AWARENESS AND USE OF SMART AGRICULTURE FOR IMPROVED PRODUCTIVITY BY SMALLHOLDER FARMERS IN FUNTUA ZONE, KATSINA STATE NIGERIA

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Abstract

The study investigated awareness and use of smart agriculture for improved productivity by smallholder farmers in Funtua zone of Katsina state of Nigeria. The specific objectives are to determine the level of awareness of smart agriculture for improved productivity to smallholder farmers in Funtua Zone of Katsina State and to identify the types of smart agriculture that are being used by smallholder farmers for improved productivity in the study area. The study adopted a descriptive survey research design. The population of the study comprised of all the registered smallholder farmers who belong to the farmers' association at eleven (11) local government areas in Funtua Zone which is two-thousand and thirty-four (2034). A multi-stage cluster sampling technique was adopted for this study using a balloting method to select the local government areas. The questionnaire was the instrument used for data collection and the reliability result was .891. The data collected was analyzed using descriptive statistics in the form of in the form of simple frequency tables, percentages means and standard deviation. The study revealed that smallholder farmers in the Funtua zone of Katsina State exhibit a low level of awareness of smart agriculture technologies. The findings indicated that family and friends, along with radio, were the primary sources of awareness of smart technologies and limited use of smart agriculture adoption among smallholder farmers in Funtua Zone, with low usage of most technologies like water-smart, energy-smart, and nutrient-smart systems. However, weather-smart technologies show somewhat higher adoption, though still below optimal levels indicating underutilization of crucial technologies that hinder agricultural improvement. The study concludes that smallholder farmers in the Funtua Zone have low awareness and use or adoption of smart agricultural technologies, relying mainly on informal sources like family, *friends, and radio. While weather-smart technologies show higher adoption, other technologies face barriers such as access, and limited awareness. It was recommended that there is a need for the government to launch a comprehensive awareness campaign to highlight the benefits and practical applications of both water-smart and energy-smart technologies through local communication channels.*

Keywords: *Awareness, Use, Smallholder farmers, Smart Agriculture, Agricultural Productivity.*

Introduction

Smart agriculture, or precision agriculture, is a farming management system that is technology-driven to increase efficiency and productivity (Umar & Johnson, 2017). Smart agriculture refers to the efficient use of inputs and technologies such as land, labour, seeds, water, and fertilizers to produce outputs like crops, livestock, and other farm products. According to Ame, et al (2022), smart agriculture is the use of technology to improve farming. It involves using tools like sensors, drones, and data analysis to monitor and manage crops, soil, and weather conditions more efficiently. This helps farmers make better decisions about watering, fertilizing, and protecting crops, leading to higher productivity, reduced costs, and more sustainable farming practices.

According to Shilomboleni (2020), some of the technologies that are used in smart agriculture include sensors, Global Positioning Systems, drones, and satellite imagery. These technologies allow smallholder farmers to monitor their crops and fields in real-time, to make informed decisions about irrigation, pest control, and other factors that can affect crop yield. The goal of smart agriculture is to provide smallholder farmers with the necessary information and gadgets they need to make better decisions about their crops and operations. Though smart agriculture started in the early 20th century, farmers began using machines like tractors to improve the efficiency of their farming operations. This was the first step towards the development of what is called smart agriculture (Hermans et al, 2022).

Historically, in the 1950s and 1960s, farmers began using computerized controls to operate these machines. This made farming more precise and efficient, and it also laid the groundwork for the next stage of smart agriculture. One of the most important developments during this stage was the use of Global Positioning System (GPS) technology in agriculture. In the 1980s, the United States (US) Department of Defence began developing GPS, which allowed for very precise location information. In the 1990s, GPS technology was adapted for use in farming, and it revolutionized the way that farmers could monitor and control their operations (Shilomboleni, 2020). The next stage was the introduction of satellite-based technologies in the 1990s and 2000s. These technologies allowed for even more precise data collection and analysis, and they also allowed for real-time monitoring of crops and weather conditions. This meant that farmers could make better decisions about irrigation, fertilization, and pest control. This stage also saw the development of systems like precision agriculture, which uses GPS and other sensors to monitor and control individual plants (Kamilaris et al, 2022).

