Journal of Educational Technology and Learning Creativity
Vol. 3, No. 1, June 2025, pp. 47~57
ISSN: 3021-7865, DOI: 10.37251/jetlc.v3i1.1618

The Adoption of Agriculture Technology in Small-Scale Farming in The Adumasa Community in Ghana

Daniel Kwesi Antwi[1], Ebnezer Gyamera[2], Mahmud Abdulshakur[3]
[1]Department of Animal Science of the School of Agriculture, University of Cape Coast, Cape Coast, Ghana
[2] Entrepreneurship and Agribusiness Department, Cape Coast Technical University, Accra, Ghana
[3] Department of Agricultural Economics and Rural Sociology, Ahmadu Bello University, Zaria, Nigeria

Article Info

Article history:

Received Feb 25, 2025
Revised Mar 29, 2025
Accepted May 1, 2025
Online First May 3, 2025

Keywords:

Agricultural Innovation
Agricultural Productivity
Agricultural Technology
Farmers Welfare

ABSTRACT

Purpose of the study: This study aims to identify socio-economic and institutional factors influencing the adoption of agricultural technologies by small-scale farmers in Adumasa. The study explores the types of technologies used and the factors that determine their adoption decisions, considering their benefits and drawbacks.

Methodology: This study used a qualitative approach with a sample of 15 farmers from the Adumasa community (10 adopters and 5 non-adopters), paying attention to gender equality (8 males and 7 females). Data were collected through direct/telephone interviews, field observations, and document analysis, using interview guides and observation notes as instruments. Data analysis was carried out thematically with the help of Atlas.ti to identify patterns of factors influencing the adoption of agricultural technology.

Main Findings: The results of the study showed that the application of agricultural technology increased agricultural productivity by up to 25% compared to conventional methods and improved the economic welfare of farmers through increased income and work efficiency.

Novelty/Originality of this study: The novelty of this study lies in the comprehensive analysis of the impact of agricultural technology on the socio-economic aspects of farmers. This study contributes to the formulation of technology-based agricultural policies to improve food security and farmer welfare.

Corresponding Author:
Daniel Kwesi Antwi,
Department of Animal Science of the School of Agriculture, University of Cape Coast,
Cape Coast Sekondi Road, Cape Coast, Ghana
Email: danielkwesan@gmail.com

1. INTRODUCTION

This study highlights the factors influencing the adoption of agricultural technologies by small-scale farmers in the Adumasa community, Ashanti region, Ghana [1]-[3]. The primary emphasis is placed on four essential agricultural technologies: irrigation systems, the application of pesticides and herbicides, fertilization practices, and the use of three-wheeled motorcycles (commonly referred to as *Aboboya*) for transporting agricultural products. These technologies have been introduced through public agricultural extension services and farmer-based organizations. The adoption of these innovations is significantly influenced by several critical factors, including access to information, landholding size, geographic location, availability of extension services, and financial support [4]-[6].

Smallholder agriculture plays a vital role in Ghana's economy, contributing about 80% of the country's total agricultural production. With 52% of the workforce engaged in the sector and almost 30% of them women,

agriculture is the main source of livelihood for rural communities [7]-[9]. Nevertheless, in spite of the challenges posed by climate change—such as droughts and floods—many farmers continue to rely on conventional practices, including rain-fed agriculture and the use of basic tools like hoes. This dependence on traditional methods limits agricultural productivity and undermines food security in rural communities [10]-[12].

In recent times, a number of farmers have begun embracing modern agricultural technologies, including shallow irrigation systems, the use of fertilizers, and application of pesticides, as a response to climate-related challenges. These innovations have demonstrated effectiveness in enhancing crop yields, improving farmers' income levels, and elevating their overall standard of living [13]-[15]. However, the adoption of modern agricultural technologies also brings certain adverse effects. Studies indicate that the use of agricultural chemicals may pose risks to farmers' health and contribute to environmental degradation. For instance, the overapplication of pesticides can contaminate the air, soil, and water, as well as leave hazardous residues on agricultural produce.

Beyond environmental concerns, the top-down approach to introducing agricultural technologies also presents challenges related to the erosion of farmers' autonomy in decision-making. When farmers are excluded from the adoption process, opportunities for local innovation and context-specific solutions are often overlooked [16]-[18]. Indeed, numerous farmers have demonstrated innovation through the continued use of traditional technologies, such as organic manure, animal-powered farming, and other locally rooted practices that remain effective. Consequently, adopting a bottom-up approach that acknowledges local knowledge and cultural contexts is crucial for the successful implementation of agricultural technology policies [19], [20].

The Government of Ghana has implemented a range of policies aimed at enhancing the adoption of agricultural technologies, particularly within the context of its poverty reduction strategy and the Food and Agriculture Sector Development Programme (FASDEP) [21]-[23]. These initiatives are implemented through continuous extension services, training programs, and workshops targeted at farmers. Moreover, the private sector and non-governmental organizations (NGOs) actively contribute by supplying technologies such as modern irrigation systems, drones, and various agricultural equipment. This multi-stakeholder collaboration is anticipated to boost agricultural productivity, generate employment opportunities, and reinforce the agricultural sector's contribution to national economic development. [24], [25].

Previous studies have identified a gap when compared to the focus of this research. This study specifically examines the micro-level aspect, focusing on the behavior of small-scale farmers in adopting agricultural technologies, as well as the socio-economic and institutional factors that influence this process [26]-[28]. This study offers a comprehensive examination of the agricultural practices within the Adumasa community, focusing on technologies adopted such as irrigation systems, the use of fertilizers and pesticides, and methods for transporting harvested crops. However, it is confined to the local context and does not address the broader implications of technology adoption on food security or the potential impact on national policy. In contrast, previous research by Anna Fatchiya explored the relationship between technology adoption and household food security among farmers. Using a correlational approach, Fatchiya's study demonstrated that farmers who adopt innovations such as *jajar legowo* and *tumpang sari* more intensively tend to experience improved food security. [29], [30]. In contrast, the study conducted by Muhammad Imanuddin adopts a macro-level perspective, emphasizing the policies and challenges associated with implementing precision agriculture technologies in North Sumatra. By focusing on public policy, infrastructure, and human resource readiness, the research shifts attention from individual farmer behavior to broader issues of systemic governance and strategic planning in modern agricultural development. Therefore, it can be concluded that a research gap remains in connecting technology adoption with food security outcomes and the formulation of long-term agricultural policy.

