

Empowering Rural Women through Technological Innovation: Pathways to Livelihood Security

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Abstract

Rural women remain central to agricultural production and household welfare, yet they continue to face structural constraints that undermine their livelihood security. Limited access to productive resources, financial services, and technological tools exacerbates their socio-economic vulnerability, particularly in Sub-Saharan Africa. This study explores how technological innovation can provide pathways to rural women's empowerment and sustainable livelihood security. Adopting a qualitative integrative review and documentary analysis approach, the study draws on policy documents, development reports, and recent scholarly literature, published between 2010 and 2026 to examine the intersection between gender, technology, and rural development. The analysis indicates that digital financial services, agricultural technologies, ICT-enabled services, and renewable energy technologies can improve women's access to markets, information, and income-generating opportunities. These innovations not only enhance productivity but also strengthen women's agency, decision-making capacity, and resilience to economic and environmental shocks. However, the analysis indicates that technological access does not automatically translate into empowerment; its benefits depend on women's capabilities, control over resources, and ability to participate in livelihood and household decision-making. More so, persistent barriers such as digital illiteracy, infrastructural deficits, and socio-cultural norms continue to limit the full realization of these benefits. The study concludes that targeted, gender-responsive policies and inclusive technological frameworks are essential for fostering equitable development and long-term livelihood security among rural women.

Keywords: Rural women; Technological innovation; Livelihood security; Women empowerment; Digital inclusion

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1- Introduction

Rural women play a pivotal role in sustaining household livelihoods and contributing to agricultural productivity in Sub-Saharan Africa. However, despite their significant contributions, they remain disproportionately affected by poverty, food insecurity, and socio-economic marginalization due to entrenched gender inequalities and limited access to productive resources (Food and Agriculture Organization [FAO], 2011; Loonam & O'Regan, 2022). In many rural contexts, women are primarily responsible for subsistence farming, food processing, and informal economic activities, yet they often lack ownership of land, access to credit, and participation in decision-making processes. These structural constraints not only undermine their productivity but also threaten the sustainability of rural livelihoods.

In recent years, technological innovation has emerged as a critical driver of socio-economic transformation, offering new opportunities to address persistent development challenges. The proliferation of digital technologies, including mobile phones, internet-based platforms, and financial technologies (fintech), has created pathways for improving access to information, markets, and financial services (Chen et al., 2023). For rural women, such technologies hold the potential to bridge longstanding gaps in access to resources and enhance their capacity to engage in productive and income-generating activities. For instance, mobile banking platforms are perceived to enable women to save securely, access microcredit, and participate in digital marketplaces, thereby fostering financial inclusion and economic empowerment (Abiona & Koppensteiner, 2022).

Beyond financial services, agricultural technologies such as climate-smart farming tools, mobile-based extension services, and improved irrigation systems have been shown to enhance productivity and resilience among smallholder farmers, many of whom are women (Sachs, 2023). Similarly, renewable energy innovations, particularly solar-powered technologies, provide reliable energy sources that support small-scale enterprises and reduce the time burden associated with traditional energy collection methods (Novovic, 2023). These technological interventions collectively contribute to improving livelihood security by increasing income stability, enhancing food production, and strengthening resilience to economic and environmental shocks.

Livelihood security, as conceptualized within development discourse, extends beyond mere income generation to encompass access to adequate food, health, education, and the capacity to withstand vulnerabilities (Natarajan et al., 2022). For rural women, achieving livelihood security is intricately linked to their ability to access and effectively utilize technological innovations. However, while technology presents significant opportunities, its benefits are not evenly distributed. For instance, in Sub-Saharan Africa, the opportunities arising from technological progress are highly linked to the structural conditions within which rural women live and work. Technologies may therefore increase women's access to markets, financial services, agricultural information and energy but their effectiveness depend on the level of affordability, the



availability of infrastructure, access to literacy, mobility and the control over the resources.

The digital divide defined by inequalities in the access and use of digital technologies, connectivity and skills also continues to hinder equitable development (Acilar & Sæbø, 2023). Rural women face compounded constraints arising from lower literacy rates, limited digital skills, and social and cultural norms that can limit access to technology and other public spheres. Furthermore, infrastructural deficits including form of unstable electricity supply and internet connectivity in rural area significantly hinder the adoption and utilization of technological innovations (Malladi et al., 2021). In Nigeria, these constraints are further shaped by limited access to formal finance and policy and institutional gaps that do not adequately address the gendered dimensions of technological access and use. Consequently, technological innovation should not therefore be viewed as a panacea to empowering rural women, rather its contribution depends on whether rural women can access, use and exercise meaningful control over technologies within their institutional and socioeconomic environments.

Against this backdrop, there is a growing need for scholarly inquiry into how technological innovation can be effectively leveraged to enhance the livelihood security of rural women. While existing literature has explored the relationship between technology and development, there is still limited integration of gender perspectives within innovation systems, particularly in rural contexts (Ahmad & Islam, 2024). Moreover, many studies focus on isolated technological interventions without examining the broader socio-economic and institutional factors that shape their outcomes. Although the issues facing rural women can be clearly observed in many developing countries, the framework for this study is confined mostly to Sub-Saharan Africa where agricultural and informal sector dominance, gender inequality in access to resources, and infrastructure deficits define most rural lives. Within this region, Nigeria provides the principal country reference to understand the connections between technological innovation, empowerment of women and livelihood security. However, SSA is not considered as a single unit as evidence drawn from other African and similar developing-country contexts supports a broader argument that relates the interaction of social/gender relations to the extent to which technological innovation may translate into significant livelihood gains are brought in.