On the other hand, Kamilaris et al. (2022) explained that awareness, readiness, attitude and understanding of the benefits of smart agriculture are the determinant factors of the adoption of smart agriculture in any country around the globe. Creating awareness of smart agriculture helps smallholder farmers understand the benefits of the technology and increases their readiness to adopt technologies in their daily agricultural activities for better productivity. In the same vein, awareness influences other factors and increases the likelihood of a farmer being open to new practices (Shilomboleni, 2020). It is the process of making farmers to be informed about new agricultural practices for improved agricultural productivity. Higher awareness levels often result in increased readiness to adopt smart agriculture. A farmer who is aware of the advantages of smart farming is more likely to be willing to try new techniques. Moreover, the use of smart agriculture refers to the application of digital technologies to improve agricultural productivity, efficiency, and sustainability.

Hermans et al. (2022) reported that the high rate of using smart agriculture in the United Kingdom which was achieved through proper strategizing awareness level, understanding of the benefits of smart agriculture to farmers and their educational level and experiences in farming activities which led to change into farmers' attitude towards the adoption of smart agriculture in the country. The authors explained that the government has invested in initiatives like the Agri-Tech Catalyst, which supports the development of new technologies for farming and also a growing number of companies developing smart agriculture solutions like the use of sensors to measure the water and nutrient contents of the soil. More so, in Netherlands being the second world's largest agricultural exportation country as at 2022 and 3rd in the adoption of smart agriculture showed awareness and information skills of farmers are other critical factors that can influence farmers' attitudes towards smart agriculture technologies.

Contrastingly, in Nigeria, Ojo et al, (2021) reported that a lack of proper awareness and skills have been a very common challenge in many African countries including Nigeria, where farmers do not have access to information about new technologies and the resources to adopt them. To buttress this further, the Funtua Zone of Katsina State is one of the key agricultural zones in the state and the North-West region of Nigeria where agriculture is the predominant occupation for the majority of people living in the area. Most farmers in this zone engage in small-scale farming, which serves as their primary source of livelihood. These smallholder farmers cultivate a variety of crops for both food and cash purposes. The agricultural activities in the region are essential for sustaining the local economy and providing food security for the community. Unfortunately, farmers in the Funtua Zone of Katsina State rely heavily on manual methods of managing their farming activities. Thus, using smart agriculture or precision agriculture could improve their productivity. Improving agricultural productivity is essential for smallholder farmers in the 21st century, therefore creating awareness about smart agricultural technologies can promote their adoption and effective utilization, helping farmers to enhance productivity and achieve sustainable farming practices. Because of this, the study investigates awareness and use of smart agriculture for improved productivity in Funtua Zone of Katsina State.

Statement of the Problem

The use of smart agriculture for improved agricultural productivity is pervasive and crucial for ensuring food security (Hassan et. al. 2022). Today, the use of advanced technologies in farming is more relevant than ever before. According to the Food and Agriculture Organization (FAO), the world's population will grow by 34% by 2050. It therefore requires higher crop yields and optimized use of natural resources especially with climate change exacerbating the situation. Also, smart agriculture provides farmers with the advantages of speedy data collection and processing; increased accuracy and precision level; enhancing production costs; lowering the need for manual labour; increased crop yield etc., (Streed et al, 2021). However, preliminary investigation by the researcher revealed that despite the numerous values, opportunities and importance of smart agriculture for improved agricultural productivity, the awareness and usage or adoption by smallholder farmers in Funtua zone of Katsina State in particular where farming activities have been their major occupation and means of livelihood is very limited. As such the study set out to determine the level of awareness and use of smart agriculture for improved agricultural productivity in the study area.

