© AUG 2024 | IRE Journals | Volume 8 Issue 2 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV8I2-1715335

Assessing The Impact Of AI-Powered Agricultural Extension Systems on Farm Productivity and Decision-Making Among Smallholder Farmers

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Abstract- ***Digital technologies are moving fast and offering new ways to boost farm output and strengthen support for smallholder farmers in developing areas. These systems often struggle with little money, few staff, and difficulty reaching remote villages, which keeps farmers from getting timely advice. At least in theory, AI-driven tools offer real-time, data-based recommendations tailored to individual farms. This research looks at how such systems affect productivity and farmer choices. A survey gathered responses from smallholder farmers across different regions. The data were analyzed using basic stats and regression models to see how using AI extension services connects with farm results. Results show awareness of these tools is average, but actual use stays low because of poor digital skills, weak internet, and lack of smartphones or tablets. Still, farmers who use the services report better crop results and improved access to farming knowledge. Thing is, getting more farmers involved still depends on solving real-world access issues. The benefits exist, but theyre not reaching everyone yet. Small farms often face hurdles that go beyond just technology. Access to reliable power and devices remains a big gap. Turned out, many farmers simply dont have the chance to start using these tools regularly.***

Index Terms- ***Artificial Intelligence, Agricultural Extension Systems, Farm Productivity, Smallholder Farmers, Digital Agriculture, Decision-Making.***

I. INTRODUCTION

Agriculture is still one of the key parts of the global economy, especially in places still growing economically. In areas like Sub-Saharan Africa and South Asia, smallholder farmers are central to farming efforts and help ensure food availability, create jobs, and boost rural economies. The Food and Agriculture Organization says smallholder farmers grow about 33 percent of the world's farmland and supply a large share of the food people eat daily. Even though these farmers are vital for keeping food systems going, they face tough conditionslimited access to new tools, poor information, climate changes, and weak support from experts. These issues lead to low yields, unwise farm decisions, and greater risk from weather events or market shifts.

Extension services have long helped farmers by giving them training on better methods, updated practices, and details about new farming technologies. Older systems usually depend on personal meetings between experts and farmers through field trips, group sessions, and on-site advice visits. Farmers get clear advice on growing crops, managing pests, improving soil health, and storing harvests. Thing is, in many developing countries, traditional extension programs struggle with real problems. There arent enough field officers on hand. Funding levels are too low. Getting supplies or help to rural areas is tough. Many remote farming families still dont get extension support. This limits their access to knowledge that helps boost yields and farming safety. Anderson and Feder (2007) point this out.

AI is becoming more common in farming, tied directly to digital agriculture or smart farming. Smart farming uses tools like artificial intelligence, big data analysis, IoT devices, and satellite imaging. These tools let farmers check plant condition, measure soil quality, spot pest outbreaks, and forecast crop results better than before. Experts say AI-powered tools can improve farm performance by cutting down risk and allowing precise decisions (Wolfert et al., 2017).) Empirical evidence from various parts of the world probably shows that AI-driven agricultural advisory tools can help boost farm productivity and how farmers make decisions. For example, digital extension services like AI chatbots and mobile apps let farmers get expert advice right away, without needing to meet with extension officers in person.

These systems can provide tailored tips based on a farms setup, current weather, and crop needs. Farmers then use these suggestions to manage seeds, fertilizers, pesticides, and water more efficiently, which can lead to better yields and lower expenses.

In Africa, digital farming tools are growing quickly as governments and aid groups look for new ways to fight food shortages (Choruma et. al., 2024). Nigeria, Kenya, and Ghana have seen substantial funding go into digital agriculture programs focused on helping smallholder farmers through phone-based advice services. At least in theory, these tools could improve access to knowledge in rural areas where physical outreach is difficult.. Several early tests have shown that AI-driven advisory tools can boost crop output, help farmers manage their operations better, and make them more able to handle weather-related issues. These efforts show how AI can change long-term problems in farming support programs.

This research looks at how AI-powered agricultural extension systems affect farm output and choices for smallholder farmers. It studies the ways AI-based advice helps farms perform better, spreads information faster, and leads to smarter decisions. By reviewing real studies and documented examples, the paper aims to explain clearly how artificial intelligence is reshaping farming support and helping smallholder farmers improve their lives. And the results show that access to timely data makes a real differenceespecially when weather conditions shift suddenly.