The study moves beyond an analysis of technological innovation as a one-off event, taking an integrated approach by understanding digital financial services, agriculture technology, information and communication technology, and renewable energy as interwoven resources within a rural livelihoods system and conceptualising women's empowerment as the link between technology and livelihood security. Informed by the Capability Approach, Sustainable Livelihoods framework and Feminist Political Economy, the study contends that technology is most meaningful when there is an expansion of women's capabilities and agency; and their control over productive and

financial resources, livelihood diversification, improvements in productivity and resilience increases.

The study also fosters a conditional conceptualization of technology-driven empowerment by discussing the structural and institutional environment under which technology-enabled paths may arise. Digital literacy, affordability, infrastructure, social factors (norms based on gender), available productive resources and institutional frameworks determine whether women can meaningfully access, use and control technological innovations. Unlike assuming every innovation is transformative, the study conceptualizes technological empowerment as the result of interaction between technological opportunities and the social, economic and institutional environments in which rural women live and work. Focused mainly in Sub-Saharan Africa with special references on Nigeria, the study has the potential to provide an integrated framework for understanding when and how technological innovation can translate into sustainable livelihood security for rural women.

In this regard, the research views technological innovation not only in terms of benefits accruing from specific technologies but rather in terms of paths or contexts in which the technologies can lead to empowerment and livelihood security of women. Specifically, the study addresses the following research questions: (1) How do technological innovations contribute to the economic and social empowerment of rural women? (2) What are the key pathways linking technological adoption to livelihood security? (3) What barriers hinder rural women's access to and utilization of technological innovations?. The remainder of the paper is structured as follows: the next section presents conceptual clarifications and theoretical framework underpinning the study; this is followed by a review of relevant literature on gender, technology, and livelihood security. Subsequent sections discuss the methodology, key findings, and policy implications, before concluding with recommendations for future research and practice.

2- Conceptual Clarifications and Theoretical Framework

To properly place the relationship between technological innovation and the livelihood security of rural women, it is necessary to have a clear understanding of the key concepts underlining this study. Rural women are women who live in non-urban areas, and whose livelihoods and income are primarily tied to agriculture and informal businesses and natural resource-based livelihoods. Often, these women work in socio-cultural and economic contexts that restrict their access to land, finance, education and decision-making power, limiting their productive potential (Food and Agriculture Organization [FAO], 2011). In this paper, rural women were identified as those residing in rural or other mostly non-urban localities and making their living in agriculture, petty trade, processing, informal ventures, or in activities with an important natural resources base. The term is used as a contextual rather than homogeneous category, recognising

that rural women's experiences differ according to country, location, household position, socioeconomic status, access to resources and local gender relations.

Technological innovation is the introduction and use of new or improved tools, systems and processes that help to increase productivity and efficiency. This encompasses agricultural technologies such as better seeds, irrigation systems and climate-smart practices, and digital technologies such as mobile phones, internet platforms, and financial technologies (Botha et al., 2026; Adeleke, 2024; Malladi et al., 2021). Technological innovation is not only about access to technology but also the ability of rural women to effectively use it to enhance their socio-economic status.

Livelihood security is more than just about income generation; it is about people or households' capacity to access resources on a sustainable basis to achieve a decent standard of living. This encompasses food security, health, education, and economic and environmental shocks and stresses (Natarajan et al, 2022). Livelihood security is closely linked to the security of agricultural production and market access in rural areas, which have the potential to be greatly affected by technological interventions (Hegazi & Seyuba, 2024; Vimfall & Levin, 2023)

Three complementary theories are used as the foundation for the study. Firstly, the Capability Approach, developed by Amartya Sen, focuses on people's capacity to have a valued functioning and exercise agency. In this sense, technological innovation increases the capacities of rural women by facilitating their access to information, financial services and economic opportunities, thus fostering their decision-making and wellbeing (Kjosavik, 2021).

Secondly, the Sustainable Livelihoods Framework (SLF) offers a comprehensive approach to the understanding of how people use a range of assets (human, social, financial, physical and natural) in a particular vulnerability context to engage in livelihood strategies (Tambe, 2022). Technological innovation can help to build these assets, through better information, greater productivity and easier market entry, and therefore more resilient and sustainable livelihoods.

Third, Feminist Political Economy is an approach that places attention on the structural inequalities and power dynamics determining women's access to resources and opportunities. It highlights the need to tackle gendered constraints, including gender norms, unequal access to resources, and lack of institutional support systems (Mezzadri, et al., 2024; Ahmad & Islam, 2024; Cantillon et al., 2023). This framework has a specific relevance to the discussion of the distribution of the benefits of technology and the need for targeted interventions for inclusiveness. These frameworks offer a strong analytical basis for analyzing the potential of technological innovation to support rural women's empowerment and livelihood security and to recognize the structural challenges that could be barriers to achieving these.