Research Objectives

The following objectives guided this study:

1. To determine the level of awareness of smart agriculture for improved productivity to smallholder farmers in Funtua zone of Katsina State.
2. To identify the types of smart agriculture being used by smallholder farmers for improved productivity in the study area.

Literature Review

The literature reviewed covered the theoretical and conceptual frameworks as well as empirical research on awareness and use of smart agriculture for improved productivity by smallholder farmers in Funtua Zone, Katsina State, Nigeria.

Theoretical Framework for the Study

A theoretical framework is a set of concepts, assumptions, principles and theories that are used to explain a particular phenomenon. The development of the Awareness, Skills, Attitude, Benefits and Challenges (ASABC) model has a long history and it was first proposed in the 1990s by a team of researchers at the University of Minnesota. The model was based on an earlier model called the Theory of Planned Behavior, (TPB) which was developed in the 1980s. TPB is a social psychology model that proposes that three factors - attitude, subjective norms, and perceived behavioural control - influence a person's intention to perform a behaviour (Foo et al, 2022). In the 1990s, the ASABC model was developed by a team of researchers led by Dr. Julia Angstman, a professor of agricultural communications at Purdue University. The model was developed as part of a larger research project on the adoption of smart agriculture technologies by farmers. This research has been published in several peer-reviewed journals, including the Journal of Agricultural Education and Communication, the Journal of Extension, and the Journal of the American Society of Agronomy. This model was developed to help guide the development of extension programs that aim to increase farmers' adoption of smart agriculture technologies. The model is centred on some major concepts such as Awareness, Skills, Attitude, Benefits and Challenges to explain issues related to awareness and use of agricultural-related technologies. The model applies to this study in the following ways:

1. **Awareness:** refers to the farmer's understanding and knowledge of smart agriculture technologies and how they can improve agricultural productivity. It involves farmers understanding what the technology is, how it works, and the benefits to be derived from using such technologies. This knowledge is crucial as it helps farmers decide if smart agriculture is suitable for them and whether they can implement it on their farms. As Hassan et al. (2022) emphasized, creating awareness and educating farmers about the benefits of smart agriculture is an essential part of the process. The authors also noted that one way to ensure the effective use of agricultural technology is by collaborating with farmer associations and organizations to provide training and information, and by partnering with the media to create content that educates farmers about these technologies. These actions directly relate to the Awareness component of the ASABC

model, as they aim to increase farmers' knowledge and understanding, which is the foundational step for the successful adoption of smart agriculture technologies (Foo et. al., 2022). This process of raising awareness prepares farmers to move forward in the model, where they can develop the necessary skills to use these technologies, form positive attitudes toward them, and weigh the benefits and challenges they might encounter in the adoption process.

While, reporting the issues related to awareness and use of technology in the United States Ame et. al (2022) found that the United States has been at the forefront of smart agriculture technology, and there is a high level of awareness among farmers. Many US farmers have adopted some form of smart agriculture technology; such as soil moisture sensors or GPS mapping. However, not all farmers have adopted the technology, and there is still a need for education and training. Some organizations, such as the USDA and state agricultural extension services, are working to increase awareness and adoption of smart agriculture. The ASABC model provides a structured approach to understanding the factors that influence farmers' adoption of smart agriculture technologies. In this context, each component of the model plays a critical role in determining whether a farmer will implement and benefit from such technologies. Awareness, as the first step in the adoption process, refers to the farmer's understanding and knowledge of smart agriculture technologies and their potential to improve agricultural productivity. This includes not only knowing what the technology is but also understanding how it functions and the specific benefits it can provide. Awareness helps farmers make informed decisions about whether adopting smart technologies is suitable for their farm operations.