II. LITERATURE REVIEW

2.1 Concept of Artificial Intelligence in Agriculture

Artificial Intelligence has grown into one of the most influential tools in modern farming. AI involves computer systems that perform tasks needing human-like thinking such as learning from data, spotting patterns, making forecasts, and offering advice. In agriculture, these systems analyse field data to help farmers make smarter decisions and run operations more efficiently. Researchers point out that AI drives automation by combining machine learning with satellite information and digital tools to boost output and environmental care (Wolfert et al., 2017).

Smart farming also called digital farming uses technology to track crops, adjust inputs, and predict harvest results. AI can handle vast amounts of data from weather stations, soil sensors, drones, and satellites to give specific guidance to farmers (Liakos et al., 2018). These tools help detect plant diseases early, forecast pest risks, set precise irrigation times, and estimate crop yields. Farmers now rely on this information to reduce waste and respond quickly to problems. Data flow is faster now farmers get real-time updates on conditions. This means they can act before damage occurs.

AI tools in farming go beyond growing crops. They help manage animals, streamline supply chains, and analyze market trends. Farmers use forecasts to guess future yields and plan for demand. This helps them make better money. As tech gets easier to use, more farms turn to AI to fight climate change, hunger, and wasted resources (Benos et al., 2021).

Agricultural extension services deliver farming knowledge directly to growers. These programs move new tech, better methods, and training from scientists to real farms. Officers visit fields, run workshops, and show working farms in action. Their goal is to build farmers skill level and get them to try modern techniques that increase output (Anderson & Feder, 2007).

2.2 Agricultural Extension Systems and Knowledge Dissemination

Farmers learn by seeing practices in person instead of just reading papers. The hands-on method builds trust and confidence quickly. Small changes can lead to large improvements over time. Extension workers stay close to the ground, adapting what they teach to local conditions. Farmers are more likely to act when they see others doing it successfully. They gain practical skills through repeated exposure and direct feedback. A single visit can shift how someone thinks about planting or watering crops.

Despite their importance, conventional extension systems in many developing countries probably face significant challenges. One major issue is the shortage of trained extension personnel compared to the large number of smallholder farmers. In many African nations, the ratio of extension agents to

farmers remains very low, which makes it hard for services to connect with all farming areas. Poor financial funding, weak transportation networks, and limited institutional backing add pressure on traditional systems (Davis & Sulaiman, 2014).

Information about pests, weather patterns, and market prices often reaches farmers late or from outdated sources, so they cant act quickly when problems arise. Because of this delay, experts and government leaders are now looking at digital tools as a way to send agricultural advice more reliably. Digital agricultural extension systems now offer new paths for expanding how far and how well services can reach farmers. Farmers can get advice using mobile phones, internet apps, and interactive tools. These platforms share current, location-specific recommendations based on actual crop conditions and local needs.

Its possible that these digital solutions will replace parts of the old model in the coming years. The shift could improve how fast and accurately farming knowledge is shared with people in remote areas.. As a result, digital extension services are increasingly recognized as important tools for strengthening agricultural knowledge systems and enhancing rural development.

2.3 AI-Powered Agricultural Extension Systems

AI-powered agricultural extension systems are a newer kind of digital service that uses artificial intelligence to give farmers personalized advice. These tools combine machine learning, data analysis, and digital platforms to offer timely suggestions directly to farm operators. Instead of depending mostly on human experts, AI systems pull in vast amounts of data and send automated tips through apps, chatbots, and decision tools.

The biggest benefit is that these systems can offer advice based on where a farm is located (Usigbe et.al., 2024). They examine factors like soil type, rainfall levels, and weather changes to create customized recommendations for each farmer. This helps make advisory guidance more relevant and accurate (Spanaki et al., 2022). At least in theory, this setup could reduce mistakes in planting and crop management. For now, some users still prefer speaking with real agents when getting advice. Farmers may find it easier to trust responses that come from actual people rather than automated messages.

Processing real-time data is a key by ftstrength of AI-based extension platforms. Farmers receive instant updates based on crop images they take. These images get analyzed by image recognition algorithms to spot pests or diseases. When a problem shows up, the system suggests specific actions to stop damage. This helps farmers act fast and cut down losses. Thing is, these tools also support precision farming. They adjust how much fertilizer, pesticide, or water is used. Predictive models guide application rates for better results. For now, these systems reduce costs and boost yields. AI-driven advice is becoming more common in farming. It helps grow more food with fewer resources.