These complementary approaches together provide an analytical framework for explaining how technological innovation may enhance rural women's empowerment and livelihood security. While capability approach describes the micro-level process through which access to technology can expand women's capabilities, agency and substantive opportunities to make choices about their livelihoods; the sustainable livelihood framework describes how technological innovation can strengthen livelihood assets, which includes human, social, financial and physical capital, that women can mobilise to pursue livelihood strategies such as income diversification, market participation and agricultural productivity. Feminist Political Economy adds a structural layer by emphasizing that women's ability to access and utilize those technological opportunities and transform it into benefits depends upon the structure of gendered relations of power, resource distribution, social norms, institutional arrangements and unequal resource ownership.

Therefore, the three theoretical perspectives operate at different but intersecting levels: technology provides opportunities and resources; women's capabilities and livelihood assets determine the capacity of women to utilize those resources into livelihood strategies; while gendered institutional and sociocultural structures constitute the basis for who can access, use and control the resulting benefits. In this integrated analysis, empowerment is understood not as an immediate by-product of technology usage but as the process whereby women utilize technological opportunities and transform them into an agentic position enabling them to develop, sustain and enhance the management, ownership, and decision making over resources, ultimately contributing to more diversified, resilient and secure livelihoods.

3- Literature Review

(a) Gender Inequality in Rural Contexts

Gender inequality is a long-standing problem in rural areas, and it affects women in a systematic manner due to the socio-cultural norms and institutional barriers. Restrictions in access to land ownership, credit facilities, education and extension services are critical for boosting agricultural productivity and economic inclusion and are often faced by rural women (Food and Agriculture Organization [FAO] 2011; Sachs 2023). In many developing nations, customary land tenure systems are skewed to benefit men, giving them greater control over productive resources than women, even though women contribute to farming activities in many countries. This marginalisation diminishes their ability to invest in more advanced technologies and their economic autonomy. Moreover, unpaid care work disproportionately affects women's time and ability to engage in income-generating activities, which further perpetuates cycles of poverty and vulnerability (Ahmad & Islam, 2024).

(b) Technology and Women's Empowerment



Innovation in technology has increasingly been acknowledged as a driver for women's empowerment, especially in rural areas. Women can use mobile phones and digital platforms to get important information about market prices, weather and agricultural best practices, enhancing their decision-making ability ((Botha et al., 2026; Adeleke, 2024). Women's access to financial resources has also grown using digital financial services such as mobile banking and microfinance, which provide women with better means of saving, obtaining credit and investing in small businesses (Abiona & Koppensteiner, 2022). Empirical studies do show that financial inclusion has a positive impact on women's economic autonomy and bargaining power within the household.

Furthermore, digital technologies enable rural women to be part of wider economic networks, with markets and supply chains. E-commerce platforms and mobile-based trading systems allow women to cut out the middleman, which helps to boost their income potential and limit exploitation, in addition, access to information and communication technologies (ICTs) has been associated with more awareness of rights and opportunities, and therefore, social empowerment and a greater role in community decision-making processes (Chen et al., 2023; Novovic, 2023).

(c) Technology and Livelihood Security

Development literature shows that the connection between technological innovation and livelihood security has been established. Improved seed varieties, mechanised tools and climate-smart farming practices are examples of agricultural technologies that have demonstrated their ability to improve crop production and mitigate environmental shock risk (Sachs, 2023). These innovations can have a positive impact on the food security and income stability of rural women, who make up a large part of the smallholder farmers.

Renewable energy technologies, especially solar energy technologies, are also important to the livelihoods of rural populations in addition to agricultural improvements. Distribution of reliable energy allows women to participate in small businesses like food processing, tailoring, and retail, which diversifies their income (Novovic, 2023). Moreover, the access to market information through ICT-enabled services helps in making better pricing decisions and minimising post-harvest losses (Malladi et al., 2021). These technologies, taken together, contribute to an increased ability to withstand economic shocks and climate change among rural women.

(d) Gaps in Existing Literature

While there is a body of knowledge on the relationship between technology and development, there are still many areas of blind spots where the intersection of gender, innovation and livelihood security is not understood. The current literature often fails to consider socio-cultural and institutional issues that impact on the adoption of technologies by rural women (Acilar & Sæbø, 2023). This, in turn, means that the effect of technology on women and men is seldom examined.



Further, most studies are concerned with individual technology interventions, rather than having an integrated approach that considers livelihood security in several dimensions.

The existing research available that explores the interaction of different technologies (digital, agricultural and energy) and the cumulative impact on women's empowerment is limited. In addition, there are still context-specific analyses which are inadequate, especially in Sub-Saharan Africa and Nigeria, where there are specific socio-economic and infrastructural challenges.

Another major gap is the absence of longitudinal studies which evaluate the sustainability of technological interventions over time. Although there is plenty of evidence on short-term impacts of technology on women's livelihoods and resilience, there is less evidence on the impacts at a longer time horizon. These gaps need to be addressed for crafting more inclusive and effective policies that leverage on technological innovation in sustainable rural development

1- Methodology :

The paper employed a qualitative integrative review and documentary analysis in exploring the extent to which technological innovation contributes to rural women's empowerment and livelihood security. The review focused on evidence relating to rural women in Sub-Saharan Africa, with a specific emphasis on Nigeria and other comparable rural contexts where relevant evidence was available. The choice of regions was intended to ensure that the discussion remained contextually grounded but not to imply that all selected articles were exclusively about Nigeria/Sub-Saharan Africa. The corpus of documentaries comprised of peer-reviewed articles, policy documents, institutional publications, development reports, and relevant literature from organizations such as the World Bank, the Food and Agriculture Organization, UN Women among other international organizations in the development field. The sources were journal publications and policies published ranging from 2010-2026 and were identified around combinations of terms relating to rural women, technological innovation, digital financial services, agricultural technology, ICTs, renewable energy, empowerment and livelihood security, and were retained where they provided substantive evidence relevant to the study's conceptual themes.