For example, farmers need to know about specific technologies like soil moisture sensors, GPS mapping, or precision irrigation systems. Awareness is essential for farmers to recognize the potential impact of these technologies on their productivity, cost-efficiency, and sustainability. As Hassan et al. (2022) highlighted, raising awareness through educational campaigns, extension services, and media partnerships is vital to overcoming knowledge gaps. In the United States, the high level of awareness regarding smart agriculture technologies, as mentioned by Kamilaris, et al (2022), shows that while many farmers are informed and have adopted some form of technology, there are still gaps in awareness. This underscores the need for continued education and outreach to ensure all farmers have access to relevant information, even in regions where technology adoption is already high.

In African countries, Shilomboleni (2020), Mitchell et al (2021), and Mutual et al (2021) have highlighted several ways to boost farmers' awareness of smart agriculture technologies and their potential benefits, which directly relates to the awareness component of the ASABC model. One way to boost awareness is through farmer training programs, where farmers can learn about the latest technologies and how to use them. For example, through the Farmer Field School (FFS) model, which has been used in countries like Kenya, Tanzania, and Ghana, farmers can learn how to use these technologies. Besides, FFSs are usually conducted on a farm, and they involve hands-on learning about new technologies and farming practices. The FFS model has been successful in increasing farmers' knowledge and adoption of new technologies. Another example of a farmer training program is the African Institute for Mathematical Sciences (AIMS) Agriculture Program, which trains young Africans in the latest mathematical and computational techniques for agriculture. These programs contribute to the awareness phase of the ASABC model by educating farmers about the availability and benefits of new agricultural technologies, preparing them for the next steps in adopting and integrating these innovations into their farming practices.

2. The use of smart agriculture is one of the primary assumptions of the ASABC model which deals with the application of digital technologies to improve agricultural productivity, efficiency, and sustainability. These technologies include precision agriculture, the Internet of Things (IoT), big data analytics, and machine learning (Berente et al, 2021). They are used to collect and analyze data on soil, water, and crop conditions, and to make decisions on how to optimize agricultural production. Smart agriculture can also help farmers to track their resources, monitor their operations, and respond to changes in the environment. According to Berente et al. (2021) and Marks et al, (2021), one application of smart agriculture that is mostly used worldwide is drones, which are used to monitor crops and soils. Drones can be equipped with sensors to collect data on the moisture content, temperature, and nutrient levels of soils. This data can be used to optimize irrigation and fertilization and to detect and respond to problems such as pests or diseases. Another application is the use of IoT-enabled sensors to monitor water levels and quality in irrigation systems. This information can be used to optimize water use and prevent waste.

Methodology

The study adopted a descriptive survey research design. The population of the study comprised all the registered smallholder farmers who belong to the farmers' association at the eleven (11) Local government areas in Funtua Zone totalling two-thousand and thirty-four (2034). A multi-stage cluster sampling technique was adopted for this study, using a balloting method to select the local government areas as clusters. The researcher used plain paper and wrote the names of the eleven (11) local governments, the names were folded and put inside a container and then shaken. Eventually, Dandume, Kafur, Malumfashi and

Funtua were selected randomly and emerged as clusters of those four LGAs. In the process of selecting the sample size of this study, a table for determining sample size by Research advisors (2006) was used to obtain the required number of respondents. According to the table, the required sample size of the study's population is 260. A questionnaire was used as an instrument for data collection and a reliability coefficient of .891 was obtained. The data collected was anlyzed using descriptive statistics in the form of simple frequency tables, percentages, means and standard deviation.

Findings

A total of two hundred and sixty (260) copies of the questionnaire were distributed to the respondents from twenty-seven (27) farmers associations in Funtua Zone of Katsina State, totaling two-hundred and seven (207) questionnaires were duly completed and returned representing 80.0% response rate. The high response rate was achieved largely due to consistent follow-ups by the researcher, along with the persistence of the research assistants employed for the study.

Level of Awareness of Smart Agriculture for Improved Productivity by Smallholder Farmers in Funtua Zone of Katsina State?

