Interactions With Digital Ecosystems: Exploring the Nexus of Quality-Tailored Content, Accessibility, and Content Creation by Smallholder Farmers

Constantine OBUYA[1]
Executive Director, The African Centre for Women, Information and Communications Technology (ACWICT), P.O Box 2702-00200, Nairobi, Kenya. Tel: +254 20 2068162, Fax: +254 20 3862907, Email: cobuya_1@acwict.org

Jimmy MACHARIA[2]
Professor of Information Systems, Department of Computing, United States International University-Africa, P.O Box 14634-00800, Nairobi, Kenya. Tel: +254 20 3036 391, Email: kmacharia@usiu.ac.ke

[2] *Corresponding Author*

Abstract

The purpose of this paper is to investigate the effect of quality-tailored digital content, Access to Digital Content, and the ability to create content on the interactions with digital ecosystems by smallholder farmers and underserved communities. The study employs a participatory, collaborative, and transformative action research methodology. Further, the study uses an analytical framework and theory of change perspective to analyse various pathways and outcomes of the study interventions. A representative sample of 1,510 smallholder farmers was selected in Laikipia County through a proportionate stratified random sampling technique. Data were obtained by administering a structured online assisted questionnaire, while descriptive statistics and linear regression were used to analyse the data.

The findings of this paper have established that quality-tailored digital content has a significant (b=0.513, t=61.652, p=.000) and positive effect on the interactions with digital ecosystems by smallholder farmers and underserved communities. Likewise, Access to digital Content significantly (b=.324, t=28.862, p=.000) and positively influenced smallholder farmers' and underserved communities' interactions with digital ecosystems. Similarly, the ability to create/add to the content had a significant (b=.081, t=8.843, p=.000) and a positive influence on the interactions with digital ecosystems by smallholder farmers and underserved communities. To enhance interactions with digital ecosystems**,** this paper recommends that policies be developed to provide relevant, reliable, and engaging digital content tailored to the specific needs of smallholder farmers and underserved communities. These policies should also ensure affordable and accessible internet connectivity in rural areas to facilitate seamless access to digital agricultural content by smallholder farmers and underserved communities.

Keywords: Farmers, Content, Tailored, Agriculture, Digital Ecosystem, Smallholder.

Acknowledgements

The project is funded under grant number 204963 by the Digital Access Programme (DAP), a UK Government flagship initiative delivered by the Foreign & Commonwealth and Development Office (FCDO). The programme operates in five countries: Kenya, Nigeria, South Africa, Brazil, and Indonesia. The Programme's overall objective is to catalyse affordable, inclusive, safe, and secure digital access for underserved or excluded populations and to use this as a basis for a thriving digital ecosystem.

ACWICT is a Kenyan-based ICT for Development (ICT4D) organisation with a regional reach whose mission is to promote women's and youth's access to and knowledge of ICTs as tools for sustainable development. ACWICT addresses challenges faced by high-potential but disadvantaged women and youth, particularly those from marginalised and underserved communities, to provide digital solutions that improve their access to education, employment, food security and health for better livelihoods.

1. INTRODUCTION

The potential of digital development in interacting with the digital eco-system (including providing Access to Information such as local weather and agricultural advice, market access, financial inclusion, agricultural practices education access, government services and policies, and community networking) has been shown to play a significant role in improving agricultural productivity, promoting sustainable development, and empowering smallholder farmers (Zhou *et al.*, 2022, p. 3). However, the engagement of smallholder farmers and underserved communities with digital ecosystems has several barriers, including a lack of digital skills, technology infrastructure, awareness of benefits, service affordability, service usability, and service discoverability (Kieti *et al.*, 2022, p. 6). Further, the effectiveness of providing agricultural advice to smallholder farmers through information and communication technologies is not always sustainable, particularly in dispersed farming systems (Campenhout, Spielman and Lecoutere, 2020, p. 318). Additionally, many smallholder farmers face challenges accessing these digital ecosystems due to underdeveloped or non-existent digital infrastructure, affordability, and digital literacy or skills (Gumbi, Gumbi and Twinomurinzi, 2023, p. 2).

