Developing Country Studies
ISSN 2224-607X (Paper) ISSN 2225-0565 (Online)
Vol.13, No.2, 2023

Influencing Factors on Adoption of Modern Agricultural Technology in Developing Economy Countries

Hamza Ahmed[1], Mousab Ahmed[2]
1. Colorado State University, Department of Systems Engineering, 6029 Campus Delivery, Fort Collins, CO 80523-130
2. Department of Mechanical engineering, Howard University, 2041 Georgia Avenue NW Washington, DC 20060
* E-mail the corresponding author: hamza.ahmed@colostate.edu

Abstract:
The adoption of advanced agricultural technologies is crucial in reducing poverty and improving food security on the developing economy countries. Despite the recognition of its importance, smallholder farmers in developing nations often face obstacles in adopting new technologies, leading to slow uptake. To better understand the factors that impact the use of agricultural technology in these nations, this study seeks to provide insights through a review of previous research on technology adoption. The results of the study highlight several key elements that determine whether or not agricultural technology is adopted, including factors related to the technology itself, the economic situation of farmers, the institutional and organizational affiliations of the farmers, and unique household factors. In order to fully comprehend the complexities involved in the adoption of agricultural technology, future research is recommended to include the perspectives and experiences of farmers. By considering their perceptions of new technologies, the range of factors influencing. The purpose of this paper is to gain a deeper understanding of the challenges faced by smallholder farmers in adopting new technologies and to identify opportunities for improvement. By considering their perceptions of new technologies, the range of factors influencing technology adoption can be broadened, providing a more comprehensive understanding of the subject.
Keywords: Agricultural Technology, smallholder farmers, Adoption, developing economy countries, economic situations, household situations.
DOI: 10.7176/DCS/13-2-01
Publication date: February 28th 2023

1. Introduction:

Agriculture is a crucial factor in securing food supplies, reducing poverty levels, and driving rural development. The majority of the world's 3.0 billion poor depend on it as their main source of income ((FAO), 2003). As part of the 2030 Agenda for Sustainable Development, the goal is to reduce the number of people living in extreme poverty and hunger by half by the year 2030, and smallholder farmers are recognized as a key instrument in reaching this objective (Bank, 2008A). Despite this recognition, many smallholder farmers continue to rely on traditional farming methods, which often lead to decreased output. For instance, smallholder farmers produce more than 70% of the corn in most developing countries using conventional techniques (Muzari et al., 2012). These farmers often experience low crop yields due to a variety of factors, such as the use of low-yielding indigenous crops, reliance on rain-fed agriculture, limited use of irrigation and fertilizers, and insufficient pest control measures ((Muzari et al., 2012). The need to improve agriculture sustainability and productivity on a global scale is widely acknowledged, but the precise methods of doing so are not well understood. Therefore, further research is needed to identify the most effective ways to support smallholder farmers in adopting new and innovative techniques to increase their yields and improve their livelihoods.

The rise in demand for food necessitates an increase in agricultural production, making it important to examine the latest advancements in agricultural technology. This includes a range of techniques and procedures aimed at boosting agricultural output (Ahmed et al., 2023; Jain et al., 2009). According to (Lavison, 2013), advancements have been made in areas such as the development and promotion of new crop varieties and farming practices, soil and soil fertility management, pest and weed control, efficient irrigation and water management, and more. The implementation of new technology often leads to increased output and reduced average production costs due to improved input-output relationships, resulting in a substantial increase in farm revenue (Challa & Tilahun, 2014). The adoption of advanced technology drives an upward trend in production and contributes to ongoing socioeconomic progress.

Adopting advanced agricultural technologies has been shown to have numerous positive impacts on both individual and collective levels. Not only does it result in improved nutrition and lower costs of staple foods, but it also leads to better job opportunities and higher wages for those without access to land (Ssewanyana & Kasirye, 2010). This widespread adoption of technology has been instrumental in the success of the green revolution that many Asian countries have experienced ((Chen & Ravallion, 2004; Ssewanyana & Kasirye,

2010). On the other hand, the failure to adopt these technologies has led to a cycle of socioeconomic stagnation, which in turn contributes to poverty (Jain et al., 2009). To ensure long-term food security and economic growth, innovative agricultural technologies that improve sustainable food and fiber production are crucial. This has sparked extensive research into the dynamics of technical change in agriculture, particularly in the early 20th century ((Lavison, 2013), Smallholder farmers in developing nations are particularly in need of these advanced technologies, as they face numerous challenges in their operations. Development programs are often geared towards these farmers, who operate in regions with low rainfall, poor soil quality, and limited access to irrigation, input and product markets, financing, and extension services (Muzari et al., 2012). This lack of resources and support exacerbates the obstacles they face, making the adoption of advanced agricultural technologies essential for their success.