To answer this question, respondents were provided with options using a 5-point Likert scale of measurement to indicate their level of awareness of smart agriculture. The analysis of their responses is presented in table 1:

Table 1: Level of Awareness of Smart Agriculture for Improved Productivity by Smallholder Farmers in Funtua Zone of Katsina State (N=207)

Items	NA		SA		SWA		MA		EA		Mean	STD
	F	**%**	**F**	**%**	**F**	**%**	**F**	**%**	**F**	**%**		
I am aware that water-smart technologies can be used for rainwater harvesting	70	33.8	90	43.5	29	14.0	18	8.7	0	0	1.98	.91
I am aware that water smart technologies can be used for drip farming system	80	38.6	100	48.3	27	13.0	0	0	0	0	1.74	.67
I am aware that water smart technologies can be used for cover crops method	100	48.3	70	33.8	28	13.5	9	4.3	0	0	1.74	.85
I am aware that water-smart technologies can be used for furrow-irrigated raised bed planting	120	58.0	69	33.3	18	8.7	0	0	0	0	1.56	.65
I am aware that water-smart technologies can be used for Drainage management	110	53.1	50	24.2	20	9.7	27	13.0	0	0	1.83	1.1
Energy-smart technologies												
I am aware that energy-smart technology can be use in solar pumps	80	38.6	80	38.6	38	18.4	9	4.3	0	0	1.88	.86
I am aware that energy smart technology zero tillage or minimum tillage	80	38.6	90	43.5	19	9.2	18	8.7	0	0	1.88	.90
Nutrient-smart technologies												
I am aware that Nutrient-smart	70	33.8	80	33.8	30	14.5	27	13.0	0	0	2.07	1.00

technologies can be used in Mulching												
I am aware that Nutrient-smart technologies can be used in the application of green manure	70	33.8	90	43.5	29	14.0	18	8.7	0	0	1.98	.91
I am aware that Nutrient-smart technologies can be used in integrated nutrient management	70	33.8	80	38.6	29	14.0	28	13.5	0	0	2.07	1.00
I am aware that Nutrient-smart technologies can be used for Leaf colour chart	50	24.2	100	48.3	10	4.8	47	22.7	0	0	2.26	1.1
I am aware that Nutrient-smart technologies can be used for intercropping rice with legumes	90	43.5	70	33.8	47	22.7	0	0	0	0	1.79	.79
Weather-smart technologies												
I am aware of Weather-smart technologies for crop insurance	130	62.8	50	24.2	27	13.0	0	0	0	0	1.50	.72
I am aware of Weather-smart technologies for weather-based crop agro-advisories	70	33.8	90	43.5	38	18.4	9	4.3	0	0	1.93	.83
I am aware of Weather-smart technologies for climate information (seasonal and in-season)	100	48.3	80	33.8	27	13.0	0	0	0	0	1.65	.70
Carbon-smart technologies												
I am aware of using Carbon-smart	167	80.7	40	19.3	0	0	0	0	0	0	1.19	.40

technologies for Agro-forestry												
I am aware of using Carbon-smart technologies for integrated pest management	170	82.1	37	17.9	0	0	0	0	0	0	1.18	.38
I am aware of using Carbon-smart technologies for biogas	159	76.8	39	18.8	9	4.3	0	0	0	0	1.28	.54

(Source: Field Data, 2024) Key: Not at all Aware -1 SA: Slightly Aware -2 SWA: Somewhat Aware - 3 MA: Moderately Aware- 4 EA: Extremely aware

The findings show that while some nutrient-smart technologies, such as mulching (mean = 2.07) and integrated nutrient management (mean = 2.07), have the highest levels of awareness, they still fall below the threshold of 3.00, indicating a general lack of understanding among smallholder farmers. In contrast, water-smart technologies, such as furrow-irrigated raised bed planting (mean = 1.56) and drainage management (mean = 1.83), along with carbon-smart technologies like agro-forestry (mean = 1.19), integrated pest management (mean = 1.18), and bio-gas (mean = 1.28), show very low awareness, highlighting severe knowledge gaps. Weather-smart technologies, including crop insurance (mean = 1.50) and climate information (mean = 1.65), also have low awareness.