The digital ecosystem consists of various interdependent sub-ecosystems, including the business ecosystem, the consumer ecosystem, the ecosystem of talent and innovation, and the ecosystem of digital platforms and communications (Aminullah *et al.*, 2022, p. 5). Interactions with the digital ecosystem in the context of smallholder farmers and digital services for agriculture and community development refer to how these groups engage with and benefit from various digital technologies and platforms and encompass a wide array of activities and tools aimed at leveraging digital innovations to enhance agricultural practices and overall farming experience (Fabregas, Kremer and Schilbach, 2019, p. 5). The term "smallholder farmers", also known as subsistence farmers, are a vital component of agricultural systems, particularly in developing countries (Morton, 2007, p. 1). These farmers are individuals or households that own or manage small plots of land, often less than 2 hectares, for agricultural purposes. They have limited resources and access to modern tools and rely on family labour, with their farms serving as the primary source of food security and income generation (Vignola *et al.*, 2015, p. 1). The current study investigates the effect of quality-tailored digital content, access to digital content, and the ability to create/add to the content on smallholder farmers' and underserved communities' interactions with the digital ecosystems.

1.1 Quality Tailored Digital Content

Tailored digital content may be defined as digital information or material that is customised or personalised to meet the specific needs, preferences, or characteristics of a particular user or audience, designed to be more relevant and engaging to the target audience, leading to increased user engagement and satisfaction (Mathew and Soliman, 2021, p. 1; Beyene, 2017, p. 1; Trivedi, 2022, p. 1). Tailored digital content in agriculture has been a subject of interest due to its potential impact on smallholder farmers and the developmental benefits of digital services in agriculture. For instance, Tailoring digital content to address specific climate challenges can be crucial for smallholder farmers (Harvey *et al.*, 2018, p. 1).

Tailored digital content for agriculture is crucial for enhancing the agricultural practices of smallholder farmers. Information and Communication Technologies (ICTs) to provide agricultural advice to smallholder farmers have shown promising results, especially when combined with timely reminders to overcome inertia and procrastination (Campenhout et al., 2020, p. 318). Additionally, digital technology, such as mobile banking, enables smallholder farmers to access investment capital to purchase quality seeds, farm machinery, fertiliser, and pesticides, increasing production and income(Myeni *et al.*, 2019, p. 7). This demonstrates the potential of digital platforms in providing financial support and enhancing access to essential agricultural resources for smallholder farmers. Furthermore, understanding smallholder farmers' intention to adopt agricultural apps is essential. The mastery approach and innovation hubs have been highlighted as influential factors in driving the adoption of digital agricultural tools(Molina-Maturano *et al.*, 2021, p. 3). The protective effect of digital financial inclusion on the agricultural supply chain during the COVID-19 pandemic has been evidenced, emphasising the importance of digital financial services in ensuring the resilience of smallholder farmers amidst crises (Fang and Zhang, 2021. p. 3203). This highlights the significance of digital financial inclusion in supporting smallholder farmers during challenging times. In conclusion, developing and disseminating tailored digital content for agriculture, including agricultural advice, financial services, and innovative digital tools, are essential for empowering smallholder farmers and improving their agricultural practices. These digital interventions have the potential to enhance access to resources, increase productivity, and build resilience among smallholder farmers. This paper asserts that developing and disseminating tailored digital content for agriculture, including agricultural advice, financial services, and innovative digital tools, are essential for empowering smallholder farmers and improving their agricultural practices. These digital interventions have the potential to enhance access to resources, increase productivity, and build resilience among smallholder farmers.

1.2 Access to digital content

Access to digital content has the potential to significantly impact the interactions of smallholder farmers and underserved communities within the digital ecosystems. Digital technologies, including mobile phones and digital advisory services, have been identified to enhance agricultural productivity and improve market access for smallholder farmers (Sekabira *et al.*, 2023, p. 6). Furthermore, digital services have been recognised as a tool to bridge information gaps and improve access to essential services, ultimately contributing to sustainable agriculture (Mushi, Serugendo and Burgi, 2022, p. 2). The study by prior researchers emphasises the importance of digital inclusion for smallholder farmers in preventing disruptions that could damage their livelihoods, particularly in the context of supply chain resilience (Quayson, Bai and Osei, 2020, p. 4). However, challenges such as limited access to reliable market information, poor infrastructure, and information asymmetry have been identified as barriers to smallholder farmers' effective utilisation of digital content (Chepape and Maoba, 2020, p. 31). Additionally, factors such as farm size, farming experience, and household size have been found to significantly influence smallholder farmers' access to credit, which in turn affects their ability to leverage digital agricultural services (Edet, Agbachom and Uwah, 2019, p. 79). Strategies to enhance digital connectivity and skills, strengthen farmer associations and increase access to extension services are crucial for the inclusive and sustainable digitalisation of smallholder farming (Abdulai, 2022a, p. 1599). This paper asserts that access to digital content has the potential to transform smallholder farming practices and improve the livelihoods of underserved communities. However, addressing the challenges related to information access, infrastructure, and digital platform accessibility is essential to fully realise the benefits of digital inclusion for smallholder farmers.