The documentary evidence was organized into themes, based upon three key related areas of interest: the contribution of technological innovation to rural women's empowerment; the pathways through which technological innovation influences livelihood security; and the barriers affecting women's access to and utilisation of technological innovation. The analysis considered evidence relating to the use of digital financial services, mobile and agriculture plus information and communication technologies renewable-energy solutions. The key relevant data were synthesized from

selected sources and organized into various types of innovation, access to economic and productive assets and opportunities, changes in women's agency and capability; livelihood strategies, and the institutional, infrastructural and sociocultural structures shaping these processes. The evidence was then compared across sources to identify recurring patterns, areas of convergence and differences between contexts.

The use of scholarly literature, policy documents, institutional reports and development publications enabled documentary triangulation and supported a more balanced interpretation of the evidence. However, the study does not claim to be a systematic review, since the manuscript does not report a formal database search strategy, search strings, screening counts or a documented quality-appraisal procedure. The analysis was guided by an integrated theoretical framework comprising the Capability Approach, the Sustainable Livelihoods Framework and Feminist Political Economy and the findings are consequently presented as patterns and relationships identified through documentary analysis and thematic synthesis, rather than as newly collected empirical findings or universal causal conclusions. The principal limitations relate to the quality and coverage of the available sources, differences between the geographical and socioeconomic contexts represented in literature, and the inability of documentary evidence alone to establish direct or universally applicable causal relationships.

1- Technological Innovations in Rural Contexts

Technological innovation is a key catalyst in socio-economic change in rural areas, especially for women farmers and those engaged in informal economic activities. The convergence of agricultural, energy and digital technologies has brought new opportunities for boosting productivity, access to resources and livelihood security. This section looks at selected areas of technological innovation and their importance for the empowerment of rural women.

(a) Digital Financial Services

The digital financial services have played a key role in enhancing financial inclusion, particularly for women who are typically left out of formal banking systems, in rural areas. Mobile banking applications, mobile money services and microfinance applications allow rural women to save, transfer funds and borrow money without having to visit a physical bank branch (Abiona & Koppensteiner, 2022). These technologies lower the transaction costs and improve financial independence, which enables women to invest in agriculture, small businesses and household requirements.

Mobile money services have been linked to higher household consumption and poverty alleviation, especially in the case of female-headed households in many developing countries (David-West et al., 2022). Moreover, digital financial tools offer a safe way of handling income, minimizing risks of cash handling. However, these services are sometimes only accessible when women are digitally literate and have



access to a mobile phone, which are not equally available to rural women (Chen et al., 2023).

Analytically, the significance of digital financial services involves more than merely enhancing access to banking services and loans. When women in rural areas are afforded opportunity to save, transfer and receive moneys, take loans and manage income; thus, this is likely to strengthen control over their financial resources and increase their ability to make decisions about productive and household activities. Digital financial services therefore present a route through which access to technology can transform into agency, and then finally to livelihood security. That route, however, is not guaranteed because those women who lack phones, digital literacy, affordability or control over financial accounts may remain excluded from its potential benefits.

(b) Agricultural Technologies

The agricultural technologies are key to enhancing the productivity and resilience of rural women farmers. New technologies and innovations like better seed varieties, fertilizers, mechanised tools and climate-smart agriculture have proven to boost yields and mitigate climate variability risks (Sachs, 2023). Mobile extension services are a valuable tool for agricultural extension as they enable farmers to get up-to-date information on weather forecasts, pest management, and the best farming techniques, which can help them make informed decisions and stay productive.

These technologies can help rural women to enhance their food security and income generation. Women, however, may not be able to fully realize the benefits of agricultural innovations due to gender gaps in access to extension services and inputs. Research has demonstrated that female farmers' agricultural production can significantly grow when they have access to the same resources and technologies as their male counterparts, which can help improve overall economic outcomes (Anderson et al., 2021).

The evidence suggests that while productive efficiency of technologies matters to their livelihood value, distribution of access is also crucial. Where women have access to inputs, extension advice and productive equipment, technological innovation can strengthen their human, physical and financial livelihood assets while improving food production and income generation. However, where men hold possession over resources and inputs such as land, credit, extension services and decision-making regarding farming practices, technological innovation may increase overall household productivity without producing equivalent gains in women's empowerment. This clearly indicates that agricultural technology contributes to livelihood security not only by enhancing productive capacities, but also through changes in the accessibility and control over livelihood sources to women.

(c) Information and Communication Technologies (ICTs)

Information and Communication Technologies, especially mobile phones and online services have transformed the rural women's information access and involvement in economic activities. ICTs empower women to access market information, reach out to buyers, and participate in digital markets, leading to a decrease in dependency on intermediaries ((Botha et al., 2026; Adeleke, 2024). This is an improvement in market access which may result in improved prices and income.