Over the years, the study of innovation and the uptake of new technologies has been a central focus for researchers, particularly in the context of developing economy countries. A significant body of research has been conducted to understand the adoption process and the impact of modern farming techniques on smallholder farmers. Despite the recognition of their importance in ending poverty in many developing nations (Rasul, 2002; Simtowe et al., 2011), the adoption of new agricultural methods has often been slow, and many of the challenges associated with adoption are still not fully understood. The purpose of this paper is to delve into the wealth of research that exists on the adoption of new technology, exploring both the reasons behind the slow uptake and the factors that contribute to the low adoption of modern farming techniques. Through this examination, the goal is to gain a deeper understanding of the challenges faced by smallholder farmers in adopting new technologies and to identify opportunities for improvement. By providing a comprehensive evaluation of existing research on the topic, the paper aims to contribute to the ongoing discourse on how best to support smallholder farmers in adopting new technologies and improving their livelihoods.

2. Previous studies and research:

The definition of technology has been the subject of much debate among writers and experts in the field. (Loevinsohn et al., 2013) define technology as the tools and processes involved in producing goods and services, including both physical and organizational methods. They also highlight that what may be considered new technology in one location or among one group of farmers may already be widespread in other regions or groups. Technology is also described as the knowledge and information that enables individuals to perform certain jobs, provide services, or create products (Loevinsohn et al., 2013). Its ultimate aim is to improve existing conditions or transform current circumstances into a more desirable state. As stated by (Bonabana-Wabbi, 2002), technology results in increased efficiency and productivity, allowing individuals to complete tasks more quickly and easily than they would be able to without it. The concept of adoption has also been defined in various ways by different scholars. (Loevinsohn et al., 2013) describe adoption as the process of integrating new technology into daily life, followed by a period of experimentation and adaptation. (Feder et al., 1985) define adoption as the mental journey that individuals undergo as they learn about an innovation and eventually incorporate it into their lives. Adoption intensity and adoption rate are two key aspects of adoption. Adoption intensity, as described by (Bonabana-Wabbi, 2002), measures the extent to which a particular technology is used over a given period, while adoption rate, as noted by Feder et al. (1985), refers to the speed at which individuals accept innovations. The concept of time is considered to be a cornerstone of the latter, playing a key role in determining adoption intensity.

Defining technology adoption is a complex task, as it relies on the technology being accepted and adopted by individuals. There are different interpretations of technology adoption, and its definition varies among studies. A study by (Doss, 2003) revealed that farmers were considered adopters in a CIMMYT survey if they were using seeds passed down from previous generations, while in other studies adoption is associated with following the extension service's advice to use new and certified seeds (Bisanda et al., 1998; Doss, 2003; Ouma et al., 2002).

The definition of technology adoption is crucial in determining whether farmers use agricultural technology and is often represented by binary response variables, indicating whether a farmer has adopted new technology or not, using values of 0 and 1. However, as C. Doss (2003) suggests, the definition of technology adoption varies depending on the context and each strategy's suitability is dependent on that specific context.

Jain et al. (2009) suggests that relying on a straightforward dichotomous variable approach in studying farmers' decisions to adopt new technologies is not sufficient. This is because a dichotomous reaction only indicates the level of awareness of new technology, not its actual adoption. Thus, researchers should explicitly specify how they are defining technology adoption so they can create the best method to measure it.

3. Adoption of agricultural technology factors:

The adoption of agricultural technology is a complex topic that has garnered a great deal of attention from researchers, economists, and experts in the field. According to (Loevinsohn et al., 2013), the decision to adopt new technology is the result of a dynamic interaction between the technology itself and the conditions and

circumstances surrounding its adoption. Farmers consider the unknown benefits and costs of a new technology before making a decision to adopt it. Understanding the factors that influence the adoption of agricultural technology is critical for economists who study growth drivers and for those who create and distribute technology. (Ahmed, 2022) has summarized the factors Influencing the adoption of agricultural technologies in Table 1.

Table 1. Factors Influencing the Adoption of Agricultural Technologies (Ahmed, 2022)

Categories	Factors	
Socio-Economic	Operator age Years of farming experience Formal education	
Agro-Ecological	Land tenure Farm specialization Farm size Farm sales Variable fertilizer rates Livestock sales Debt-to-asset ratio Production value Owned land minus rented land Yield	Part-owner farmers Full-owner farmers Farm income/profitability Soil quality Percentage of the main crop in total farmland Percentage of farmland as county land area Percentage of cropped land to total farmland Percentage of farmland as large farms Off-farm employment
Institutional	Distance from a fertilizer dealer Region	Use of forwarding contract Development pressure
Informational	Use consultant Perceived usefulness of extension services in implementing precision farming practices	
Farmer Perception	Perceived profitability of using precision agriculture	
Behavioral	Willingness to adopt variable-rate technology	
Technological	Yield mapping Use of computer Farm has an irrigation facility Generated own map-based input prescription	

Despite the potential benefits of agricultural machinery, traditional farmers can face a number of barriers to its adoption. For example, traditional farmers may be unable to access credit or loans to purchase new machinery, or they may lack the skills and knowledge required to operate and maintain the equipment (Hertel & Rosch, 2010). Additionally, traditional farmers may be resistant to change, and may not see the value in investing in new machinery, especially if they have been practicing traditional farming methods for generations (Dos Santos et al., 2021).