1.3 Ability to Create/Add to the Content

The ability of smallholder farmers and underserved communities to create and add to digital content has a significant impact on their interactions with the digital ecosystem. Smallholder farmers show a high interest in accessing agricultural digital content (Kirui, Ombati and Nkurumwa, 2022, p. 557). This content is accessed through various means such as radio, TV, and mobile phones. Empirical evidence suggests that individual social networks are relevant for adopting technologies among smallholder farmers (Kirui, Ombati and Nkurumwa, 2022, p. 560). Furthermore, digital technologies and inclusion can prevent disruptions from damaging the livelihoods of vulnerable communities (Quayson, Bai and Osei, 2020, p. 105). It is important to note that many scientists and organisations have used different approaches to enable smallholder farmers to use digital technology to increase productivity and income (Mushi, Serugendo and Burgi, 2022, p. 2). Additionally, ecosystem-based adaptation measures have proven to build the adaptive capacity of both agroecosystems and smallholder farmers(Bhusal, Udas and Bhatta, 2022, p. 1). Unfortunately, inadequate digital literacy skills and awareness of the benefits of digital services in agriculture persist as hindrances to smallholder farmers and underserved communities’ interactions with the digital ecosystems

1.4 Study Context

The study took place in Laikipia County, located in Central Kenya. Laikipia County experiences hot and dry climate for most of the year as it is located in Kenya's ASAL regions. Laikipia North sub-county is highly susceptible to drought and experiences low rainfall. The East and West sub-counties consist of smallholder farmers who engage in mixed farming, primarily practising dryland agriculture and no irrigated agriculture. Farmers In the county rely on rain-fed agriculture, making them vulnerable to climate change risks (MoALF, 2017, pp. 1-17).

In Laikipia County, it was determined that the absolute poverty rate stood at 46 per cent, exceeding the national average of 36.1 per cent. Similarly, the food poverty rate was assessed at 24.2 per cent, lower than the national average of 32 per cent (MoALF, 2017, pp. 1-17). Agriculture served as the livelihood for over 60 per cent of the population. The region experiences annual rainfall ranging from 400 to 750 millimetres, with a mean annual temperature fluctuating between 16 and 26 degrees Celsius (MoALF, 2017, pp. 1-17). The predominant crop cultivated in the area is maise, constituting 51 per cent of the total crop area. This study was part of more considerable cross-sectional research under the Digital Services for enhanced agricultural productivity, improved livelihoods, and social inclusion of farmers in three remote sub-counties of Laikipia County in Kenya. The paper leveraged a survey design using an assisted survey questionnaire.

1.5 Digital Divide of Smallholder Framers in Sub-Shara Africa

Sub-Sahara Africa has the unique capability to increase its agricultural productivity to lift over 400 million people out of poverty and improve the livelihood of over 250 million smallholder farmers (FAO and ITU, 2022, p. 2). To achieve that, the region must improve its digital ecosystem in many ways, such as by creating quality tailored digital content. Smallholder farmers and underserved communities often face challenges accessing relevant information due to limited resources and inadequate infrastructure. However, the value of tailored content has been researched and documented. Abdulai, Bahadur and Fraser, (2022, pp. 8-10) has established that a gap persists in understanding how quality-tailored digital content, as the independent variable, enhances the interactions of smallholder farmers and underserved communities with the digital ecosystem.