Furthermore, ICTs enable social networking and sharing of knowledge, enabling rural women to learn from each other and access support networks. Education and skill-building are also available on digital platforms and are critical to improving women's ability to effectively use other technologies (Acilar & Sæbø, 2023). Yet, the digital divide, which is the lack of access to the internet and low digital literacy, is still a big hurdle in the way of pervasive use of ICTs in rural areas.

A key dimension for the analytical value of ICTs concerns their potential to overcome information asymmetries, which often constrains women in rural areas from engaging with markets and economic networks. Information about prices, buyers, weather, production methods allows women to negotiate more favorably with traders, to cut down their reliance on middlemen, etc. In this respect, ICTs might even reinforce social capital by linking them up with knowledge, markets, social networks, thereby strengthening human as well as social capital. For information to represent economic empowerment, however, women need access to financial resources, mobility, and decision-making power.

(d) Renewable Energy Technologies

Renewable energy technologies, especially solar energy, have become very important to enhance rural livelihoods. Poor access to electricity in many rural areas has a negative impact on economic activities and production. Solar powered systems are an energy source that is reliable and sustainable and can be used to power a range of income-generating activities, including food processing, tailoring, retail, and more (Gbolonyo, & Tetteh, 2025; Chandrasekaran et al, 2023).

Access to clean energy saves rural women time and energy from traditional energy sources like firewood, which can be used for productive activities and education. Moreover, renewable energy technologies also have positive impacts on health due to their ability to reduce exposure to indoor air pollution. All these benefits contribute to improving livelihood, security and well-being. To conclude, technological advancements in the financial, agricultural, information and energy sectors provide great opportunities to support the empowerment of rural women and their livelihoods. But their effects will be amplified if they overcome the barriers to access, affordability and socio-cultural issues.



Thus, renewable energy technologies do not just generate electricity; they also potentially shorten energy-associated labor and can facilitate income-generating activities to augment the amount of time available and physical capacity of rural women to carry out other income generating activities and education and build up enterprises. Energy services can thereby augment both livelihoods and practical capacities of women. Yet the amount to which women benefit depends on affordability, maintenance, ownership and the power women have over how energy is used in household/enterprise uses.

2- Pathways to Livelihood Security

Technological innovation can support rural women's empowerment in a number of interrelated ways, all of which lead to an increase in livelihood security. Beyond economic benefits, these pathways include greater food security, social empowerment, and resilience to external shocks. It is important to understand these mechanisms for designing interventions that will fully leverage the benefits of technology for rural women.

(a) Income Diversification

Income diversification is one of the most important ways that technology contributes to livelihood security. Rural women can use digital platforms and mobile technologies to diversify their livelihoods from subsistence farming. Mobile banking services and digital marketplaces can enable women to engage in small-scale business, directly sell their farm produce to consumers and undertake value-added operations like food processing and packaging (Hegazi & Seyuba, 2024; Vimefall & Levin, 2023; Abiona & Koppensteiner, 2022).

Diversifying income helps to spread the risk of relying on a single source of income, such as farming, and can help to protect individuals from the risks of climate change and other environmental shocks. Research indicates that households that have multiple income streams are more resilient to economic shocks and have more stable consumption (Musumba et al., 2022). The improvement in welfare and the financial independence and bargaining power among women in the household is not only achieved through income gains for women in rural areas, but also for their families (Hegazi & Seyuba, 2024; Ahmad & Islam, 2024; Vimefall & Levin, 2023; Malešević, 2022).

It can be stated that technology access, by itself does not directly lead to livelihood diversification; but where it allows for the development of better information, finance, markets and production capabilities, women can forge technology into effective livelihoods. These livelihoods and pathways of empowerment are therefore cumulative: technological innovation can strengthen livelihood assets, these assets can expand

women's economic choices, and the resulting diversification can improve both household resilience and women's bargaining power. The evidence consequently shows that for technologies to have an empowerment effect over women; they should be able to maintain real control over the technology-based income generating activity

(b) Food Security Enhancement

Technological innovation also is a key factor in enhancing food security for rural households. Women farmers can improve productivity and lower post-harvest losses (PHL) using agricultural technologies such as climate smart technologies, improved seeds, and improved fertilizers (Sachs, 2023; Kassie et al., 2020). Mobile extension services also help boost productivity by offering farmers timely information on weather forecasts, pest control and best practices in farming (Botha et al., 2026; Adeleke, 2024).

Better agricultural production means more food available and better nutrition outcomes for households. Women in many rural areas are mainly engaged in food production and food preparation, which is the reason why their empowerment is essential for food security (Hegazi & Seyuba, 2024; Vimefall & Levin, 2023; Anderson et al., 2021). Furthermore, more income from agriculture enables households to afford a variety of food and supplement their diets with a variety of nutrient-rich foods, which leads to better overall food and nutrition security. As such, interventions that focus on women farmers have multiplier effects that impact on household wellbeing and community health.

The links between agricultural technology and food security are hence mediated through women's access to and control of productive resources and their participation in decision making within the household. It appears that more food supply could increase food availability, however its impact in terms of empowerment is conditional on whether and how women's participation in the household affects the distribution and application of agricultural income and investment decisions. In such food security thus must be considered not simply as an outcome which emanates from the farming sector, but as one that may result from women's control over resources and women's intra household decision-making processes (Theis et al., 2018).