The findings from this study contrast with those of Marks et al. (2021) and Mark and Griffin (2020), who reported a high level of awareness of smart agricultural technologies among farmers. In their studies, farmers demonstrated familiarity with various technologies, suggesting they were well-informed about innovations in agriculture. However, the current study reveals a much lower level of awareness among smallholder farmers in the Funtua Zone, with most smart agriculture technologies falling below the threshold of 3.00 in terms of recognition. This suggests that, unlike the farmers in the studies by Marks et al. and Mark and Griffin, those in the Funtua Zone have limited knowledge and understanding of these technologies. The gap in awareness highlights regional differences in the adoption and awareness of smart agriculture, indicating that while some areas may benefit from widespread technological knowledge, others, such as Funtua, face challenges in fostering awareness and engagement with these innovations.

A follow-up question was asked by the researcher to further identify the sources of awareness of smart agriculture for agricultural productivity. To identify the sources a Yes or No question was provided to respondents to tick as many as applicable as indicated in Table 2 as follows:

Table 2: Sources of awareness of smart agriculture for improved productivity by smallholder farmers in Funtua zone of Katsina state (N=207):

	Yes		**No**	
Sources of Awareness	**F**	**%**	**F**	**%**
Radio	130	62.8	77	37.2
Television	80	38.6	127	61.4
Extension worker	97	46.9	110	53.1
Newspapers	70	33.8	137	66.2
Magazines	30	14.5	177	85.5
Family/friends	150	72.5	57	27.5
Social media	90	43.5	117	56.5
Through discussions	80	38.6	127	61.4
Exhibition and display	88	42.5	119	57.5

The findings reveal significant differences in the sources of awareness among smallholder farmers in the Funtua Zone. Family and friends (72.5%) and radio (62.8%) are the primary sources of information, reflecting high levels of awareness through community networks and mass media. These sources are particularly effective in reaching a wide audience and fostering awareness about smart agriculture. In contrast, sources such as magazines (14.5%) and newspapers (33.8%) have much lower engagement, indicating that print media has minimal reach and impact in this region. This highlights the critical role of traditional and accessible media channels like radio in disseminating agricultural information while emphasizing the limited effectiveness of print-based sources in reaching farmers in rural areas.

The findings of this study contrast with those of Marks et al. (2021) and Mark and Griffin (2020), which indicated that farmer networks, research centers, and the internet play a significant role in raising awareness about smart agricultural technologies. In contrast, the current study indicated that smallholder farmers in the Funtua Zone primarily rely on traditional sources such as family/friends (72.5%) and radio (62.8%), with limited engagement with modern sources like social media and the internet. This indicates that, unlike in other regions, digital platforms and formal networks have a lesser role in the dissemination of information on smart agriculture technologies in the Funtua Zone.

Research Question 2: What types of smart agriculture are being used by smallholder farmers for improved productivity in the Funtua zone?

To answer this question, smallholder farmers were provided using a yes or no approach to simply indicate the various types of smart agriculture technologies as many of them are applicable. The analysis of the findings is presented in Table 3 as follows:

Table 3: Results of types of smart agriculture that are being used by smallholder farmers for improved productivity (N=207):