The digital divide in developing countries further exacerbates the challenges faced by smallholder farmers, hindering their ability to participate in the digital economy. Quality-tailored digital content has the potential to bridge this gap by providing customised information that meets the specific needs of these communities. If developing countries are ever to realise the benefits of digitisation, accessibility and availability of quality-tailored content must be addressed. (Krone, Dannenberg and Nduru, 2016, p. 1505) defined the digital divide as a gap where some farmers have access to and can engage with technologies in a way that other farmers cannot.

A digital gap persists between rural and urban areas. Considering that smallholder farmers and underserved communities exist in rural areas, what this means is that there is an imbalance as one section of the population is unable to reap the benefits of digitalisation. Studies have looked into why this gap persists, from issues such as affordability of phones, internet accessibility and affordability, and digital training, amongst others (FAO and ITU, 2022, p. 77). According to a survey of 577 farming households, 98% of respondents own a mobile phone. Approximately 25% use it to access information about agriculture and livestock, 23% access information about buying and selling products, and 18% receive alerts (Krell *et al.*, 2021, p. 1). Although Kenya has made marked improvements in digitalisation, the agricultural sector remains high-risk as the ecosystem is highly volatile and unstructured (FAO and Worldbank, 2021, p. 5). The available technologies have not crossed mainstream use. Some main constraints are low digital literacy, limited infrastructure access, and a weak enabling policy environment. Smallholder farmers still depend on face-to-face interactions with extension officers, which impedes quick access to timely and relevant information (Chepape and Maoba, 2020, p. 1)

There have been calls by previous researchers for solutions to the slow-paced adoption of digital solutions in developing countries (Vimal *et al.*, 2023, p. 1557). The lack of practical solutions indicates a need for multi-stakeholder engagement to bridge the information gap and empower smallholder farmers and underserved communities. Limited resources and inadequate infrastructure have historically worked against smallholder farmers and underserved communities, hindering their ability to participate effectively in the rapidly advancing digital economy. Quality and tailored content trends indicate a persistent issue requiring urgent attention. We aim to bridge the knowledge gap by paying attention to the issue. The variables are introduced, defined, and supported by relevant research for each study objective. Issues and interventions are mentioned, backed by current authoritative resources underscoring the significance of addressing the lack of quality tailored digital content for smallholder farmers and underserved communities.

Thus, the hypotheses of this study are as follows:

H_1: Quality Tailored Digital Content has a positive and significant influence on the interaction with the digital eco-system by smallholder farmers,

H_2: Access to Digital Content has a positive and significant influence on the interaction with the digital eco-system by smallholder farmers and

H_3: The ability to Create/Add Digital content has a positive and significant influence on the interaction with the digital ecosystem by smallholder farmers.

1.6 **Statement of the Problem**

The interaction with the digital ecosystem by smallholder farmers and underserved communities is a critical issue addressed in the literature. However, smallholder farmers, who represent the majority of food producers globally, face challenges in accessing and utilising digital services for sustainable agriculture (Mushi, Serugendo and Burgi, 2022, p. 11). Moreover, the existing digital services for smallholder farmers often lack sustainability and fail to meet the comprehensive needs of farming cycles (Mushi, Serugendo and Burgi, 2022, p. 1). Additionally, the literature indicates that smallholder farms are complex socio-ecological systems, and the vulnerability of these farms to changes in natural ecosystem services affects agricultural production (Timberlake *et al.*, 2022, p. 567). Consequently, the potential for digital tools and services to enhance agricultural productivity for smallholder farming households is recognised, particularly with the rapid spread of mobile phones (Fabregas, Kremer and Schilbach, 2019, p. 2). However, the literature also highlights underserved communities' challenges in engaging with digital tools, such as lack of digital skills, technology infrastructure, lack of awareness of benefits, service affordability, service usability, and service discoverability (Kieti *et al.*, 2022, p. 10). Moreover, the digital divide persists for vulnerable populations, including smallholder farmers, despite the increasing digital access for most groups. The low literacy and digital skills gap continue to undermine the adoption and use of digital agricultural services among smallholders in rural Africa (Abdulai, Bahadur and Fraser, 2022, p. 2).