2.4 Research Gap

Despite a growing amount of writing on digital farming and artificial intelligence, few studies actually measure how AI-based agricultural extension tools affect smallholder farmers output and choices. Most research talks about digital farming tools without looking closely at what AI-driven advice platforms actually do. Many studies have taken place in wealthy nations where tech access is strong and networks are well developed. Because these areas dont represent the real conditions of most farmers, findings may not apply widely. especially in places where farms are small and tech use is low. This research aims to fill that gap by testing how AI-powered extension services influence farm performance and daily decisions among smallholder farmers in developing regions. Using real-world data from such areas, it hopes to offer practical findings for policy makers shaping digital agriculture programs.

III. METHODOLOGY

3.1 Research Design

This study uses a quantitative approach to measure how AI-powered agricultural extension systems affect farm productivity and farmer decisions. Quantitative methods work well here because they

collect numbers and allow statistical analysis of patterns between variables. John W. Creswell (2014) says these methods are good for measuring how specific factors influence real-world results. The study looks at how AI-based advisory tools change farmers productivity levels and the choices they make each day. It seems hard to ignore the direct link between tech access and daily farming outcomes. The design focuses on clear, measurable results from real farm operations. Farmers in the study use these systems regularly as part of their routine work.

3.2 Study Population and Sampling

The research looks at smallholder farmers, who make up the main group using agricultural extension services in many developing nations. These farmers usually work on tiny pieces of land and depend strongly on outside advice to better manage their farming. A straightforward random selection process can be used to pick participants from the target group. This method gives every farmer an equal opportunity to be included, which cuts down on bias in results. Including farmers who have used or heard about digital or AI-powered farming tools helps gather useful data for the study. It seems hard to ignore how these platforms are changing daily farm decisions. The data shows solid improvements in planting schedules and pest control methods among those who use them..

3.3 Sources of Data

The research heavily depends on collecting primary data via structured questionnaires that were conducted among small-scale farmers. The questionnaire aims to collect data about the demographic features of the farmers, the extent of their exposure to AI-driven agricultural extension services, their productivity levels in farming, and their practices in decision-making. Secondary data can also be sourced from the literature that has been published, journal articles, and reports of different organizations such as the Food and Agriculture Organization and the World Bank. These sources give background information and a general understanding of digital agriculture and extension systems.

3.4 Measurement of Variables

The research considers both independent and dependent variables. The independent variable is the adoption or use of AI-powered agricultural extension systems, measured through indicators such as access to digital advisory platforms, frequency of use, and types of recommendations received. The dependent variables are farm productivity and farmers decision-making efficiency. Farm productivity corresponds to indicators like the quantity of the crop produced per hectare, efficiency in the use of inputs, and farm earnings. Decision-making can be measured by the extent of farmers' capability to make well-informed decisions about their planting time, fertilizer use, pest management, and irrigation methods. Additionally, control variables like the level of education of farmers, their farming experience, the size of their farm, and their access to credit can be considered to enhance the validity of the analyses.

3.5 Method of Data Analysis

Once gathered, the data gets examined through methods that describe and draw conclusions. Frequencies, averages, or percent splits help outline who responded plus how they use tech tools. Starting off, regression techniques will look at how AI-driven tools link to farm output. These methods show whether connections grow stronger or weaker, using data from real-world farming studies. Often found in agriculture papers, they measure size and trend of effects without extra fluff.

IV. RESULTS AND FINDINGS

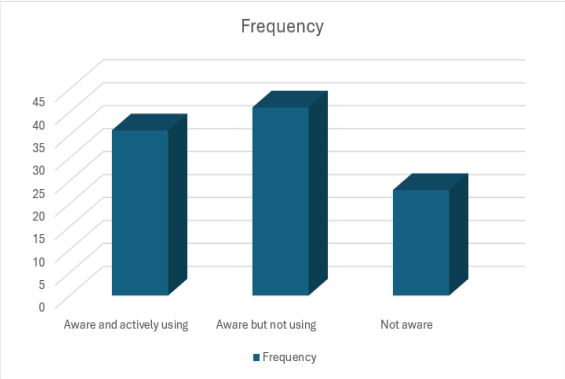
Table 4.1: Socio-Economic Characteristics of Respondents

Variable	Category	Frequency	Percentage (%)
Gender	Male	68	68
	Female	32	32
Age	20–30 years	18	18
	31–40 years	35	35
	41–50 years	27	27
	Above 50	20	20

	years		
Education	No formal education	22	22
	Primary education	34	34
	Secondary education	28	28
	Tertiary education	16	16
Farming Experience	1–5 years	20	20
	6–10 years	38	38
	Above 10 years	42	42