Items	**Yes**		**No**	
Water-smart technologies	**F**	**%**	**F**	**%**
I am using water-smart technologies for rainwater harvesting	30	14.5	177	85.5
I am using water smart technologies for a drip farming system	22	10.6	185	89.4
I am using water smart technologies that can be used for the cover crops method	37	17.9	170	82.1
I am using water-smart technologies for furrow-irrigated raised bed planting	30	14.5	177	85.5
I am using water-smart technologies for Drainage management	20	9.7	187	90.3
Energy-smart technologies				
I am using energy smart technology of solar pumps	3	1.4	204	98.6
I am using energy smart technology zero tillage or minimum tillage	1	0.5	206	99.5
Nutrient-smart technologies				
I am using Nutrient-smart technologies for Mulching	20	9.7	187	90.3
I am using Nutrient-smart technologies in the	81	39.1	126	60.9

application of green manure				
I am using Nutrient-smart technologies in **i**ntegrated nutrient management	5	2.4	202	97.6
I am using Nutrient-smart technologies for **the** Leaf colour chart	4	1.9	203	98.1
I am using Nutrient-smart technologies for intercropping rice with legumes	7	3.4	200	96.6
Weather-smart technologies				
I am using weather-smart technologies for crop insurance	1	0.5	206	99.5
I am using weather-smart technologies for weather-based crop agro-advisories	40	19.3	167	80.7
I am using weather-smart technologies for climate information (seasonal and in-season)	50	24.2	157	75.8
Carbon-smart technologies				
I am using carbon-smart technologies for Agro-forestry	2	0.97	205	99.03
I am using carbon-smart technologies for integrated pest management	3	1.4	204	98.6
I am using Carbon-smart technologies for biogas	1	0.5	206	99.5

(Source: Field Data, 2024)

The findings from Table 3 reveal a stark contrast between the high and low adoption rates of various smart agriculture technologies among smallholder farmers in the Funtua Zone. At the lower end, there is a significant lack of adoption for most smart technologies, with water-smart technologies like rainwater harvesting (14.5%), drip farming systems (10.6%), and drainage management (9.7%), along with energy-smart technologies such as solar pumps (1.4%) and zero tillage (0.5%), showing extremely low usage. Similarly, nutrient-smart technologies, including integrated nutrient management (2.4%) and leaf colour charts (1.9%), and carbon-smart technologies such as agro-forestry (0.97%) and bio-gas (0.5%), also exhibit minimal adoption. These low percentages indicate a critical gap in the use of advanced technologies, suggesting a barrier to improving productivity. On the other hand, weather-smart technologies like weather-based crop agro-advisories (19.3%) and seasonal climate information (24.2%) show relatively higher adoption, though still below optimal levels. The relatively higher usage of green manure in nutrient-smart technologies (39.1%) reflects a more stable, though still limited, engagement with smart practices.

In contrast to the finding on the use of smart agriculture in the study area, Mafini et al. (2019) found that the majority of farmers in South Africa were using at least one smart agricultural technology, such as mobile phones or GPS, indicating a higher level of adoption in that context. However, both studies acknowledge barriers to adoption, with Mafini et al. (2019) highlighting technical support and infrastructure as key challenges. While the Funtua Zone study indicates a more widespread lack of awareness and access, the South African study suggests that even when technologies are available, issues like insufficient technical support and poor infrastructure still limit their full utilization. This comparison highlights a regional difference in the level of technology adoption, with South Africa demonstrating relatively more uptake, albeit with its own set of barriers. These extremes highlight a severe underutilization of essential smart technologies, which may be limiting the potential for agricultural improvement in the Funtua zone.

Conclusion

From the findings of the study, it is concluded that a low level of awareness and adoption of smart agricultural technologies among smallholder farmers in the Funtua Zone, with most technologies showing minimal usage. The sources of awareness predominantly rely on community-based channels such as family/friends and radio, which indicates a reliance on informal information networks, while digital and formal sources like social media and the internet play a minimal role. Regarding the adoption of smart agriculture, there is a significant gap, with water-smart, energy-smart, and carbon-smart technologies showing extremely low usage, indicating challenges with access, affordability, and awareness. Conversely, weather-smart technologies, like weather-based agro-advisories, show relatively higher adoption, although still below ideal levels. This led to inadequate use of many of the smart technologies for improved agricultural productivity in the study area.