(c) Social Empowerment

Technological innovation not only brings economic advantages but also contributes to social empowerment by increasing the participation of women in decision-making and their confidence and agency. Access to information and communication technologies (ICTs) allows for rural women to learn, to connect to social networks and to be informed on their rights and opportunities (Acilar & Sæbø, 2023). The greater information available can challenge traditional gender roles and contribute to greater gender equality.



Digital financial services also add to the social empowerment by giving women more autonomy over the financial resources. Women's access to and control over income is correlated with their involvement in household decision making and investments in education and other health-related services (Abiona & Koppensteiner, 2022). Moreover, women's involvement in the digital and economic networks increases their visibility and recognition in their communities, thus improving their social standing and influence.

These findings suggest that social empowerment is both an outcome and an enabling condition of livelihood security. Control over income, access to information and participation in markets could potentially raise women's sense of efficacy and decision-making power. In turn, stronger agency could lead women to be better equipped to incorporate technology and to negotiate access and entry to sources of sustenance and livelihood. Empowerment thus does not appear as an end-state or an effect to be enjoyed after an economic impact has occurred, but a process that also fosters it.

(d) Resilience to Economic and Climate Shocks

Technological innovations increase the resilience of rural women by helping them to anticipate, cope and bounce back from economic and environmental shocks. For instance, climate-smart agricultural technologies are a way for farmers to adjust to the new climate conditions and minimize the risks of drought, flood, and pests (Sachs, 2023). Likewise, women can access real-time market information, helping them decide on the timing and the place for selling their produce, thus reducing losses and increasing profits.

Digital financial services, such as savings platforms, microinsurance, and more, can help women manage unplanned for expenditures and income losses (David-West et al., 2022). These can help households to smooth consumption and prevent negative coping mechanisms like selling productive assets or cutting back on food. Furthermore, resilient technologies for renewable energy help ensure the continuity of economic activities even in the presence of infrastructure issues, thus further enhancing resilience (Gbolonyo, & Tetteh, 2025; Chandrasekaran et al, 2023).

Overall, technological innovation contributes to the livelihood security of rural women in multiple pathways, such as through increasing income diversification, improving food security, social empowerment and resilience. But if these pathways are to be effective, underlying structural and institutional barriers that impede women's access to, and use of technology must be addressed.

These findings suggest that resilience results from the convergence of multiple technologies and livelihood pathways rather than through any single intervention. Climate-smart agriculture can reduce the risk associated with production, digital

finances provide financial buffer, ICT facilitates ability to respond to market, renewable energy provides possibility for continuing economic activities and through convergence technologies they assist rural women develop the assets, capacities and ability to plan for and absorb shocks and respond to them. However, the benefits remain uneven where women lack the financial, institutional or social resources required to access and control these technologies.

3- Barriers to Technological Adoption

The potential of the technological innovations is still enormous and yet, there are certain constraints that prevent rural women from accessing and using them to their full capacity and thus, their contribution to livelihood security. These barriers are complex and include economic, infrastructural, socio-cultural and institutional components.

(a) Digital Divide

A key barrier is the enduring digital divide, characterized by disparities in digital skills, internet access, and digital devices. In addition, rural women are less likely than men to own a mobile phone or have internet access, which hinders their ability to access mobile banking services, agricultural apps, and e-commerce platforms (Acilar & Sæbø, 2023; Chen et al., 2023). Poor digital literacy is a barrier to effective use of technology even if it is available, limiting the impact of technology interventions. Socio-economic inequalities are also a major factor in the digital divide, and these inequalities are magnified by the inability to access and afford technology, particularly for poorer households.

(b) Infrastructural Deficits

Another major constraint is the lack of infrastructure in rural areas. Inadequate electricity power, road infrastructure and telecommunication services in many rural areas limit technological tools in their usage and reach (Malladi et al., 2021). In areas where there is no grid access, for instance, solar powered devices could be solutions, but only if they can be made cost effective and if technical assistance is available in the region. Likewise, in areas where internet connections are unreliable, there is limited scalability of digital interventions because mobile apps and online platforms are not effective.

(c) Socio-Cultural Norms

Socio-cultural constraints are also important in limiting women's access to technology. In many rural areas, gender norms limit women's mobility, decision-making authority, and their access to productive resources, including land or devices (Ahmad & Islam, 2024; Malešević, 2022). Women's cultural perceptions might deter their involvement in formal or digital economic networks and household responsibilities may limit time to learn and adapt to new technologies. These norms restrict women's access



to technology and affect the overall social acceptance of women's empowerment programs.

(d) Policy and Institutional Limitations

Poor institutional structures and policy support also hinder the use of technologies. Rural development policies are not gender responsive, in the sense that they do not consider women users' needs and constraints (Anderson et al., 2021). Interventions are less effective when there are no specific initiatives in place to address digital literacy, financial inclusion or access to agricultural technologies. Moreover, the lack of regulatory assistance for digital markets in rural areas and the lack of partnership among government, NGOs and private sector actors are hampering sustainable technology deployment.