However, recent research suggests that traditional farmers can be motivated to adopt agricultural machinery if the benefits are clearly demonstrated and if they receive the necessary support and training. For example, a study conducted by the International Fund for Agricultural Development (IFAD) in Ethiopia found that traditional farmers who received training in the use of new machinery were more likely to adopt these technologies, and that this led to significant increases in their productivity and income (Takahashi et al., 2020).

Another study, conducted by the Inter-American Development Bank (IDB) in Honduras, found that the provision of affordable credit and technical assistance to traditional farmers was crucial in encouraging the adoption of agricultural machinery, especially among small-scale farmers (Van Loon et al., 2020). This highlights the importance of creating supportive environments for the adoption of agricultural machinery by traditional farmers, and the role that governments and other organizations can play in promoting and facilitating this transition.

Studies have historically focused on understanding adoption by analyzing individual traits and endowments, incomplete knowledge, risk and uncertainty, institutional restrictions, input accessibility, and infrastructure (Mwangi & Kariuki, 2015; Ruttan, 2010; Uaiene, 2009). Recent research has also looked at the role of social networks and education in technology adoption (Uaiene, 2009). Different studies categorize the factors that influence technology adoption in various ways. For example, (Akudugu et al., 2012) separated these factors into institutional, social, and economic categories, while (Kebede et al., 1990), classified them into economic, physiological, and social elements. (McNamara et al., 1991) divided the factors into farmer, farm structure, organizational, and leadership structure features, while (Wu & Babcock, 1998) categorized them as human capital and productivity.

The categorization of determinants of technology acceptance can vary depending on the location, researcher preferences, and even the needs of the client (Bonabana-Wabbi, 2002). For instance, the level of education may be classified as human capital by some scholars and as a family-specific characteristic by others. In the present study, we will examine the technological, economic, organizational, and household-specific factors that influence the adoption of agricultural technology. By examining each factor in greater detail, we can gain a deeper understanding of its impact on technology adoption.

4. Factors related to farmer perception on the adoption:

Farming machinery plays a crucial role in improving agricultural productivity and supporting economic growth in developing economies. However, the adoption of modern farming machinery in these economies is often slow, partly due to farmer perception towards this technology. The perception of farmers towards farming machinery has a significant impact on their adoption decisions (Singh & Singh, 2020). Farmers who view farming machinery as a positive tool are more likely to adopt the technology than those who see it as a threat to their livelihoods (Koubi, 2019). Positive perceptions of farming machinery are influenced by a range of factors, including the perceived benefits of the technology, such as improved productivity, reduced labor costs, and better-quality crops (Ahmed & Miller, 2022; Rejeb et al., 2021). Farmers who view farming machinery as a valuable investment are also more likely to adopt the technology (Ahmed, 2022; Al Hosani et al., 2022). On the other hand, negative perceptions of farming machinery, such as the high cost of investment, the perceived complexity of operating the machinery, and the threat to traditional farming practices, can lead to slow adoption or resistance to the technology (Ahmed, 2022). The farmers perception is also a factor of the financial barriers as it's a major factor hindering the adoption of farming machinery (Sattler & Nagel, 2010). The high cost of investment is one of the biggest challenges faced by farmers in these economies (Bapela et al., 2022). In many cases, farmers lack the financial resources to purchase modern farming machinery, and often have limited access to credit (Ahmed & Miller, 2022). This makes it difficult for them to invest in the technology and upgrade their farming practices. In addition, the lack of government support and subsidies in some developing economies also contributes to the slow adoption of farming machinery (Arshad et al., 2022).

In addition to financial barriers, infrastructure and technical challenges can also hinder the adoption of farming machinery in developing economies (Aker, 2011). The lack of infrastructure, such as poor roads and limited access to electricity, makes it difficult for farmers to transport and use modern farming machinery (Ahmed & Miller, 2022) In addition, the lack of technical knowledge and skills among farmers can also be a barrier to the adoption of farming machinery (Pivoto et al., 2019). This is particularly true in rural areas, where access to education and training is limited (Aker, 2011).

To promote the adoption of farming machinery in developing economies, it is important to address the barriers to adoption, including the high cost of investment, lack of infrastructure, and limited access to credit (Diao et al., 2016). Governments in these economies can play a key role in promoting the adoption of farming machinery by providing subsidies, financing, and technical support to farmers (Al Hosani et al., 2022). In addition, private sector companies can also play a role in promoting the adoption of farming machinery by providing affordable financing options and technical support to farmers (Diao et al., 2016). The role of farmer training and education is also crucial in promoting the adoption of farming machinery in developing economies. By providing farmers with the necessary technical knowledge and skills, they will be better equipped to operate and maintain modern farming machinery (Malabo, 2018). In addition, training programs can also help to address negative perceptions of farming machinery and promote its benefits to farmers (Cortner et al., 2019).

5. Factors related to technology:

Adoption of technology is a complex process that is influenced by various factors. One of the key determinants of technology adoption is trialability, which refers to the willingness of potential users to engage in a limited test of the technology before making a full commitment. Studies have shown that the attributes of the technology play a significant role in shaping the decision-making process for adoption. For example, (Doss, 2003; D. B. Mignouna et al., 2011) found that when analyzing the adoption of Imazapyr-Resistant Maize (IRM) technology in Western Kenya, farmers' perceptions of the technology's compatibility and efficacy were major drivers of their adoption decision. (Adesina & Zinnah, 1993), also found that farmers' perceptions of the contemporary rice variety and fish aquaculture technology, respectively, greatly impacted their adoption decisions.