Efforts to bridge the digital divide and improve smallholder agricultural productivity through ecological intensification technologies have been explored, emphasising the need for interventions that reflect smallholder farmer circumstances and acknowledge their environmental realities and food security needs (Rusere et al., 2019, pp. 1-2). Additionally, the potential of internet-connected devices to apply digital tools and services on smallholder farms, such as monitoring soil and plants, presents opportunities for enhancing agricultural practices in these settings (Antony *et al.*, 2020, p. 1). Furthermore, smallholders' limited access to guaranteed markets for their produce and the acquisition of inputs are significant problems that hinder their market participation (Kyaw, Ahn and Lee, 2018, p. 2). Additionally, smallholder farmers' access to microfinance credits remains marginal for several years after the regularisation of microfinance activity in certain regions (Ouattara *et al.*, 2020, pp. 402-408).

These challenges are compounded by the high levels of vulnerability and low resilience to the adverse effects of climatic variations and changes, which constitute significant threats to smallholder farms and farmers (Awazi, Temgoua and Shidiki, 2021, p. 51).

This study, therefore, contributes to addressing these challenges by investigating the effect of quality-tailored digital content, access to digital content, and the ability to create/add to the content on the interactions with the digital ecosystems by smallholder farmers and underserved communities. Using the theory of change as a framework for study, we argue that by improving the content and its access, we will experience an increase in farmers engaging and interacting with the content. The outcome of such a change will enhance agricultural production, social and digital inclusion, sustainable livelihoods, quality of life empowerment, and environmental sustainability agricultural practices. Consequently, the hypotheses of this paper are as follows:

H_1: Quality Tailored Digital Content has a positive and significant influence on the interaction with the digital eco-system by smallholder farmers,

H_2: Access to Digital Content has a positive and significant influence on the interaction with the digital eco-system by smallholder farmers and

H_3: The ability to Create/Add Digital content has a positive and significant influence on the interaction with the digital ecosystem by smallholder farmers.

2. LITERATURE REVIEW

The Kenyan government has been promoting digital agriculture to enhance productivity, efficiency, and sustainability in the agricultural sector. Some general policy directions include: Kenya Agricultural Sector Transformation and Growth Strategy **(ASTGS)** (The Government of Kenya, 2019)**,** Agricultural Policy (Republic of Kenya, 2021), Climate Smart Agriculture Strategy (Government of Kenya, 2017), National Information & Communications Technology (ICT) Policy (Government of Kenya, 2019), Digital Literacy Programme(DLP) (Ogolla, 2019), and Digital Economy Blueprint (Republic of Kenya, 2020).

2.1 Theoretical Foundation

Kataike et al., (2018, p. 1) present a parametric test evaluating smallholder farmers' training needs, offering empirical evidence of identifying smallholder farmers' needs. This empirical evidence informs the theoretical framework by providing a basis for understanding smallholder farmers' specific training and content needs in digital agriculture. Moreover, Zhang and Fan, (2023, p. 1) construct a theoretical model of agricultural digitisation to promote farmers' income increase, which can be integrated into the theoretical framework to understand the potential impact of digital content on the economic outcomes of smallholder farmers and underserved communities. Furthermore, Nameere-Kivunike et al., (2023, p. 1) assesses the contribution of a crop health surveillance tool on the food security and livelihoods of smallholder farmers, providing a suitable theoretical framework for measuring the contribution of digital tools to farmers' livelihoods. In summary, the theoretical framework for the research paper can be constructed by integrating dimensions of ecosystem-based adaptation, digital inclusion, training needs, income increase, and livelihood assessment from the available literature. The theory of change for the community project under which this paper is extracted can be constructed by integrating various dimensions and perspectives from the available literature. These may include the impacts of climate change and the resilience of smallholder farmers within the context of the digital ecosystem. Quayson et al., (2020, p. 107), and the role of digital content (Sekabira et al., 2023, pp. 1-7).

The theory of change, as delineated in Figure 1, is used in the context of this paper. The independent variable is quality-tailored digital content, whereas the dependent variable is interactions with the digital ecosystem. The theory of change is based on the simple concept of dependent and independent variables. The independent variables are Tailored farming practices, crop diseases and management, animal diseases and management, weather information, market information and price analysis, suppliers of agricultural inputs, buyers and markets of agricultural inputs, buyers and markets of agricultural produce, e-commerce (selling and buying online), agricultural education and training, financial services, research and development. The quality of digital content will also be measured as an independent variable.