(e) Economic Constraints

Lastly, the availability of and access to technological tools is a major problem for the rural women who are the ones who are deprived of them due to their financial constraints. The initial investment requirements for equipment, technology or agricultural machinery might be too high, and women can also not have access to collateral or credit to invest in such technologies (Abiona & Koppensteiner, 2022). Even if technologically effective, the most vulnerable populations may not be reached if there are no financial support mechanisms. These barriers raised in this section should not be treated as distinct or isolated barriers but interlinked and can define women's capacity to access, use and profit from technology innovation. Limited financial means can affect access to devices such as a mobile phone or the opportunity to install a solar panel while poor knowledge about operating digital tools can undermine their efficiency. Gender norms may further limit women's control over these technologies, and weak infrastructure or inadequate institutional support can prevent sustained use. These interlinked constraints illustrate how technological exclusion is a resultant condition of interplay of financial, infrastructural, socio-cultural and institutional factors. Hence, improving livelihood security requires more than distributing technological tools; it requires addressing the conditions that enable women to convert technological access into meaningful capabilities and livelihood benefits.

To sum up, although technology offers great potential to empower rural women, these obstacles need to be overcome to ensure equitable access and impact. Promoting gender-sensitive policies, providing financial support, bridging the digital divide and improving rural infrastructure are key to the adoption and effectiveness of technological interventions.

4- Policy and Practical Implications



The synthesis indicates the necessity of policies and practical measures to increase the adoption of technological innovations among rural women to boost their livelihood security. Policymakers and development practitioners need to understand that technology is just the beginning; its impact is tied to developing environments that overcome structural, socio-cultural and economic constraints.

(a) Gender-Sensitive Technology Policies

There is a need for governments and development institutions to develop policies that are gender-responsive and explicitly consider the needs of rural women in their technology policies. This involves providing access to digital tools, agricultural inputs and financial services in an equitable manner. Policies should focus on digital literacy initiatives for women, providing them with training on how to use their smartphones effectively, agricultural apps, and e-commerce platforms (Chen et al., 2023). These interventions not only increase the number of girls and women who adopt and use these technologies, but they also help women to be more engaged in the economic and social decision-making processes.

(b) Investment in Rural Digital and Physical Infrastructure

To increase the adoption of technology, rural infrastructure must be improved. Access to digital financial services, ICT platforms, and renewable energy technologies is made easier by investments in dependable electricity, internet connectivity, and transportation networks (Malladi et al., 2021). Particularly in off-grid villages, public-private partnerships can be used to implement affordable alternatives like solar-powered energy systems and mobile network development. These actions guarantee that the most disadvantaged groups receive technology interventions and lessen access inequities.

(c) Capacity-Building and Knowledge Sharing

To ensure that rural women can fully benefit from innovation, capacity-building programs are crucial. These include training on the use of digital financial services, climate-smart agriculture, and market-oriented technology (Botha et al., 2026; Adeleke, 2024). Women's cooperatives and community-based initiatives can act as venues for knowledge exchange and peer learning, creating networks that improve resilience and social capital.

(d) Collaboration and Multi-Stakeholder Engagement

Governmental organizations, non-profits, businesses, and local communities must work together for implementation to be successful. Involving multiple stakeholders guarantees that technological solutions are durable, culturally suitable, and contextually relevant (Novovic, 2023). In order to evaluate the effects and improve techniques over time, development initiatives should also have monitoring and evaluation procedures.



In conclusion, coordinated policy initiatives, infrastructure development, capacity-building, and inclusive governance are necessary to increase rural women's empowerment through technological innovation. Policymakers can promote fair access to technology, increase livelihood security, and support more general sustainable development objectives by tackling the obstacles found in this study.

5- Discussion

The synthesis of the reviewed evidence indicates that technological innovation has a great deal of potential to improve livelihood security and empower rural women, but its efficacy is mediated by institutional, sociocultural, and structural factors. The research provides a detailed view of the ways in which technology affects rural women's livelihoods and is consistent with the theoretical perspectives utilized, particularly the Capability Approach, the Sustainable Livelihoods Framework (SLF), and the Feminist Political Economy perspective.

Beyond confirming the potential benefits of technological innovation identified in previous studies, the findings contribute to the literature by demonstrating that the relationship between technology, women's empowerment and livelihood security is best understood as an interconnected and conditional process. The analysis indicates that different forms of technological innovation can operate through complementary pathways: digital financial services can strengthen financial access and autonomy; agricultural technologies can enhance productive capacity and food security; ICT-enabled platforms can improve access to information and markets; and renewable energy technologies can reduce energy constraints while supporting income-generating activities. These benefits become more significant when they expand women's capabilities, strengthen their control over resources and increase their capacity to make decisions about livelihood activities. The contribution of the study therefore lies in bringing these pathways together rather than treating technological interventions as isolated mechanisms.

The analysis further indicates that empowerment is not an automatic consequence of technological access. Instead, technological access represents an enabling resource whose effects depend on women's ability to convert that resource into meaningful capabilities and livelihood opportunities. This conversion is shaped by digital literacy, affordability, infrastructure, gender norms, access to productive resources and institutional support. The study therefore advances a conditional interpretation of technological empowerment: technology is potentially transformative, but its transformative capacity is realised only when women possess the resources, capabilities and institutional space required to access, use and control it. This provides a more nuanced explanation of why similar technological interventions may generate different outcomes across rural contexts.