Given the significant role that farmers' perceptions play in the adoption of technology, it is crucial that they be involved in the evaluation of any new technology to assess its suitability for their specific needs and environment. According to (Sinja et al., 2004), involving farmers in the review process before giving them access to a new technology helps to ensure its successful adoption. In summary, trialability and farmers' perceptions of technology attributes are two critical factors that must be considered when looking to adopt new technology.

6. Factors related to the armers Agro-Ecological situations:

There are several factors related to the farmers' agro-ecological situations that can influence the adoption of farming machinery. These factors include:

6.1 Farm size:

The adoption of agricultural machinery has been a major factor in increasing agricultural productivity and efficiency. The development of new technologies and the use of machines have helped farmers to increase their crop yields and reduce the time and labor required for various agricultural tasks (Talaviya et al., 2020). One of the factors that influence the adoption of agricultural machinery is the size of the farm.

Large-scale farms are more likely to adopt agricultural machinery due to the economies of scale associated with larger operations (Duffy, 2009). Smaller farms, on the other hand, are more likely to continue using traditional farming practices due to the higher cost of investment in agricultural machinery and the lack of access to credit and information (Muzari et al., 2012). The adoption of agricultural machinery by traditional farmers has been limited due to a number of factors, including the high cost of equipment, lack of access to credit (Ullah et al., 2016), and lack of knowledge about the benefits of the technology (Riasati et al., 2012).

Despite these challenges, there has been a growing trend towards the adoption of agricultural machinery by traditional farmers in recent years. This is due in part to the increasing availability of credit (Mohan, 2006), improved access to information (Ahmed & Miller, 2022), and the development of new technologies that are more affordable and accessible to small-scale farmers (Ahmed, 2022).

In addition, the introduction of programs and policies aimed at supporting the adoption of agricultural machinery by traditional farmers has helped to increase the rate of adoption (Knowler & Bradshaw, 2007). The adoption of agricultural machinery by traditional farmers is influenced by a variety of factors, including farm size, access to credit, availability of information, and government policies. While large-scale farms are more likely to adopt agricultural machinery, smaller farms face challenges in accessing the technology. Despite these challenges, the adoption of agricultural machinery by traditional farmers is increasing due to the introduction of government policies, the availability of credit, and improved access to information.

6.2 Livestock sales:

Livestock sales have been identified as one of the key drivers of agricultural mechanization in many parts of the world. This is because farmers who sell livestock can use the proceeds from these sales to invest in new machinery and equipment, which can help to increase productivity and efficiency. For example, a study conducted by the International Food Policy Research Institute (IFPRI) in Kenya found that farmers who sold livestock were more likely to adopt new agricultural technologies(Adato & Meinzen-Dick, 2002), such as tractors and plows, compared to farmers who did not sell livestock (Adato & Meinzen-Dick, 2002). Another study, conducted by the World Bank in India, found that livestock sales were positively associated with the adoption of agricultural machinery, particularly in regions where livestock farming was an important source of income (Viswanathan et al., 2020). This research highlights the importance of livestock sales as a source of income and capital for farmers, and the role they play in promoting the adoption of agricultural machinery. However, while livestock sales can provide farmers with the capital they need to invest in new machinery, they can also have negative consequences for traditional farming communities. For example, a study conducted by the Food and Agriculture Organization (Hertel & Rosch, 2010) in Bangladesh found that the sale of livestock by traditional farmers was often driven by poverty and desperation, and that this led to a decline in the number of farmers and the quality of the land ((Chambers, 1987). This highlights the need for more comprehensive approaches to agricultural development that take into account the needs of traditional farmers, and that support their transition to more sustainable and profitable farming practices.

6.3 Percentage of cropped land to total farmland:

One of these factors is the percentage of cropped land to total farmland. The percentage of cropped land to total farmland is one of the key factors affecting the adoption of agricultural machinery by traditional farmers (Sattler & Nagel, 2010). A higher percentage of cropped land to total farmland indicates that a larger portion of the farm is being used for crops, and therefore there is a greater need for more efficient and productive farming practices (Pretty et al., 2003). This can increase the adoption of agricultural machinery as traditional farmers seek ways to improve their yields and increase their income (Bradshaw et al., 2004). In areas where there is a high percentage of cropped land to total farmland, farmers are more likely to adopt agricultural machinery, as they are able to realize the benefits of these technologies more quickly and easily. This is because they have a larger area of land that is being used for agriculture, and therefore a greater need for efficiency and productivity. In contrast, in areas where there is a low percentage of cropped land to total farmland, farmers are less likely to adopt agricultural machinery (Derpsch et al., 2010). This is because they have a smaller area of land that is being used for agriculture, and therefore a smaller need for efficiency and productivity. This means that they are less likely

to see the benefits of agricultural machinery and may be less motivated to adopt these technologies (Rotz et al., 2019). However, while the percentage of cropped land to total farmland is a significant factor in determining whether or not traditional farmers will adopt agricultural machinery, it is not the only factor. There are several other factors that can influence a farmer's decision to adopt or not adopt agricultural machinery (Ahmed, 2022).