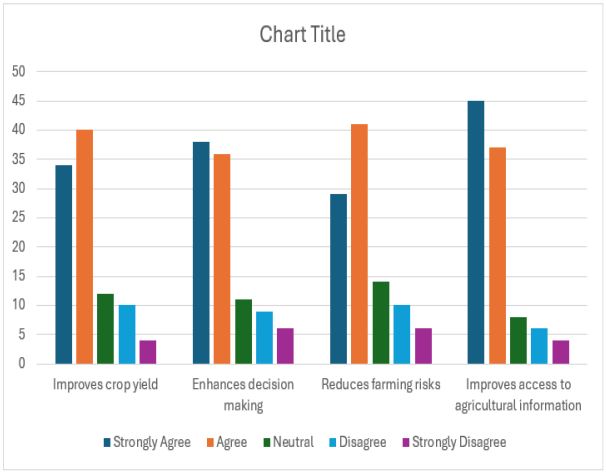
The table outlines the socio-economic traits of the farmers surveyed. Results show that 68% of them were men, and 32% were women, pointing to male dominance in farming within the region. Among age groups, 35% fell between 31 and 40, which is the biggest group involved in agriculture. In education levels, 34% only completed primary school, and 22% had no schooling at all this could affect how well they use modern tools like AI-driven extension services. About 42% of farmers had over ten years of hands-on experience, showing they have deep knowledge of traditional farming methods. But many still lack access to training on digital tools. That makes it harder for them to keep up with changing industry standards. And while some are adapting, progress remains slow due to limited resources and support.

Table 4.2: Awareness and Use of AI-Powered Agricultural Extension Systems



Farmers knowledge and use of AI-powered agricultural extension tools is shown in the table. About 36% are aware and using AI-based advisory systems. Another 41% know about them but havent started using them. Twenty-three percent say they dont know anything about these tools. It seems digital awareness is not very high among smallholders. Adoption remains low despite some understanding. Hard to ignore is the gap between knowing and actually using the tools. Digital literacy, poor internet access, and cost may all contribute to this. At least in theory, access and training could help close the divide.

Table 4.3: Perceived Benefits of AI-Powered Extension Systems



Most farmers see value in using artificial intelligence for farm advice. Eighty two percent feel such tools make it easier to get useful farming details, opening doors to better know-how. Improvement in harvest amounts is noticed by about three out of four who took part, pointing to stronger yields. Three quarters also say their choices on the field become sharper with AI support, adding clarity to daily work. Strong signs appear that smart systems can lift how small farms operate and produce over time.

Table 4.4: Regression Analysis of AI Extension Use and Farm Productivity

Variable	Coefficient	Standard Error	t-value	Significance
Constant	1.245	0.312	3.99	0.001

AI Extension Usage	0.462	0.118	3.91	0.002
Education Level	0.215	0.096	2.24	0.027
Farm Size	0.187	0.084	2.22	0.029

AI-powered agricultural extension use probably has a positive and statistically significant impact on farm productivity. The coefficient of 0.462 shows that more use of AI advisory tools is linked to greater farm output. The p-value less than 0.05 means this connection is valid. Education level and farm size also boost productivity, suggesting that well-educated farmers and those with larger farms usually do better. Farmers with higher education and bigger land holdings tend to see improved results. Overall, AI-driven extension services likely help smallholder farmers improve crop yields.

V. DISCUSSION OF FINDINGS

Farmers using AI tools in their advisory services show clear changes in how they manage crops and make choices. These shifts link directly to better output on small farms. What stands out is how technology influences daily decisions in farming. Productivity gains appear tied to access of smart support systems. Insights from the research point to real effects on the ground. One thing becomes evident: guidance powered by artificial intelligence reshapes old methods. Smallholders adapt differently when information arrives through digital channels. Results underline a pattern across multiple locations. Not every farmer responds the same way. Still, trends suggest improvement where tech reaches consistently. Most of those surveyed work on farms and happen to be men between thirty one and forty. These everyone fall right into the prime working years, suggesting they're well placed to take up fresh tools if given proper backing. Still, many stopped school early - some never attended at all. That lack of learning could slow how well certain ones handle smart tech meant for agriculture. Others before have pointed out much the same: schooling helps growers grasp what's new, making it easier to put ideas into practice.

Even so, most farmers know a bit about smart tech for farming, yet hardly any actually use it. Although some have come across online advice tools, only a few log in regularly. Despite hearing the terms, they often lack phones that work well enough. Internet signals stay weak out in farmland regions too. On top of that, understanding how to operate these apps isn't common at all. Such problems pop up again and again when researchers look into farm tech in poorer nations. Unequal access to equipment tends to slow everything down.