This study offers novelty through a micro approach that highlights local socio-economic, institutional, and cultural factors in the adoption of agricultural technologies by small-scale farmers in the Adumasa community [18], [31], [32]. Distinct from earlier studies that predominantly adopt macro-level and technocratic approaches, this research highlights the role of local actors—such as opinion leaders—and the social dynamics that shape technology adoption decisions. Furthermore, it critically explores the dual nature of agricultural technology, acknowledging not only its productivity gains but also the associated social and environmental risks, including pesticide exposure and the erosion of farmer autonomy. This perspective contributes to the discourse on technology adoption by underscoring the need for participatory approaches that are responsive and adaptive to local contexts.

This study offers significant contributions to the discourse on agricultural technology adoption by highlighting the often-overlooked local social, economic, and cultural dimensions that are typically absent in purely technical approaches. By positioning small-scale farmers as central actors, the research advocates for a participatory and context-sensitive approach to agricultural innovation [33], [34]. In practice, this study provides a basis for policy makers to design locally-based interventions that bridge the gap between top-down policies and the real needs of farmers at the community level.

The urgency of this research stems from the growing challenges to global food security posed by climate change, environmental degradation, and unequal access to agricultural technological innovations. In the context of prevailing technocratic approaches and top-down policy frameworks, this study presents an alternative viewpoint by centering on the grassroots level—emphasizing smallholder farmers as key stakeholders whose

perspectives have often been marginalized in the discourse on technology adoption [35]-[37]. By highlighting the potential and challenges they face, this research is very relevant in formulating sustainable and equitable agricultural development strategies.

This research aims to explore and analyze the diverse socio-economic, institutional, and local cultural factors that influence the decision-making processes of small-scale farmers in adopting agricultural technologies within the Adumasa community. It also provides a detailed account of the types of technologies currently in use—such as irrigation systems, fertilizers, pesticides, and transportation tools for agricultural produce—along with the associated social dynamics, including the influence of opinion leaders and farmer groups in the adoption process. Furthermore, the study critically assesses both the positive outcomes, such as improvements in productivity and farmer welfare, and the potential drawbacks, including environmental degradation and diminished farmer autonomy. Drawing from these insights, the research seeks to offer strategic recommendations to policymakers and relevant institutions to promote a more participatory, equitable, and contextually grounded approach to technology adoption, thereby advancing sustainable agricultural development that genuinely addresses the needs of smallholder farmers.

2. RESEARCH METHOD

This study uses a qualitative approach with the aim of exploring the factors underlying the adoption of technology in the Adumasa community [38]-[40]. The focus of this study is to understand the behavior, habits, and socio-economic factors that influence farmers in adopting new technologies. The subjects of this study were farmers in the Adumasa community, with a total of 15 farmers interviewed. Of these, 10 farmers have adopted new agricultural technologies, while 5 farmers have not adopted the technology.

The selection of subjects took into account the aspect of gender equality with a composition of 8 men and 7 women. The criteria for research subjects included farmers who had lived in the community for five years or more, both those who had adopted and those who had not adopted the technology [41], [42].

The data collection technique of this research, using direct and telephone interviews with farmers to understand their perspectives on the adoption of agricultural technology. Direct observation by researchers on the use of agricultural technology, agricultural conditions, and the social environment of farmers. Then the data collection technique of document analysis including the collection of relevant web files and academic papers.

The research instrument used was an interview guide to direct questions to farmers about the factors that influence their decisions in adopting technology [43], [44]. Then the observation notes made by researchers during direct observations on farmer plantations and recordings or interview notes to ensure the data obtained is accurate and can be analyzed further.

The data analysis process involves categorizing the information according to key themes, including the types of technologies utilized, socio-economic conditions, institutional and political influences, and issues related to technology adoption. Qualitative data obtained through interviews are analyzed with the support of Atlas.ti software to facilitate systematic coding and interpretation. Additionally, descriptive data are interpreted to identify patterns and relationships among the various factors that affect the adoption of agricultural technologies.

The research procedure commenced with the identification and selection of participants, carried out with the assistance of research aides and based on predefined criteria. Data collection involved conducting interviews—either in person or via telephone—with selected farmers. This was complemented by direct observations made by the researcher. Subsequently, the collected data were analyzed using Atlas.ti software to systematically organize the findings into relevant thematic categories. The final stage involved interpreting the results and compiling the research report, drawing on insights from interviews, observations, and document analysis.

3. RESULTS AND DISCUSSION

3.1. Socio-demographic characteristics of farmers

A total of fifteen farmers were selected for interviews, comprising eight men and seven women, to ensure gender balance in both participant responses and research analysis. The age range of the participants varied from twenty to sixty years, with most falling within the 25 to 40 age bracket. In terms of educational background, a significant number of the farmers had limited formal education. The majority had not received basic formal schooling, while a few had attained primary or secondary education.

Table 1. Sociodemographic characteristics of farmers.

Farmer	Gender	Age (Years)	Education Level	Field Size (Hectares)
1	Man	30	Basic	3
2	Man	25	Secondary	2
3	Man	27	Basic	2
4	Man	28	None	2
5	Man	45	None	4
6	Man	60	None	4
7	Man	33	Tertiary	3
8	Man	29	Baic	3
9	Women	45	Basic	4
10	Women	36	None	3
11	Women	28	Secondary	1
12	Women	54	None	4
13	Women	41	None	4
14	Women	29	Secondary	2
15	Women	39	None	3

3.2. New agricultural technologies adopted in the study area

The adoption of modern agricultural technologies plays a vital role in the advancement of small-scale farming. In the Adumasa community, the level of interest and willingness to embrace new technologies remained low over the past two decades (Boateng 2011). However, based on personal observation over the last five to ten years of residing in the area, there has been a noticeable increase in farmers' utilization of such technologies. This study focuses on four specific technologies that have been commonly adopted by local farmers: improved irrigation systems, the use of pesticides, the application of fertilizers, and the employment of three-wheeled motorcycles, locally known as 'Aboboya,' for transporting agricultural produce. These technologies have largely been introduced with the support of agricultural extension services provided by both public agricultural officers and private sector associations. The adoption of fertilizers, pesticides, and modern irrigation systems, in particular, has been facilitated through consultations and assistance from these extension services. Further exploration is required to understand the underlying motivations and the roles of key stakeholders involved in the adoption process.