The Capability Approach highlights how technology can increase the actual freedoms and agency of rural women (Kjosavik, 2021). Women are better equipped to manage resources, make wise financial decisions, and pursue worthwhile endeavors when they have access to digital banking services, mobile-based agricultural applications, and renewable energy technologies. For example, e-commerce tools and mobile banking platforms give women the ability to manage their finances independently, increasing their negotiating power in homes and communities (Abiona & Koppensteiner, 2022). In a similar vein, women who have access to agricultural information via ICTs can ensure reliable food sources, adopt best practices, and boost productivity, all of which translate improved capacities into observable gains in livelihood security.

According to Tambe (2022), the Sustainable Livelihoods Framework elaborates on how technology interventions enhance rural women's asset base, resulting in more resilient livelihoods. Technological methods boost financial capital through digital savings and credit facilities, raise physical capital through access to mechanized farming equipment and renewable energy technologies, and improve human capital through learning and skill development. These developments increase food security, make it easier to diversify sources of income, and lessen susceptibility to shocks from the economy and climate. The SLF claims that sustainable livelihoods are attained through the purposeful deployment of a variety of assets in ways that react to vulnerability situations is supported by the multifaceted impact seen.

The institutional obstacles that still prevent rural women from fully benefiting from technological innovation are highlighted by the feminist political economy approach (Mezzadri, et al., 2024; Ahmad & Islam, 2024; Cantillon et al., 2023). Women's adoption and use of technology instruments are restricted by sociocultural norms, restricted mobility, gendered land access, and unequal decision-making authority. Furthermore, these limitations are made worse by infrastructure deficiencies like erratic electricity and inadequate internet connectivity, underscoring the way that structural inequality and gender intersect to influence technical outcomes. The continued existence of the digital divide highlights the fact that empowerment depends on supportive social and institutional contexts in addition to having access to technology.

Literature shows the interconnectedness and mutual reinforcement of the pathways connecting technological innovation to livelihood stability, income diversification, improving food security, social empowerment, and resilience. For instance, women's financial autonomy is strengthened by greater revenue from digital marketplaces, which in turn improves their social empowerment and ability to make decisions, ultimately boosts home welfare. Similarly, having access to climate-smart agricultural technologies contributes to long-term livelihood stability by increasing crop yields and strengthening resistance to climatic variability (Sachs, 2023; Novovic, 2023).



The study does, however, also point out weaknesses in the current frameworks for implementation and policy. The lack of gender responsiveness in many technology-driven solutions restricts sustainability and inclusion. Technological advancements run the potential of perpetuating rather than reducing current disparities if digital literacy, sociocultural norms, and infrastructure issues are not addressed. This finding emphasizes the value of integrated strategies that incorporate community involvement, legislative changes, capacity-building, and technology implementation.

In summary, the conversation confirms that, given support from enabling policies, gender-sensitive frameworks, and infrastructure investments, technological innovation may be a transformative tool for rural women's empowerment and livelihood stability. Empowerment is multifaceted and dependent on resources, agency, and structural support, as shown by the alignment of literature with theoretical frameworks. Policymakers, development organizations, and practitioners looking to create inclusive and long-lasting technology solutions in rural settings can benefit from these ideas.

6- Conclusion

This analysis emphasizes how technological innovation can empower rural women and improve the security of their livelihoods. The study shows that digital financial services, agricultural technologies, information and communication technologies (ICTs), and renewable energy solutions offer several ways to enhance income, food security, social empowerment, and resilience to shocks to the economy and environment. These technologies improve rural women's economic and social well-being by allowing them to diversify their sources of income, participate in markets, make educated agricultural decisions, and participate in community decision-making (Botha et al., 2026; Adeleke, 2024; Abiona & Koppensteiner, 2022; Sachs, 2023).

The report also emphasizes that institutional, sociocultural, and structural hurdles severely limit rural women's capacity to fully benefit from technology adoption. The impact of technology interventions is limited by problems including the digital divide, low literacy, gendered access to resources, poor infrastructure, and non-gender-responsive policies (Acilar & Saebø, 2023; Ahmad & Islam, 2023; Chen et al., 2023). For technology advancements to result in real gains in livelihood security, these obstacles must be removed.

The results theoretically support the Sustainable Livelihoods Framework, the Capability Approach, and the Feminist Political Economy viewpoint. Together, these theories demonstrate that empowerment is multifaceted and includes agency, structural support, and resource access. Women's skills and assets are strengthened by technological advancements, but long-term effects call for inclusive institutional frameworks, capacity-building programs, and supportive legislation.



The study highlights the significance of gender-sensitive technology policies, investments in rural infrastructure, training in digital literacy, and multi-stakeholder engagement from a policy and practical perspective. To ensure that the most marginalized women benefit from technology advancements, public-private partnerships, community-based knowledge-sharing platforms, and focused interventions can assist close the digital and infrastructure gaps.

In conclusion, empowering rural women with technological innovation presents a feasible route to economic independence, livelihood stability, and more general sustainable development. Governments, non-governmental organizations, and development organizations can establish inclusive possibilities that improve the lives of rural women, lessen poverty, and foster resilient communities by combining technical solutions with supporting social, institutional, and policy contexts. Future studies should examine the long-term effects of technology treatments and look into context-specific tactics to increase rural women's adoption and efficiency of technology.

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