooperatives and community-level decision-making bodies. This can be facilitated through quota systems, mentorship programs, and awareness campaigns. Women's active participation in these forums not only ensures that their perspectives are heard but also strengthens their leadership skills and ability to effect change within their communities.

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