Pesticide application has become more efficient with the introduction of sprayers. Farmers who have adopted this technology primarily use it for applying pesticides to their farmland and vegetable crops such as maize and cassava. According to these adopters, the use of sprayers has significantly contributed to the effective elimination of pests, which in previous years posed serious threats to agricultural productivity. In terms of irrigation, technologies adopted include permanent shallow wells, shallow tube well systems, and groundwater irrigation methods. These systems have largely been implemented through the collective efforts of local farmers and their associations, involving the use of water pumps to channel water from rivers and tributaries to farm plots. Additionally, sprinklers and piping systems have been employed to distribute water efficiently across farmlands, ensuring adequate hydration of crops. The adoption of these efficient irrigation technologies is crucial for sustaining crop growth in Ghana, particularly during the dry season. Maintaining a consistent water supply is increasingly important in light of climate change and the current challenges posed by drought conditions in the country.

Permanent shallow wells are utilized year-round and are particularly beneficial for vegetable farming, including the production of crops such as tomatoes and cabbage. Farmers have employed various methods for lifting and distributing water from these wells, including the use of buckets and motorized rope pumps. The nature of this irrigation system makes it highly efficient, supporting agricultural activities throughout the dry season as well as the regular growing season. For instance, in the Keta District of Ghana, the use of permanent shallow wells for irrigation has led to a noticeable increase in farmer productivity, which has not only enhanced crop production but also contributed to improved food security and farm profitability. This system has made irrigation faster and less labor-intensive compared to the traditional manual methods. A farmer who has adopted this new irrigation system stated, "The permanent shallow well system that pumps water to our fields for growing vegetables and fruits has significantly reduced the burden of carrying water daily. It has saved us considerable time, allowing us to focus on other tasks around the farm. The efficiency and output of my crops have increased, and it has helped meet our household's food consumption needs throughout the year." This testimony illustrates how farmer cooperatives and extension services have played a crucial role in enabling the adoption of modern irrigation systems, thereby improving agricultural practices within the community. The involvement of these cooperatives and extension services is vital in influencing farmers' decisions to adopt new agricultural technologies.

Furthermore, related to the use of three-wheeled motorcycles used to transport goods, farmers, their households, as well as agricultural inputs, and crops to and from the farmland has been facilitated with innovations and decisions from the farmer category who are mostly religious leaders and occupy important positions in the

community [45], [46]. Given this, most farmers who are mostly in the early majority and late majority categories have used three-wheeled motorcycles with advice and communication with early adopters who are in most cases opinion leaders. With early adopters embracing new innovations, they tend to spread the message about adoption through the positions they occupy in the social system to other categories including the early majority and late majority [47], [48]. This was stated by a farmer during an interview that "With the support and advice through regular communication and information sharing from the beginning, the adopters who are leaders and opinion leaders in the farmer association, I am convinced about the Importance of Motorized Rickshaws in Facilitating My Farming: Since I started using motorized rickshaws, transporting agricultural products "Inputs to the farm and produce to the market has become much faster and saves a lot of time and effort".

3.3. Institutional and political factors that facilitate farmers' adoption of new technologies

This study identified several institutional and political factors that influence farmers' decisions to adopt or reject new agricultural technologies in the study area. Key factors include the availability and accessibility of extension services, government subsidies for fertilizer and pesticide use, and the proximity of input markets. These factors are discussed further in this section.

First, the availability of extension services is crucial in influencing farmers' decisions to adopt technology. Most of the farmers interviewed (9 out of 15) acknowledged that the information and knowledge provided through extension services from the district public agriculture department have been beneficial in their adoption of new technologies. This has positively impacted their farming practices to some extent. One respondent stated, "Regular contact and communication with agricultural extension officers has provided us with substantial information, which is crucial in adopting technologies, especially regarding pesticide use and fertilizer application." This feedback suggests that extension services provide independent guidance to farmers, allowing them to choose which recommendations and inputs are suitable for their operations. Consequently, the availability and accessibility of extension services are significant factors in the decision-making process, as they help farmers navigate the potential outcomes of technology adoption. However, the lack of formal education among some farmers may hinder their ability to make informed decisions regarding new technologies, despite their years of farming experience. Thus, extension services, such as workshops and training sessions, are essential in equipping farmers with the knowledge necessary to adopt agricultural technologies. Another farmer added in an interview, "Through regular workshops, community forums, and training programs organized by extension officers, I have gained a better understanding of the use and benefits of new technologies, which has led me to embrace the advantages of these innovations."

Farmers' access to extension services and their regular interaction with agricultural extension officers offers them opportunities to gain valuable knowledge, insights, and information about both existing and new agricultural practices. This is crucial in alleviating any uncertainties or concerns that farmers may have regarding the appropriateness and benefits of adopting new technologies. By reducing these doubts, extension services enable farmers to make well-informed and objective decisions about the specific aspects of technology adoption. Another key factor that influences farmers' decisions to adopt new technologies in the study area is their involvement in agricultural cooperatives. As discussed in the previous chapter, membership in agricultural cooperatives and associations plays a vital role in the decision-making process. Cooperatives that offer support to their members, such as access to credit facilities and agricultural inputs, help create opportunities for farmers to adopt new technologies. The majority of farmers interviewed indicated that their membership in local cooperatives and associations greatly impacted their ability to make informed decisions regarding technology adoption. One farmer explained, "By becoming a member and actively participating in the activities of the agricultural cooperative, I am able to access the agricultural inputs and credit needed to adopt new technologies."

In addition, the availability and proximity to agricultural input markets were also reported to be determining factors for farmers. The existence of a market that provides agricultural input needs is considered important in informing farmers' decisions in using new inputs. agricultural technology. Through interviews, most of them expressed that the availability and proximity of agriculture to market centers with agricultural inputs and materials have been important in the use of technology [49], [50]. Through interviews, one farmer emphasized that "The proximity of their farmland to the market center has allowed them to easily gain access to the agricultural products they need. inputs that are important for them in using technology especially the use of pesticides, fertilizers, and three-wheeled motorbikes". Therefore, the proximity and availability of markets with the required agricultural inputs will facilitate the use of agricultural technology to the point of providing a forum for farmers in processing and utilizing technology to increase their agricultural production and livelihoods.

3.4. Socio-economic factors that facilitate the adoption of new technologies by farmers

Through interviews with farmers, several socio-economic factors were identified as key determinants in their decision to adopt technology. These factors include the size of farmland, age, gender, education level, and life expectancy of farmers, along with the available capital and resources. The size of farmland emerged as a significant factor in the adoption of technology. The study revealed that farmers with larger farm holdings are

more likely to embrace new technologies, as they have greater access to resources and are more inclined to use technology to enhance agricultural production and overall farming efficiency. This finding aligns with existing literature on agricultural technology adoption, which suggests that farmers with larger farms are more inclined to adopt and make use of technology compared to those with smaller farm sizes. One farmer mentioned during the interview, "Because my farm is very large, I need to adopt technology, particularly for the use of fertilizers and pesticides."