6.4 Soil quality

One of the key factors affecting the adoption of agricultural machinery by traditional farmers is the soil quality of their farmland. Soil quality is a complex issue, and it is influenced by various factors such as soil structure, soil fertility, soil moisture, and soil pH. Good soil quality is characterized by physical, chemical, and biological attributes that promote plant growth and fertility. In traditional agriculture, soil quality is maintained through traditional practices such as crop rotation, intercropping, and the use of organic fertilizers. However, in some cases, these practices may not be enough to maintain soil quality, and the adoption of agricultural machinery may be necessary (Watson et al., 2002). Traditional farmers who have high-quality soil are more likely to adopt agricultural machinery as they seek to improve their yields and increase their income (Muzari et al., 2012).

7. Factors related to farmers economic situations:

In agriculture, the size of a farm plays a critical role in the adoption of new technology. Several studies have shown that farm size is a significant factor in determining the speed of technology adoption (Bonabana-Wabbi, 2002; Lavison, 2013). The relationship between farm size and the adoption of agricultural technology is well documented (Ahmed & Bagchi, 2004; Gabre-Madhin & Haggblade, 2004; Kasenge, 1998; D. Mignouna et al., 2011; Uaiene, 2009). Generally, larger farms are more likely to adopt new technologies as they have the resources to set aside a portion of their land for research purposes (Uaiene, 2009). For some technologies, such as heavy machinery or animal traction, economies of scale are required for success (Feder et al., 1985).

However, not all studies are in agreement on the relationship between farm size and technology adoption. Some studies have found that small farms may have difficulty adopting modern agricultural technology due to factors such as high input requirements (Harper et al., 1990; Yaron et al., 1992). On the other hand, small-scale farmers with limited land could potentially adopt land-saving techniques such as zero grazing or greenhouse technology to increase agricultural productivity (Harper et al., 1990; Yaron et al., 1992).

Several studies have explored the relationship between adoption and farm size, with findings indicating that adoption has either no effect or a neutral effect. For instance, a series of investigations by researchers such as (Bonabana-Wabbi, 2002; Grieshop et al., 1988; Ridgley & Brush, 1992; Waller et al., 1998), found that the size of the farm had no impact on the adoption of integrated pest prevention (IPP) methods. Additionally, research by Simtowe et al. (2011) found that the vast land ownership had no significant effect on the likelihood of adopting ICM-FFS practices.

However, these studies consider the overall size of the farm and not just the cropland on which the new technology is used. (Lowenberg-DeBoer, 2000) suggests that the total farm size may affect overall adoption, so it might be more informative to look at the crop acreage using the current technology as an indicator of the rate and degree of technology adoption. In this regard, (Bonabana-Wabbi, 2002) argues that estimating the proportion of all land area that the new technology can use can provide a better understanding of the effect of technology adoption on farm size. (Foster & Rosenzweig, 2010) highlight that the farmer's net profit, which takes into account all expenditures related to the adoption of new technology, is a critical factor in determining technology acceptance.

The adoption of technology in agriculture is hindered by several factors, including the high cost of implementation. Research by Muzari et al. (2012) has revealed that the loss of incentives on seed and fertilizer prices due to institutional reforms in sub-Saharan Africa supported by the World Bank has added to this limitation. The high cost of technology has been widely recognized as a barrier to adoption, as evidenced by previous studies on the factors that influence it. For example, (Makokha et al., 2001) conducted research on the variables that influence the use of fertilization and manure in the cultivation of maize in Kiambu County, Kenya, and found that the primary obstacles to adoption were the high cost of labor and other inputs, the scarcity of packages, and the delay in deliveries. Similar findings were reported by (Ouma et al., 2002) in the Kenyan county of Embu, where the high cost of hired labor was identified as a deterrent to the use of fertilizer and hybrid seeds. When studying the variables that led to the adoption of a better maize variety in Kenya's coastal lowlands, (Wekesa et al., 2003) found that the high cost of seed and scarcity were significant contributors to the low adoption rate. These findings underscore the importance of addressing the financial barriers to technology adoption in agriculture to ensure widespread and sustainable implementation.

The impact of off-farm income on technology adoption has been well documented. This is because in many developing countries, off-farm income is seen as a crucial strategy for rural people to overcome their credit limitations (Reardon et al., 2007). In local economies with ineffective or absent credit markets, off-farm income is frequently used to replace borrowed capital (Diiro, 2013). The availability of liquid funds generated by off-

farm earnings is expected to provide farmers with the resources to invest in inputs that increase production, such as better seeds and fertilizers (Diiro, 2013). For instance, Diiro (2013) found that households with off-farm earnings spent significantly more on purchased inputs compared to those without off-farm earnings, when examining the effect of off-farm income on the adoption of improved maize varieties and productivity of maize production in Uganda.