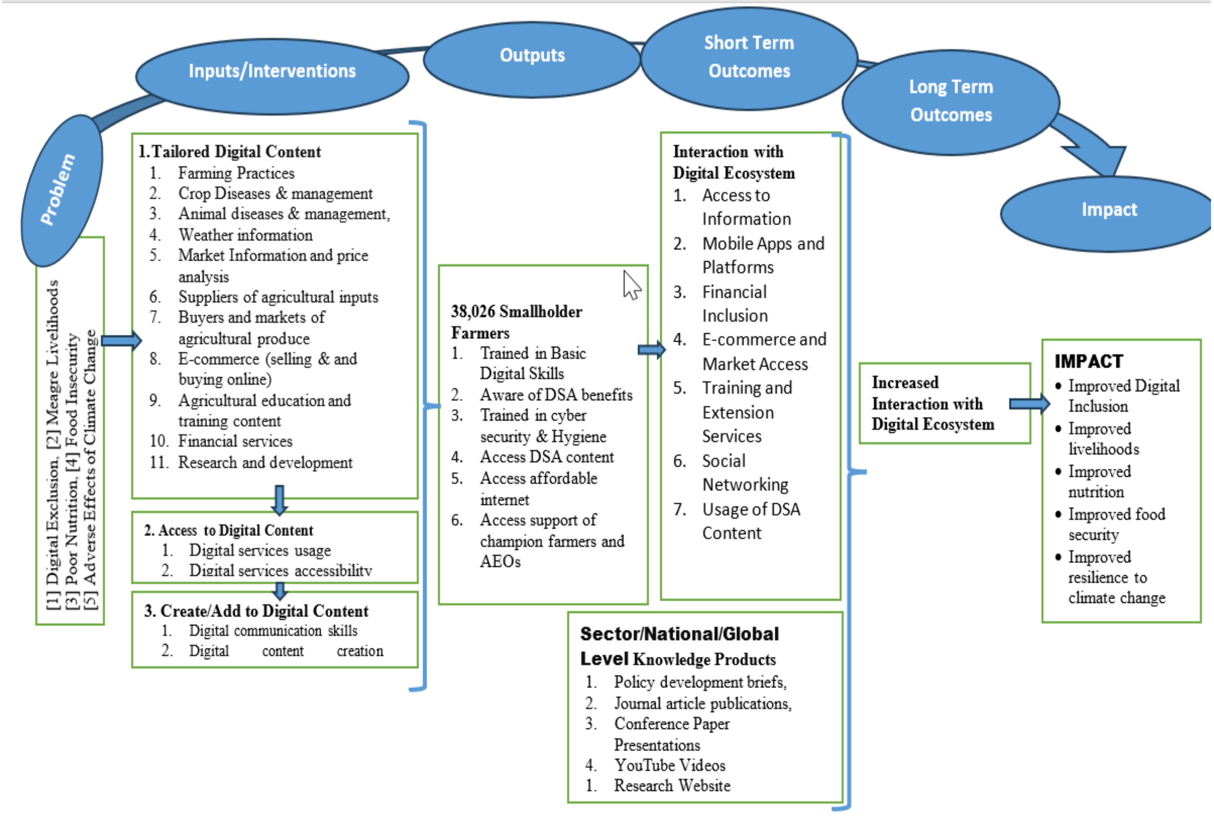

Figure 1: Theory of change for smallholder farmers Interactions with Digital Ecosystem

2.2 Tailored Digital Content and Interaction With Digital Content (IWDE)

Some studies focus on the impact of tailored farming practices content on smallholder farmers and underserved communities. In the study ￼, the authors observed that farmers were likely to engage in the digital ecosystem if the information provided was timely, actionable information that supported the farmer in decision-making. Similarly, Glendenning and Ficarelli, (2012, pp. 1-66) reports that how ICT projects assess, apply, and deliver content may increase the likelihood of farmers engaging in the digital ecosystem. The researchers report that relevant content is a critical component in ICT projects. The extent to which the content is customised and localised to a farmer’s needs and conditions influences its relevance. Tailored farming practices content encourages farmers to give feedback on the platform and promotes the participation of underserved communities such as women and youth (Coggins *et al.*, 2022,p. 5). Such studies recommend participatory video, mediated instruction, or voice messages (Gandhi *et al.*, 2009, pp. 1-10).