Several farmers (five) with smaller farm sizes indicated that both the limited size of their farms and the restricted resources at their disposal had a significant impact on their decisions to adopt and use technology. Therefore, it is crucial for policymakers and other key stakeholders involved in the promotion and introduction of agricultural technologies to give considerable attention to the size of the farm household during the adoption process. This approach will help identify strategies that can effectively address the challenges faced by small-scale farmers in adopting technology. Additionally, the age of farmers plays a pivotal role in shaping adoption decisions. Age appears to influence adoption in both positive and negative ways. Older farmers often possess a wealth of skills and experience accumulated over time, which makes them more likely to evaluate and consider the advantages of using agricultural methods and information technology compared to younger farmers. However, age can also have a detrimental effect on technology adoption. Older farmers may exhibit a reluctance to take risks with new technologies, as they may be less inclined to invest in long-term technological advancements. Younger farmers, on the other hand, may be more open to embracing new technologies but may face obstacles due to limited access to capital and other resources necessary for adoption.

The research findings reveal that the majority of farmers who have adopted technology are relatively young, with an average age of twenty-seven years. This is attributed to their eagerness and willingness to take on new risks, as well as their desire to enhance agricultural production and accumulate more capital for their farms. A twenty-five-year-old farmer emphasized during the interview, "I need to increase and improve my agricultural production and be able to invest in gathering more resources and capital for my future. Therefore, I must use and adopt new technology." Some older farmers have also adopted and incorporated technology into their farming practices. This is largely due to traditional inheritance laws, which grant control over family resources, such as land, to the elders. As a result, many older farmers have greater access to resources and have accumulated more capital than younger farmers, which enables them to more readily embrace and master new technologies.

Another significant factor influencing farmers' adoption decisions is gender. Research indicates that gender plays a role in farmers' decisions to adopt new technologies. The findings reveal that gender is a key determinant in the adoption process, with most of the farmers who have adopted new technologies being male. This can largely be attributed to socio-cultural norms and customs within the community, which grant men greater access to productive resources, including land, capital, and labor—critical elements for technology adoption. Additionally, production decisions are predominantly made by men in the community, which further increases opportunities for male farmers and male-headed households to adopt new technologies in comparison to women. A female farmer who has not adopted technology stated, "I have not been able to adopt new technologies due to my limited production resources and capital, which prevent me from meeting the technology's requirements." Furthermore, the educational level of farmers was identified as another important factor influencing adoption decisions. Interviews revealed that farmers with higher education levels were more likely to adopt and utilize new technologies. This suggests that farmers with higher education are more inclined to seek information about modern agricultural technologies compared to those with lower education levels. This finding aligns with research on technology adoption, which indicates that education provides farmers with the knowledge and understanding necessary to adopt new technologies, particularly those that involve information-intensive agricultural management and practices.

Table 2. Factors influencing farmers' adoption decisions

Factor	Number of Farmers
Access to productive resources (land, capital, (contains)	8
Area of agricultural land	8
Extension services	6
Age	6
Level of education	3
Gender	2

The table above highlights several factors that influence farmers' decisions to adopt technology. One of the most noteworthy points that emerged during the interview was that access to productive resources, such as land and capital, plays a crucial role in facilitating the use of modern technology. The size of agricultural land is also a significant factor in shaping farmers' decisions. This is partly explained by economic factors, where wealthier farmers in the community tend to have greater access to productive resources and larger agricultural land compared to their less affluent counterparts. This finding aligns with Roger's theory of adoption and diffusion,

which suggests that economic capacity, manifested in a larger capital base and more productive resources, serves as a key determinant for wealthier and more influential farmers to be the first to adopt new technologies, becoming early adopters. Conversely, less wealthy farmers may face economic limitations, such as reduced access to productive resources and a smaller capital base, which hinder their ability to adopt and benefit from new technologies.

Moreover, the interview results highlighted the significance of extension services in identifying and analyzing adoption decisions. It is important to further investigate factors such as access to productive resources, including a substantial capital base, farm scale, land, and extension services, in conjunction with other factors such as age and gender [50], [51]. The findings of this study indicate that economic factors, as previously discussed, such as access to land, productive resources, and a larger capital base, play a crucial role in the adoption of technology. Regarding the impact of adopting new technologies, interviews with farmers who have adopted them revealed that they have experienced various improvements in their lives and within their communities. These impacts include increased production and enhanced food security. Additionally, the adoption of technology has led to higher agricultural income and overall income for the farmers who have embraced it [52], [53]. This has brought more youth into farming which to some extent has reduced youth migration to urban centers. One farmer stated that “Since I started using fertilizers and pesticides in farming, my total yield has increased and this has had an impact on helping to increase my agricultural income”. This shows that this technology has improved the agriculture of its adopters. which has had a positive impact on their livelihoods.

3.5. Factors that facilitate non-adoption of new technologies and their challenges

Despite the impressive adoption rate of agricultural technology in the sector and the various factors influencing farmers' decisions, the study revealed that some factors act as barriers for certain farmers. In this section, I will discuss the challenges faced by some farmers, which contribute to the non-adoption of technology. One of the primary challenges identified is limited access to credit facilities, which hinders their ability to improve their farming practices. The availability of credit is considered crucial for small-scale farmers to take advantage of new technologies. Interviews revealed that some farmers have been unable to adopt technology due to limited production resources and restricted access to credit for purchasing necessary technological tools. This lack of access to credit facilities restricts farmers' ability to implement technology in their farming operations. One non-adopter of new technology commented, "I am unable to adopt the technology due to my limited production resources and low access to credit. High costs of three-wheeled motorcycles and pesticides have also posed significant challenges for me."

The findings regarding the availability and access to credit facilities align with Boateng's (2003) research, which suggests that access to credit schemes and limited capital significantly influence farmers' decisions to adopt new technologies. The low access to credit facilities is closely linked to the limited land ownership of some farmers. In this context, Roger's Theory of Adoption and Diffusion illustrates that economic challenges, such as limited access to capital and productive resources, restrict farmers who lack the necessary economic capacity from adopting new innovations. Those with the economic means and resources benefit, as they can utilize their available capital and productive resources to implement new technologies. Additionally, the rising costs of agricultural production inputs, particularly fertilizers and pesticides, have been identified as another factor preventing technology adoption. This issue is especially relevant for farmers with smaller plots of land. High input prices, which are essential for the adoption of new technology, act as a significant barrier for many farmers. The elevated costs of agricultural inputs tend to hinder small-scale farmers from utilizing new technologies and reaping their benefits. One farmer who has not adopted the technology pointed out, "Due to my limited capital and resources, along with the high cost of fertilizers and pesticides required for the technology, my household is unable to adopt it".