However, not all technologies have shown a positive relationship between off-farm income and their adoption. Research on labor-intensive technologies has found little correlation between adoption and off-farm income. According to (Goodwin & Mishra, 2004), farmers who are pursuing off-farm income may be discouraged from adopting new technologies due to the reduction in household work allocated to farming operations. These findings suggest that while off-farm income can have a positive impact on technology adoption in some cases, its impact on adoption may vary based on the type of technology and the household's labor allocation patterns.

8. Factors related to farmers formal education:

Studies have shown that formal education can have a significant impact on the adoption of agricultural machinery by traditional farmers (Adesope et al., 2012). In one study conducted in Philippines, it was found that farmers who received formal training on the use of agricultural machinery were more likely to adopt these technologies and make effective use of them in their work ((Mariano et al., 2012). Similarly, another study in Nigeria found that farmers who received formal training on the use of machinery and equipment were more likely to adopt these technologies and experience increased productivity as a result (Abdoulaye et al., 2014).

The adoption of agricultural machinery by traditional farmers has been slow and limited, and many factors have been cited as contributing to this phenomenon, including the lack of education and training on how to use these machines effectively (Abdoulaye et al., 2014). In this article, we will examine the effect of formal education on traditional farmers' adoption of agricultural machinery and explore how this education can help farmers overcome the challenges associated with implementing new technologies in their work.

Traditional farmers often face significant challenges when it comes to adopting new technologies, including agricultural machinery. These challenges can be linked to a lack of knowledge, skills, and understanding of the technology, as well as the costs and difficulties of obtaining the machines themselves (Endsley & Garland, 2000). The need for education and training on the use of these machines is critical, as it helps to mitigate these challenges and promote the successful adoption of these technologies by traditional farmers (Endsley & Garland, 2000).

Formal education is an effective tool for teaching farmers the skills they need to operate and maintain agricultural machinery effectively (Binns et al., 2012). This education can take many forms, including classroom-based instruction, online training courses, and hands-on training programs (Platz et al., 2010). Regardless of the delivery method, formal education provides farmers with the knowledge and skills they need to use these machines in a safe, efficient, and effective manner (Swanson, 2008).

In addition to providing farmers with the necessary skills and knowledge, formal education also has the potential to increase their confidence and motivation to adopt new technologies (Swanson, 2008). By learning about the benefits and potential applications of agricultural machinery, farmers may become more willing to invest in these technologies and implement them in their work (McCown, 2002). This increased confidence and motivation can also help to overcome the barriers that may be preventing farmers from adopting these technologies, such as the costs involved, the difficulties of obtaining financing, and the lack of local support or resources (Dowd et al., 2008).

These findings suggest that formal education can play an important role in promoting the adoption of agricultural machinery by traditional farmers (Caffaro et al., 2020). By providing farmers with the skills and knowledge they need to use these machines effectively, formal education can help to overcome the barriers that may be preventing the adoption of these technologies and promote their widespread implementation (Mariano et al., 2012).

9. Factors related to farmers organizational affiliation:

The concept of being part of a social group has been proven to enhance social capacity and foster the exchange of information, trust, and ideas (D. Mignouna et al., 2011). In the agricultural sector, farmers have the opportunity to share their knowledge and experiences with the use of new technologies within their specific social group. According to (Uaiene, 2009), social network effects play a significant role in shaping the decisions made by individuals and this can be especially true for farmers who can benefit from the experiences and knowledge of their peers. (Katung & Akankwasa, 2008)found that when they studied the impact of community-based organizations on the adoption of innovative banana technology in Uganda, farmers who were more involved in these groups were more likely to learn about the technology through social networks, which increased their chances of adopting it.

While the benefits of social groups on technology adoption have been widely recognized, particularly in cases where free-riding behavior is present, these groups can also have a negative impact on technology adoption. (Foster & Rosenzweig, 1995) discovered this when they studied the usage of Green Movement technology in India and found that although social learning externalities can increase the profitability of technology adoption, farmers may also benefit from the expensive technological experimentation of their neighbors. (Bandiera et al., 2005) suggests that the conflicting effects of learning externalities lead to an inverted U-shaped individual adoption curve, where network effects are advantageous at low adoption rates but become detrimental as adoption rates increase. This is consistent with the findings of (Hogset, 2005) who cites (Bandiera et al., 2005) in suggesting that social groups can have a significant impact on technology adoption.

The acquisition of knowledge about technology is a critical factor in its adoption. Knowledge enables farmers to understand the technology and how to use it effectively, thereby facilitating its adoption. Only those technologies that farmers are familiar with or have heard about will be adopted. Having access to accurate information reduces uncertainty about the technology's effectiveness and can help farmers shift from a subjective to an objective evaluation. However, access to information does not guarantee adoption, as farmers may interpret and evaluate technology differently from scientists (Uaiene, 2009). In some cases, access to information may actually decrease the adoption of technology. For instance, when the public has limited experience with a new technology, increased knowledge can make people less likely to adopt it due to the increased risk associated with a wider information gap (Bonabana-Wabbi, 2002). Hence, it is crucial to ensure that the information available is reliable, consistent, and accurate. Farmers need to be informed about the existence, benefits, and applications of technology to use it effectively.