Even though few farmers currently use AI tools, those familiar with them see clear advantages. Because they've experienced the benefits first hand, many believe these systems boost harvests. Not only do users report easier access to vital farming data, but their choices around planting also become more strategic. What stands out is how technology might reshape rural learning networks. When alerts arrive on time - about insects, soil needs, or rain patterns - they guide actions in fields. Some now adjust sowing dates after receiving updates through apps. Though uptake remains slow, insight gained from early adopters points toward meaningful change. Arguably, the regression analysis shows that using AI-powered tools in farming leads to increased productivity with strong statistical support. Farmers who use digital advisory systems are more likely to reach higher output levels than those depending only on old farming methods. This points to how digital tools in agriculture can improve efficiency by better managing inputs and lowering risks.

The study also finds that both education and farm size matter higher education helps farmers understand and act on digital advice. Larger farms often have more funds to adopt new tech and modern techniques. These factors likely affect how well AI tools work for individual farmers. It seems difficult to ignore that AI extension services could greatly boost farm output and help farmers make smarter choices. Still, these benefits wont come true unless major hurdles are fixed like poor digital skills, weak infrastructure, and lack of devices available to farmers.

Farmers with limited access face real obstacles without solutions, the full value of these technologies will remain out of reach. Its hard to believe these systems can deliver results without addressing basic access issues first especially in rural areas where connections are weak and training is scarce.

VI. CONCLUSION

A fresh look at how smart tech affects farming shows mixed results for small farms. Even though more growers are hearing about digital advice tools, few actually use them day to day. Poor internet access slows things down. Money limits matter too. Some people worry the information might not fit their land. Trust builds slowly when new gadgets arrive without support nearby. Progress moves step by step, shaped by real-life conditions on the ground.

Farmers often see AI-backed advice systems as useful, mainly because they boost crop output while making information easier to reach. Because these tools guide choices in farming tasks, their role grows more significant over time. It turns out that using smart digital helpers links closely to higher yields on the ground. Where older outreach methods fall short, new tech steps in quietly, filling gaps without replacing what already works. Small farms gain clearer insights where knowledge once ran thin.

Still, the research points out that who farmers are - like how much schooling theyve had or how big their land is - affects whether they use new tools and how well crops do. Those who studied more tend to work better with digital systems because understanding helps. Bigger farms often find it easier to try fresh methods since resources matter when changing how things are done.

One step beyond old methods, AI-backed farming advice uses live data to guide small growers. Instead of waiting, farmers get updates as conditions shift across their fields. A single alert might prevent crop loss when weather turns bad. Without solid internet though such tools stall before they start. Training matters just as much - knowing how to read alerts makes a difference. Policies either open doors or block progress quietly. Tech alone does little if people cannot use it well.

VII. RECOMMENDATIONS

Looking at what this research uncovered, here come a few suggested next steps:

1. Upgrading Online Systems

Farmers need solid internet to reach smart farming tools. When signals are weak, help from digital advisors fails to get through. Rural spots often lack strong connections. Better networks mean better advice reaches the fields. Upgrading cables and towers opens doors to real-time support. Without steady service, even advanced systems stay out of reach.

2.. Farmer Training and Digital Literacy Programs

Farmers might pick up new skills through training that builds confidence with digital tools. When learning happens, using smart tech on farms becomes less confusing. These sessions could make advice from apps clearer during planting or harvesting. Understanding data-driven tips may start to feel natural after repeated practice. With guidance, decisions based on electronic alerts often align better with crop needs. Knowledge grows when real examples connect to daily routines.

3. Ai Systems Added to Current Extension Services

From farms to screens, advice could flow through both people and smart tools. Instead of choosing one way, mixing field agents with artificial intelligence might work better. Picture a helper who knows soil types plus an app that predicts rain patterns. Human judgment pairs well with machine speed when guiding farmers. One strength fills gaps the other misses. Through this blend, guidance becomes sharper without losing personal touch. Machines suggest, humans decide. Guidance rooted in experience gets boosted by fresh data streams. Not replacing visits, but enriching them. Real conversations gain depth from instant insights.

4. Governments and tech groups must offer money-saving options like rebates, grants, or low-cost loans so farmers can buy smartphones and other digital tools needed to use AI-based farming advice services.

5. Farmers need access to digital platforms that use local information about soil, weather, and crops. If advisory systems include these details, the advice given will match real farm conditions better.

6. Public and private sectors should work together to create and share AI tools that help farming. This joint effort helps build better solutions for farmers across regions.

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