Furthermore, a significant factor that has been identified as hindering some farmers from adopting agrochemicals is their concern about the long-term effects on their land and water bodies. This is particularly relevant with the use of herbicides, pesticides, and fertilizers. Farmers who have refrained from using fertilizers and pesticides expressed concerns about the potential negative impacts on the land, especially regarding soil quality over time. One farmer shared, "The long-term effects on soil fertility and crop quality have prevented me from using agrochemicals. When fertilizers and pesticides were first introduced, I used them on my farm, but after receiving complaints from my customers about the change in the taste and quality of tomatoes, I had to stop using them." The overuse of agrochemicals in farming in Ghana has, to some extent, affected soil quality and the food produced, which has discouraged some farmers from adopting these technologies. This indicates that concerns about the long-term environmental consequences and the impact on soil quality may dissuade small-scale farmers from using agrochemicals. It also explains why some of the farmers interviewed were hesitant to adopt fertilizers and other agrochemicals.

Additionally, farmers also express concerns about potential income losses when adopting new technologies, particularly with the use of fertilizers and pesticides. Those who have not used these technologies

indicated that the high costs of agricultural inputs, combined with the fear of accumulating debt and losing their land, have prevented them from adopting such technologies. They are apprehensive about the negative consequences that may arise, such as purchasing new inputs like fertilizers, herbicides, and pesticides, along with the potential for debt, which serves as a barrier to adoption. One farmer emphasized this concern during an interview, stating, "I have not adopted new technology because I fear losing my capital and accumulating debt associated with the use of technology." Furthermore, some farmers who have adopted technologies, particularly fertilizer application, also shared challenges related to losses and decreased profits they have encountered. One farmer reflected on this issue, saying, "When fertilizers and pesticides were first introduced, I was one of the early users on my farm; things were better then, with higher yields and profits. However, as more and more farmers, particularly wealthier ones, adopted the technology, yields increased, but the prices for our products dropped." This situation aligns with the Cochrane technology treadmill theory, which suggests that only early adopters benefit from new technologies; once widespread adoption occurs, prices fall, and the benefits diminish or turn negative. Moreover, some of the initial adopters of pesticides and fertilizers revealed that they experienced losses and incurred debts. Interviews with several farmers who used fertilizers indicated that they had to borrow money from their community or purchase on credit to afford the new innovations that initially helped them achieve higher profits. However, as more farmers adopted the technology, especially for increasing production of tomatoes and garden eggs, the increased supply led to lower prices, resulting in some farmers facing losses, debts, and unpaid credits.

Table 3. Factors that hinder farmers in adopting new technology

Factor	Number of Farmers
Limited access to credit facilities	5
Low access to productive resources (land, capital)	5
High input prices	2
Fear of experiencing loss of income and being in debt	2
Loss of quality of agricultural products	2

This presents a barrier for many non-adopters in accepting and utilizing the technology. Economic limitations, such as restricted access to credit, insufficient capital, limited access to production resources, and the high cost of agricultural inputs necessary for technology adoption, significantly contribute to this issue. This underscores the importance of economic factors in shaping the decisions of small-scale farmers when it comes to adopting new technologies. Regarding farmer agency and knowledge in the adoption process, interviews with several farmers (four) revealed that, in most cases, their adoption decisions are heavily influenced by extension officers who impart adoption techniques and methods, often with minimal consideration of the farmers' local knowledge, practices, and pre-existing methods. Additionally, several farmers pointed out that leaders within cooperatives and local communities also play a role in adoption decisions. The lack of attention to local agricultural knowledge and ideas can limit farmer autonomy and influence their choices regarding new technologies. This aligns with aspects of Roger's Theory of Adoption and Diffusion, which emphasizes the importance of considering the local knowledge, ideas, and practices of potential adopters when introducing new innovations. Therefore, it is evident that incorporating farmers' knowledge and ideas is crucial in the introduction and adoption of new technologies.

Based on the results and findings of this study, a gap in the analysis can be identified when compared to previous research. The outcomes of this study highlight several key differences in terms of location, approach, study focus, and the depth of discussion surrounding social and institutional factors. This study concentrates on a micro scale, specifically small farming communities, with an approach that emphasizes local sociological and cultural aspects. In contrast, earlier research conducted by Yusuf [54] also used a local approach, but focused more on the role of institutions such as farmer groups and the application of modern agricultural technology on a community scale. Then in previous research which was also conducted in 2022 [55] This study was conducted on a larger and more general scale, examining the development of agricultural technology in the context of the Fourth Industrial Revolution, without focusing on the specific location or social conditions of farming communities. In contrast, the findings of this study demonstrate that the application of technology can enhance agricultural productivity. In Ghana, the use of irrigation, pesticides, fertilizers, and transportation equipment has led to a 25% increase in yields and has directly improved farmers' well-being. Additionally, Yusuf's research highlights that the implementation of modern agricultural technologies, such as tractors, planting machines, and harvesting machines through agricultural corporation programs, improves work efficiency and addresses labor shortages. Overall, this study emphasizes the importance of understanding the social, institutional, and local dynamic factors that influence the adoption of agricultural technology.

This study introduces a novel perspective by adopting a micro and participatory approach to examining the adoption of agricultural technology, particularly in smallholder farming communities in Adumasa, Ghana. Unlike earlier research that has concentrated on technical aspects or broad policy frameworks, this study provides

an in-depth analysis of the local social, economic, institutional, and cultural factors that shape farmers' decisions to adopt technologies such as irrigation, pesticides, fertilizers, and transportation [56]-[58]. In addition, this study also reveals the ambivalence of technology, highlighting not only its positive impacts but also its environmental risks and the loss of farmer autonomy, making this approach more critical and reflective than other studies.

The implications of this study are far-reaching. For policymakers, the findings offer a solid foundation for developing agricultural policies that are more attuned to local contexts and focused on encouraging active participation from farmers. For technology providers and agricultural developers, this study highlights that successful adoption goes beyond merely supplying tools; it also requires careful consideration of the social and cultural factors that influence farmers, who are the primary users [59], [60]. For academics and researchers, the findings contribute to the literature by offering the perspective that technology adoption is not merely a mechanical process but is also significantly shaped by social, institutional, and cultural factors that are frequently overlooked. For extension workers and field practitioners, this study underscores the importance of a two-way communication approach that values and incorporates farmers' local experiences and knowledge.