The provision of extension services is a critical aspect in the adoption of technology within the agricultural sector. Through the interaction with extension agents, farmers are able to access information about new technologies, their applications, and the benefits they offer. This connection between farmers and technology developers (researchers) decreases the transaction costs associated with providing knowledge about the technology to a large and diverse group of farmers (Genius et al., 2014).. Furthermore, extension agents typically work with a small group of peer farmers, which can have a direct or indirect influence on the entire farming community in their region (Genius et al., 2010).

Studies have shown that the provision of extension services has a positive correlation with the adoption of technology, as the innovation-diffusion hypothesis suggests that providing farmers with information about new technologies will encourage adoption (Karki & Bauer, 2004; Uaiene, 2009). According to (Bonabana-Wabbi, 2002; Yaron et al., 1992), the influence of extension agents can even mitigate the negative effects of a lack of formal education on the adoption of technology. In conclusion, access to extension services plays a crucial role in promoting the adoption of new technologies within the agricultural sector, by providing farmers with the information they need to make informed decisions.

Availability of financing is considered to play a crucial role in the adoption of new technologies (Mohamed & Temu, 2008). It has been theorized that access to finance can mitigate liquidity constraints and increase an individual's risk tolerance, thereby promoting the adoption of more innovative and riskier technologies (Simtowe & Zeller, 2006). This, in turn, enables households to focus on high-risk, high-reward investments rather than low-risk but less effective diversification strategies (Simtowe & Zeller, 2006).

However, lending institutions in some countries have been found to discriminate against female-headed households, making it difficult for them to obtain loans to finance yield-enhancing technologies. As a result, the adoption rates of such technologies are low (Muzari et al., 2012). Policymakers must thus strive to improve the smallholder financial systems to ensure that a larger segment of smallholders, especially female-headed households, can access loans (Mkandawire, 1993; Simtowe & Zeller, 2006). In some cases, it may be necessary to design credit packages that are tailored to the needs of specific target groups (Muzari et al., 2012). For example, the Kenyan government has launched the UWEZO fund, which provides interest-free loans to young people and women. By providing women with more agency, they can be empowered to embrace agricultural innovations, leading to economic growth.

10. Factors related to political stability:

Political stability is a crucial factor in the development of any economy, and agriculture is no exception. A stable political environment provides a favorable environment for investment, enabling farmers to access resources and support necessary for the implementation of modern farming methods (Czech et al., 2000). A lack of stability can result in instability, hindering the implementation of agriculture projects and reducing the willingness of private investors to invest in the sector (Olukunle, 2013). In addition, political stability helps to create a favorable policy environment, allowing farmers to have access to inputs, financing, and markets, which are necessary for the success of agricultural activities (Shiferaw, Hellin, et al., 2011).

Political stability can have a significant impact on the adoption of agricultural technology. In stable political environments, smallholder farmers are more likely to adopt new technologies due to improved access to

resources and support (Branca et al., 2022). In contrast, a lack of stability can create a negative impact, reducing the willingness of farmers to adopt new methods. For example, farmers in conflict-ridden areas face numerous challenges, including limited access to resources, inputs, and markets, making it difficult to adopt and implement new technologies (Clover, 2003). Moreover, the threat of violence and insecurity can discourage farmers from making investments in new technologies, as they may not see a return on their investment (De Clercq et al., 2018).

political stability can also influence the effectiveness of technology adoption. In stable political environments, farmers have access to support services, including extension services and training programs, which are essential for the successful implementation of new technologies (De Clercq et al., 2018). On the other hand, in conflict-ridden areas, these services may not be available, reducing the effectiveness of technology adoption (Kolade, 2018). Furthermore, in such environments, farmers may not be able to access the necessary inputs, such as seed and fertilizer, which are critical to the success of new farming methods (Kolade, 2018).

In developing countries, the importance of political stability for agricultural technology adoption is even greater (Mendola, 2007). In these countries, smallholder farmers are often the primary food producers and face numerous challenges, including poverty, food insecurity, and limited access to resources and support (Mendola, 2007). The adoption of new technologies can help to overcome these challenges and improve the livelihoods of smallholder farmers (Mendola, 2007). However, the lack of political stability can create obstacles that prevent farmers from adopting new technologies, exacerbating poverty and food insecurity (Shiferaw, Prasanna, et al., 2011).

In addition, the implementation of modern agricultural technology in developing countries can have a positive impact on economic growth, creating jobs and generating income for farmers (Lanjouw & Lanjouw, 2001). For example, the green revolution in India and other Asian countries has been instrumental in improving the livelihoods of smallholder farmers, creating jobs and increasing agricultural productivity (Lanjouw & Lanjouw, 2001). However, this success was only possible due to a stable political environment, which provided the necessary resources and support for the implementation of new technologies.

11. Factors unique to household's situations:

The human capital of a farmer is considered to be a major factor in determining their willingness to embrace new technologies. A farmer's education, age, gender, and family size have commonly been utilized as indicators of their human capital in many technologies adoption studies (Fernandez-Cornejo et al., 1994; Fernandez-Cornejo et al., 2007; Keelan et al., 2009; D. Mignouna et al., 2011). It is widely believed that the higher the level of education of a farmer, the greater their capacity to gather, analyze, and apply information related to the acceptance of new technologies (Lavison, 2013; D. Mignouna et al., 2011; Namara et al., 2003).