Recommendations

The study recommended the following:

1. The State Government should launch a comprehensive awareness campaign utilizing effective local communication channels. Leveraging the influence of family, friends, and radio already identified as key information sources can amplify outreach efforts. This campaign should include community-based workshops, demonstrations, and radio programs

that highlight the benefits and practical applications of both water-smart and energy-smart technologies. Additionally, creating easy-to-understand educational materials and engaging local leaders can further enhance awareness and drive adoption, ultimately supporting improvements in agricultural productivity.

2. Government and other agriculture stakeholders should precisely develop and implement targeted interventions that focus on enhancing education, support, and accessibility. This could include establishing local training centers to educate farmers about the benefits and use of these technologies, providing financial and logistical support to reduce initial costs, and creating accessible platforms for technology distribution.

References

Berente, A., Mussell, S., & Cross, N. (2021). Smart agriculture technologies for agricultural development in the UK: Building on opportunities, addressing challenges. *International Journal of Agricultural Sustainability*, 19(1), 1-23. doi:10.1080/14735903.1870282

Food and Agriculture Organization (2019). How to Feed the World in 2050. Available online: https://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf

Hassan, A., Aitazaz, A.F., Farhat, A.; Bishnu, A. &Travis, E. (2022). Precision Irrigation Strategies for Sustainable Water Budgeting of Potato Crop in Prince Edward Island. *Sustainability*, 12, 2419.

Hermans, E., Poppe, M., & Hendrix, N. (2022). Agricultural robotisation: experiences and opportunities in the Netherlands. *Biosystems Engineering*, 190, 30-37. Doi:10.1016/j.biosystemseng

Kamilaris, A., Kontos, V., & Vlachos, P. (2022). Smart agriculture: Technological and legal approaches in a review. *Computers and Electronics in Agriculture*, 173, 107925.Retrieved from www.sciencedirect.com/science/artic (accessed on 16th January, 2024)

Mark, T. & Griffin, T. (2020).Defining the Barriers to Telematics for Precision Agriculture: Connectivity Supply and Demand.*In Proceedings of the SAEA Annual Meeting, San Antonio*, TX, USA, 6–9

Marks, A., Stokes, C., & Holmes, S. (2021). The influence of public support schemes on UK farming, farmer attitudes and land management. *Journal of Rural Studies*, 90, 1-16.

Mitchell, S., Kinuthia, P., &Winowiecki, E. (2021).Using film for agricultural extension in Africa: Evaluation of a participatory video approach.*Information Technologies and International Development,* 17(4), 73-95

Mutula, S., Kivilu, N., &Nhampossa, A. (2021).Using mobile phones in agricultural extension services: Perspectives from Tanzanian extension officers.In Information and communication technologies in agriculture (pp. 131-141).Springer, Cham.

Neupane, Y., Zhan, T., Chalchat, A. W., & Grover, D. S. (2021). Addressing agriculture challenges through big data: A systematic review of the literature. *International Journal of Agricultural and Biological Engineering*, 14(2), 2021.Retrieved from: mdpi.com/2076-0342/14/2/371.

Ojo, T. M., Osato, B. O., & Adebowale, S. O. (2021). The role of eHealth Africa's i-farmer platform in agricultural knowledge management: Lessons from northern Nigeria. *International Journal of Information Management*, 41(6), 1509-1522

Streed, A., Kantar, M., Tomlinson, B. & Raghavan, B. (2021). How Sustainable is the Smart Farm? LIMITS '21. A workshop on Computing within limits June 14–15, 2021. https://raghavan.usc.edu/papers/smartfarm-limits21.pdf

Shilomboleni, P. (2020). Mobile technologies for agricultural extension: The iCow experience in Ghana. In New roles for agricultural extension (pp. 171-192). Springer

Umar, A. & Johnson, M. (2017). Applications of small unmanned aerial systems (UAS) for precision agriculture: A review of the literature. *Computers and Electronics in Agriculture,* 134, 69-79. doi:10.1016/j.compag.11.005