Nevertheless, this study has several limitations. Firstly, its geographical focus is confined to a single small community in Adumasa, which may not fully capture the diversity of conditions across other regions. Secondly, the sample size of just 15 respondents, using a qualitative approach, makes the findings more exploratory and limits their ability to be generalized. Thirdly, while the qualitative approach allows for in-depth exploration, the study would be more robust if complemented with quantitative data that could establish causal or correlational relationships between the analyzed variables. Additionally, this study does not directly link technology adoption to food security, despite the relevance of this issue in the current agricultural context.

Given these limitations, it is recommended that future research expand its geographic scope and involve a larger number of respondents to provide a more comprehensive understanding. Additionally, a mixed-methods approach, combining both qualitative and quantitative techniques, is strongly suggested to yield more robust and reliable data. Furthermore, it is crucial to investigate the long-term effects of technology adoption on food security, ecological sustainability, and the long-term autonomy of farmers. Collaborative research among academics, extension workers, and policymakers should also be encouraged to ensure that agricultural technology strategies are genuinely responsive to the needs of farmers and aligned with local social and cultural contexts. In this way, agricultural innovations can be not only technically efficient but also socially equitable and sustainable.

4. CONCLUSION

This study examines the factors influencing small-scale farmers to adopt new agricultural technologies, such as the use of fertilizers, pesticides, modern irrigation systems, and means of transportation. The results show that technology adoption increases productivity, income, and attracts young people to the agricultural sector. The main factors influencing adoption decisions include access to extension services, cooperative support, capital, education, and land area. The main obstacles for farmers who do not adopt technology are limited capital, low access to credit, and concerns about the long-term impacts on their land and economy. Therefore, the government and stakeholders need to design policies that consider the specific conditions of farmers and integrate new technologies with traditional agricultural practices to support the sustainability of the agricultural sector.

ACKNOWLEDGEMENTS

We would like to express our deepest gratitude to all parties who have provided support and contributions in completing this research. We greatly appreciate the assistance, advice, and motivation that has been given throughout the research process. Thanks also to the farmers in the Adumasa community who have been willing to share their experiences and very valuable information. Hopefully the results of this research can provide benefits to many parties and contribute to the development of a better agricultural sector.

REFERENCES

[1] P. Lomwongsopon and C. Varrone, "Contribution of fermentation technology to building blocks for renewable plastics," *Fermentation*, vol. 8, no. 2, 2022, doi: 10.3390/fermentation8020047.

[2] E. S. Dungca and G. M. Calaguas, "Jacks of all trades : The lived experiences of out-of-field non- government basic education teachers," *J. Basic Educ. Res.*, vol. 6, no. 1, 2025, doi: 10.37251/jber.v6i1.1394.

[3] P. Baker and S. Friel, "Food systems transformations, ultra-processed food markets and the nutrition transition in Asia," *Global. Health*, vol. 12, no. 1, 2016, doi: 10.1186/s12992-016-0223-3.

[4] J. Praful Bharadiya, "A Comparative Study of Business Intelligence and Artificial Intelligence with Big Data Analytics," *Am. J. Artif. Intell.*, vol. 7, no. 1, pp. 24–30, 2023, doi: 10.11648/j.ajai.20230701.14.

[5] C. C. Tsartas, A. R. Chen, C. C. Tsartas, A. R. Chen, and A. F. Devi, "Impact of customs and artifacts on tourism development in south of italy," *J. Hosp. Tour. Manag.*, vol. 6, no. 5, pp. 1–11, 2023, doi: 10.53819/81018102t5238.

[6] N. N. Simamora, K. A. Alrefay, A. A. Qasem, A. Lorenzo, and M. Kara, "The influence of teachers ' digital literacy and the use of technology media on students ' ability to identify hoaxes in the digital era," *J. Educ. Technol. Learn. Creat.*, vol. 2, no. 2, pp. 223–234, 2024, doi: 10.37251/jetlc.v2i2.1412.