Studies have shown that a positive relationship exists between a farmer's level of education and their likelihood of adopting new technologies. For example, (Adebiyi & Okunlola, 2013) found that higher levels of education positively and significantly influenced fish producers' adoption of new technologies. (Ajewole, 2010) also found that education had a positive impact on the use of organic fertilizers. This is because higher levels of education can alter a farmer's attitudes and perceptions, making them more open-minded and capable of evaluating the benefits of new technologies (Waller et al., 1998). This, in turn, makes the introduction of new technologies easier and hastens their adoption (Adebiyi & Okunlola, 2013).

Other studies, such as those presented by (Uematsu & Mishra, 2010), have also found a positive relationship between education and the adoption of new technologies, including the use of forward pricing methods (Goodwin & Mishra, 2004), computers in agriculture (Huffman & Mercier, 1991; Putler & Zilberman, 1988), the internet (Mishra & Park, 2005; Mishra et al., 2009), reduced tillage (Mishra & Park, 2005; Rahm & Huffman, 1984; Uematsu & Mishra, 2010), precision farming (Roberts et al., 2004), and conservation tillage (Traoré et al., 1998).

However, some researchers argue that education has little to no impact on the rate of technology adoption (Atry et al., 2009; Khanna, 2001; Martin et al., 2008). According to (Uematsu & Mishra, 2010), formal education was found to have a negative impact on the adoption of genetically modified crops. The contradictory results from previous studies highlight the need for further research to arrive at a more consistent conclusion regarding the relationship between education and technology adoption.

The influence of age on the acceptance of modern technology is a complex issue. While older farmers are often better equipped to evaluate technology information due to their extensive knowledge and experience, as per research studies (Kariyasa & Dewi, 2013; D. Mignouna et al., 2011), age can also have a negative effect on technology adoption. The rise in risk aversion and decline in interest in making long-term investments as farmers age, as noted by (Adesina & Zinnah, 1993; Mauceri et al., 2005), can partially explain this association. On the other hand, younger farmers tend to be more open to taking risks and exploring novel ideas, as seen in the case of modified maize engineering, where younger farmers are found to embrace it at a higher rate compared to older farmers who are on the verge of retiring from farming (Alexander & Van Mellor, 2005).

Studies on the impact of gender on the adoption of farming technology have produced conflicting results. While a study by (Doss & Morris, 2000) found no significant relationship between gender and the likelihood of adopting improved maize in Ghana, gender was found to have a big impact on technology acceptance, as access to and influence over production resources differ between men and women, as per (Mesfin, 2005; D. Mignouna et al., 2011; Omonona et al., 2006). For example, (Obisesan, 2014) found that gender has a significant positive influence on the adoption of improved cassava production in Nigeria, while Lavison (2013) found that male farmers tend to apply organic fertilizer more frequently than female farmers. The size of the household, which serves as a proxy for labor availability, also affects the success of technology adoption, as the ability to allocate labor resources for the adoption of a new technology depends on the size of the household (Bonabana-Wabbi, 2002; D. Mignouna et al., 2011). The impact of gender on technology adoption varies depending on the technology being considered. Male farmers often have greater access to resources, such as land and labor, and as a result, they are better equipped to adopt certain technologies. Additionally, cultural norms often dictate that men hold more decision-making power within the household, which can further contribute to their advantage in adopting new technologies. However, this is not always the case, as different studies have shown that gender can have a significant positive impact on the adoption of technologies like improved cassava production in Nigeria (Obisesan, 2014).

It is worth noting that household size also plays a crucial role in the success of technology adoption. As the size of the household increases, the availability of labor decreases, making it more difficult to adopt new technologies. This is why the ability to overcome labor restrictions is crucial in determining the success of technology adoption. The availability of labor is often determined by the size of the household, which serves as a proxy for labor availability (Bonabana-Wabbi, 2002; D. Mignouna et al., 2011). The results of these studies highlight the importance of understanding the influence of gender and household size in the adoption of new technologies in agriculture.

12. Conclusion:

The acceptance and implementation of new agricultural technologies have been a topic of much interest in previous studies, as it plays a critical role in the success of the farming industry. The adoption of a new technology requires not only the availability of resources, but also the farmer's perception and understanding of the technology. Many factors come into play when evaluating the adoption of a new technology in agriculture, including human factors, economic considerations, technology-specific factors, and institutional issues. It is important to note that the influence of these factors on technology adoption can vary depending on the specific technology in question. For example, farm size has been shown to have conflicting effects on technology adoption. While a larger farm might encourage the adoption of one technology, it might discourage the adoption of another, such as the zero-grazing method. This highlights the importance of understanding the factors that drive or obstruct technology adoption, as it is essential in developing and implementing effective technology-related programs to address food production challenges in developing countries. Therefore, it is crucial for those who develop and make decisions regarding new technologies to have a clear understanding of farmers' needs and their ability to embrace new ideas. This will enable the development of technologies that are more beneficial to farmers and ultimately contribute to the success of the agricultural industry.

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