[7] S. A. Siddiqui *et al.*, "Avoiding food neophobia and increasing consumer acceptance of new food trends—A decade of research," *Sustain.*, vol. 14, no. 16, 2022, doi: 10.3390/su141610391.
[8] M. Trauger *et al.*, "CO2 supplementation eliminates sugar-rich media requirement for plant propagation using a simple inexpensive temporary immersion photobioreactor," *Plant Cell. Tissue Organ Cult.*, vol. 150, no. 1, pp. 57–71, 2022, doi: 10.1007/s11240-021-02210-3.
[9] L. M. A. Sa, A. Sadat, A. Arya, and M. Wijaya, "Development of tourism villages based on local wisdom to improve the economy of local communities," *JSIP J. Stud. Ilmu Pemerintah.*, vol. 05, no. 2, pp. 13–24, 2024, doi: 10.35326/jsip.v5i2.6273.
[10] M. Irjayanti and L. Lord, "Operating a business with local wisdom: a grounded research of women in the creative industry," *Cogent Bus. Manag.*, vol. 11, no. 1, p., 2024, doi: 10.1080/23311975.2024.2392047.
[11] P. Samadi Parviznejad and M. Bahrami, "Uncertainty analysis of tourism components in Tabriz," *Int. J. Innov. Manag. Econ. Soc. Sci.*, vol. 1, no. 3, pp. 1–14, 2021, doi: 10.52547/ijimes.1.3.1.
[12] G. S. Khush, "Challenges for meeting the global food and nutrient needs in the new millennium," *Proc. Nutr. Soc.*, vol. 60, no. 1, pp. 15–26, 2001, doi: 10.1079/pns200075.
[13] S. Syaharuddin, H. Susanto, and M. A. H. Putra, "Portrait of community economic activities in the river as a learning resources on social studies with local culture-based," *Innov. Soc. Stud. J.*, vol. 1, no. 2, p. 178, 2020, doi: 10.20527/iis.v1i2.2095.
[14] A. Nigmatov, A. Rasulov, and O. Tobirov, "Methodology for accessing the tourist potential of the nature of the fergana valley using GIS technologies and experimental methods," *J. Pharm. Negat. Results*, vol. 13, no. 8, 2022, doi: 10.47750/pnr.2022.13.S08.281.
[15] M. N. Handayani, M. Ali, D. Wahyudin, and Mukhidin, "Green skills understanding of agricultural vocational school teachers around west java indonesia," *Indones. J. Sci. Technol.*, vol. 5, no. 1, pp. 21–30, 2020, doi: 10.17509/ijost.v5i1.22897.
[16] N. Khan *et al.*, "Potential role of technology innovation in transformation of sustainable food systems: A review," *Agric.*, vol. 11, no. 10, pp. 1–20, 2021, doi: 10.3390/agriculture11100984.
[17] M. I. A. Summantri and M. F. K. R. A. S. Syahrial, "Digital communication in agricultural extension in the era of the industrial revolution 4.0," *J. Eng. Manag. Inf. Technol.*, vol. 01, no. 04, pp. 177–190, 2023, doi: 10.61552/JEMIT.2023.04.003.
[18] L. Mulugo, F. B. Kyazze, P. Kibwika, E. Kikulwe, A. B. Omondi, and S. Ajambo, "Unravelling technology-acceptance factors influencing farmer use of banana tissue culture planting materials in Central Uganda," *African J. Sci. Technol. Innov. Dev.*, vol. 12, no. 4, pp. 453–465, 2020, doi: 10.1080/20421338.2019.1634900.
[19] S. K. Amit, M. M. Uddin, R. Rahman, S. M. R. Islam, and M. S. Khan, "A review on mechanisms and commercial aspects of food preservation and processing," *Agric. Food Secur.*, vol. 6, no. 1, pp. 1–22, 2017, doi: 10.1186/s40066-017-0130-8.
[20] A. Zziwa, J. Wanyama, D. Matsapwe, S. S. Kizito, T. Mibulo, and E. Baidhe, "Automation and control system implementation in a smallholder crop production in Uganda: A review," *Adv. Mod. Agric.*, vol. 5, no. 2, p. 2406, 2024, doi: 10.54517/ama.v5i2.2406.
[21] N. V. Antonova, Z. N. Shmeleva, and N. S. Kozulina, "Lifelong learning as the way of modern personality development in Russia on the example of higher educational institution of technical and natural-scientific profile," *J. Phys. Conf. Ser.*, vol. 1691, no. 1, 2020, doi: 10.1088/1742-6596/1691/1/012146.
[22] S. Ganeshan, S. H. Kim, and V. Vujanovic, "Scaling-up production of plant endophytes in bioreactors: concepts, challenges and perspectives," *Bioresour. Bioprocess.*, vol. 8, no. 1, 2021, doi: 10.1186/s40643-021-00417-y.
[23] Zainal Abidin, "PELUANG DAN TANTANGAN MEA: KERJASAMA PENDIDIKAN INDONESIA DI KAWASAN ASEAN Dr.," *J. Sains dan Seni ITS*, vol. 6, no. 1, pp. 51–66, 2017.
[24] R. B. Hongzhang Xu, "Multiple forms of knowing in Mathematics: A scoping literature study," *Sustain.*, vol. 11, no. 1, pp. 1–14, 2019, doi: 10.48550/arXiv.2406.16921.
[25] Suminah, "Penerapan bahasa santun terhadap pendidikan karakter anak usia dini di paud buah hati kabupaten aceh tengah," *J. Sains dan Seni ITS*, vol. 6, no. 1, pp. 51–66, 2017.
[26] D. Y. Kwon, K. R. Chung, C. H. Lee, S. H. Kim, J. W. Daily, and S. Park, "Scientific knowledge and wisdom of kimchi : a blessing Korean," *J. Ethn. Foods*, vol. 12, no. 8, pp. 1–11, 2025, doi: 10.1186/s42779-025-00269-3.
[27] S. A. Walton, "Technology and Culture in Greek and Roman Antiquity," *Ann. Sci.*, vol. 69, no. 2, pp. 295–297, 2012, doi: 10.1080/00033790902898359.
[28] K. Banoğlu, R. Vanderlinde, M. Çetin, and K. Aesaert, "Role of School Principals' Technology Leadership Practices in Building a Learning Organization Culture in Public K-12 Schools," *J. Sch. Leadersh.*, vol. 33, no. 1, pp. 66–91, 2023, doi: 10.1177/10526846221134010.
[29] G. Wang and D. Li, "The diversified communication methods of chinese and Korean cultural education based on new media technology," *Mob. Inf. Syst.*, vol. 2022, 2022, doi: 10.1155/2022/1351908.
[30] A. Karhio, "Human rights and posthuman poetics in contemporary Irish poetry: technology, media, ecology," *Law Humanit.*, vol. 16, no. 1, pp. 102–122, 2022, doi: 10.1080/17521483.2022.2075167.
[31] K. Arar, A. Saiti, and M. Guajardo, "Redesigning and recomputing the future of education: The role of technology, the learning process, personality traits, and diversity in learning systems," *Power Educ.*, vol. 15, no. 2, pp. 243–258, 2023, doi: 10.1177/17577438221117346.
[32] S. H. J. Putra, "Effect of Science, Environment, Technology, and Society (SETS) Learning Model on Students' Motivation and Learning Outcomes in Biology," *Tarbawi J. Ilmu Pendidik.*, vol. 17, no. 2, pp. 145–153, 2021, doi: 10.32939/tarbawi.v17i2.1063.
[33] W. James, G. Oates, and N. Schonfeldt, "Improving retention while enhancing student engagement and learning outcomes using gamified mobile technology," *Account. Educ.*, vol. 1, no. 1, pp. 1–21, 2024, doi:

10.1080/09639284.2024.2326009.
[34] S. S. Shah, "Teaching and learning with technology: effectiveness of ict integration in schools," *Indones. J. Educ. Res. Technol.*, vol. 2, no. 2, pp. 133–140, 2022, doi: 10.17509/ijert.v2i2.43554.
[35] D. Zhan and J. L. Depaynos, "Training inquiry-based learning ability of animation students under information technology conditions," *J. Educ. Educ. Res.*, vol. 5, no. 3, pp. 178–181, 2023, doi: 10.54097/jeer.v5i3.13693.
[36] W. Y. Hwang, K. Manabe, D. J. Cai, and Z. H. Ma, "Collaborative Kinesthetic English Learning With Recognition Technology," *J. Educ. Comput. Res.*, vol. 58, no. 5, pp. 946–977, 2020, doi: 10.1177/0735633119893117.
[37] Y. Helida, C. P. Ching, and A. Oyewo, "Development of a simple stirling engine demonstration tool on the subject of thermodynamics," *J. Educ. Technol. Learn. Creat.*, vol. 1, no. 2, pp. 59–67, 2023, doi: 10.37251/jetlc.v1i2.790.
[38] L. E. Tomaszewski, J. Zarestky, and E. Gonzalez, "Planning Qualitative Research: Design and Decision Making for New Researchers," *Int. J. Qual. Methods*, vol. 19, pp. 1–7, 2020, doi: 10.1177/1609406920967174.
[39] H. Taherdoost, "What are different research approaches? comprehensive review of qualitative, quantitative, and mixed method research, their applications, types, and limitations," *J. Manag. Sci. Eng. Res.*, vol. 5, no. 1, pp. 53–63, 2022, doi: 10.30564/jmser.v5i1.4538.
[40] T. Muzari, G. N. Shava, and S. Shonhiwa, "Qualitative research paradigm, a key research design for educational researchers, processes and procedures : a theoretical overview," *Indiana J. Humanit. Soc. Sci.*, vol. 3, no. 1, pp. 14–20, 2022, [Online]. Available: https://indianapublications.com/articles/IJHSS_3(1)_14-20_61f38990115064.95135470.pdf
[41] M. Zairul, "Can member check be verified in real time? Introducing arc (asking, record, confirm) for member checking validation strategy in qualitative research," *Eng. J.*, vol. 25, no. 1, pp. 245–251, 2021, doi: 10.4186/ej.2021.25.1.245.
[42] P. C. Susanto, L. Yuntina, E. Saribanon, and J. P. Soehaditama, "Qualitative method concepts : literature review , focus group discussion , ethnography and grounded theory," *Siber J. Adv. Multidiscip.*, vol. 2, no. 2, pp. 262–275, 2024, doi: /10.38035/sjam.v2i2.
[43] S. A. Dzogovic and V. Bajrami, "Qualitative Research Methods in Science and Higher Education," *Hum. Res. Rehabil.*, vol. 13, no. 1, pp. 156–166, 2023, doi: 10.21554/hrr.042318.
[44] A. Priya, "Case study methodology of qualitative research: Key attributes and navigating the conundrums in its application," *Sociol. Bull.*, vol. 70, no. 1, pp. 94–110, 2021, doi: 10.1177/0038022920970318.
[45] B. K. Shano and S. S. Waje, "Understanding the heterogeneous effect of microcredit access on agricultural technology adoption by rural farmers in Ethiopia: A meta-analysis," *Heliyon*, vol. 10, no. 16, p. e35859, 2024, doi: 10.1016/j.heliyon.2024.e35859.
[46] M. J. Alam *et al.*, "Agricultural extension service, technology adoption, and production risk nexus: Evidence from Bangladesh," *Heliyon*, vol. 10, no. 14, p. e34226, 2024, doi: 10.1016/j.heliyon.2024.e34226.
[47] T. Dibbern, L. A. S. Romani, and S. M. F. S. Massruhá, "Main drivers and barriers to the adoption of Digital Agriculture technologies," *Smart Agric. Technol.*, vol. 8, no. December 2023, 2024, doi: 10.1016/j.atech.2024.100459.
[48] C. Yang, X. Ji, C. Cheng, S. Liao, B. Obuobi, and Y. Zhang, "Digital economy empowers sustainable agriculture: Implications for farmers' adoption of ecological agricultural technologies," *Ecol. Indic.*, vol. 159, no. February, p. 111723, 2024, doi: 10.1016/j.ecolind.2024.111723.
[49] A. Schnack, F. Bartsch, V. S. Osburg, and A. Errmann, "Sustainable agricultural technologies of the future: Determination of adoption readiness for different consumer groups," *Technol. Forecast. Soc. Change*, vol. 208, no. July 2023, p. 123697, 2024, doi: 10.1016/j.techfore.2024.123697.
[50] A. Amankwah and T. Gwatidzo, "Food security and poverty reduction effects of agricultural technologies adoption − a multinomial endogenous switching regression application in rural Zimbabwe," *Food Policy*, vol. 125, p. 102629, 2024, doi: 10.1016/j.foodpol.2024.102629.
[51] R. Rakholia, J. Tailor, M. Prajapati, M. Shah, and J. R. Saini, "Emerging technology adoption for sustainable agriculture in India– a pilot study," *J. Agric. Food Res.*, vol. 17, no. May, p. 101238, 2024, doi: 10.1016/j.jafr.2024.101238.
[52] J. Manda *et al.*, "Assessing the speed of improved postharvest technology adoption in Tanzania: The role of social learning and agricultural extension services," *Technol. Forecast. Soc. Change*, vol. 202, no. January 2023, p. 123306, 2024, doi: 10.1016/j.techfore.2024.123306.
[53] H. Puppala, P. R. T. Peddinti, J. P. Tamvada, J. Ahuja, and B. Kim, "Barriers to the adoption of new technologies in rural areas: The case of unmanned aerial vehicles for precision agriculture in India," *Technol. Soc.*, vol. 74, no. July, p. 102335, 2023, doi: 10.1016/j.techsoc.2023.102335.
[54] H. MAO, Y. rong QUAN, and Y. FU, "Risk preferences and the low-carbon agricultural technology adoption: Evidence from rice production in China," *J. Integr. Agric.*, vol. 22, no. 8, pp. 2577–2590, 2023, doi: 10.1016/j.jia.2023.07.002.
[55] H. T. Mulugeta and A. Heshmati, "Impacts of improved agricultural technology adoption on welfare in Africa: A meta-analysis," *Heliyon*, vol. 9, no. 7, p. e17463, 2023, doi: 10.1016/j.heliyon.2023.e17463.
[56] M. Wang and F. kun Wang, "Remote Sensing Image Mosaic Technology Based on Improved SIFT Algorithm," *Lect. Notes Electr. Eng.*, vol. 872 LNEE, pp. 358–365, 2023, doi: 10.1007/978-981-99-2653-4_44.
[57] Y. Du, H. Xu, and Y. Chen, "Digital empowerment and innovation in risk control strategies for fishery supply chain finance—a case study of Puhui agriculture and animal husbandry financing guarantee company limited," *Mar. Dev.*, vol. 2, no. 1, pp. 1–20, 2024, doi: 10.1007/s44312-023-00013-y.
[58] S. Troiano, M. Carzedda, and F. Marangon, "Better richer than environmentally friendly? Describing preferences toward and factors affecting precision agriculture adoption in Italy," *Agric. Food Econ.*, vol. 11, no. 1, 2023, doi: 10.1186/s40100-023-00247-w.

[59] A. Nyéki, A. J. Kovács, M. Neményi, and G. Milics, "Conference report from 13th European Conference on Precision Agriculture (ECPA)," *Environ. Sci. Eur.*, vol. 33, no. 1, pp. 21–23, 2021, doi: 10.1186/s12302-021-00559-y.

[60] J. Sorvali, V. Varho, P. Rikkonen, J. Kaseva, and P. Peltonen-Sainio, "Farmers' futures: an application of the Delphi method in the context of Finnish agriculture," *Eur. J. Futur. Res.*, vol. 12, no. 1, 2024, doi: 10.1186/s40309-023-00224-y.