Providing smallholder farmers with tailored crop diseases and management content has been pointed out as one of the ways of providing timely, relevant information that bridges the gap between agricultural research outputs and yield. Other researchers argue for localised and content-specific within the content management and development framework to improve the value and actionability of the information (Tsinigo and Behrman, 2017, p. 48). The gap in research on the connection between tailored quality content and smallholder farmers' engagement is the reason behind this research (Fortner, 2022, pp. 1-55; Munialo *et al.*, 2023, p. 15). Some researchers have cited concern that digitalisation may become the tool leading to further marginalisation and disadvantaged groups instead of eliminating the gap between the rich and the poor farmers (Beaunoyer, Dupéré and Guitton, 2020, pp. 1-7). The interaction of smallholder farmers within the digital innovation ecosystem and the value co-creation process require further exploration to understand the dynamics of digital innovation in agriculture fully (Xie *et al.*, 2023, pp. 1-10). Therefore, the inclusion of this variable in this paper's study is justified.

2.3 Access to Digital Content and Interaction With Digital Content (IWDE)

The impact of access to digital content and digital services usage on the interaction with the digital ecosystem in agriculture is a complex and evolving area that requires a comprehensive understanding of technology adoption, extension services, and the potential benefits and challenges associated with digitalisation in agriculture. The increasing usage of digital solutions in agriculture can improve farm productivity and welfare by bridging the gap between potential and actual yields (Wossen *et al.*, 2017, p. 224). However, it also raises concerns about agriculture's dependence on digital infrastructures (Kuntke *et al.*, 2022, p. 219). Factors such as farmer characteristics, digital competencies, and access to digital resources are critical in determining participation in agricultural digitalisation (Abdulai, Bahadur and Fraser, 2022, p. 60).The use of digital technology, including mobile phones and social media, has been identified as an important tool to increase the reach and impact of agricultural advisory services (Shanmuka *et al.*, 2022, pp. 1-5) and can help farmers overcome constraints faced by traditional agricultural extension and advisory services (Emeana, Trenchard and Dehnen-Schmutz, 2020, pp. 1-5). Furthermore, the development of a digital agricultural service platform and the evolution of a healthy digital ecology are expected to contribute to the sustainable transformation of agriculture(Dayioğlu and Türker, 2021, p. 385). Creating an agro-digital platform is highlighted as a core element for the sustainable development of agricultural production based on digital technologies (Chamuah and Singh, 2020, p. 7). However, challenges such as the marginal level of technology usage in agriculture in certain regions, including India, persist (Cheruku and Katekar, 2021, pp. 1-6).

2.4 Creation/Adding to Digital Content and Interaction With Digital Content (IWDE)

Developing digital competencies, including communication, content creation, and information literacy, is crucial in shaping engagement with digital ecosystems in the agricultural sector (Zhang and Fan, 2023, pp.5-8). Creating and adding digital content is essential for effective communication and collaboration within the digital ecosystem, particularly in the context of agricultural advisory services and older adults (Tang, Ding and Zhou, 2023, pp. 1-6). Moreover, the level of digital skills and the adoption and integration of digital technologies will likely determine the acquisition and use of digital skills, influencing the likelihood of rural farmer participation in digital agricultural services (Abdulai, 2022, p. 59). The creation and addition of digital content are also linked to the development of digital literacy and pedagogy, which are essential for effective communication and content creation in the digital space(López-meneses and Vázquez-cano, 2020) Furthermore, the study emphasises the significance of value co-creation in the digital innovation ecosystem for promoting enterprise advantages and high-quality economic development (Xie *et al.*, 2023, pp. 1-10). This highlights the importance of digital content creation competency in contributing to value co-creation within the digital innovation ecosystem. In addition, the study by Torres et al. emphasises that ecosystem members can focus on their core competencies and strengthen their forces by cooperating, underscoring the importance of digital competencies in navigating the systemic conditions of a digital ecosystem (Dugstad *et al.*, 2019, pp. 1-3). Overall, the creation and addition of digital content, along with the development of digital communication skills and content creation competency, are critical factors that influence the interaction with the digital ecosystem in digital services in agriculture. These competencies are essential for effective communication, collaboration, and value co-creation within the digital innovation ecosystem, ultimately contributing to the sustainable transformation of agriculture. Table 1 provides the definitions for all the key variables: -

Table 1: Definition of Terms

Citation	Variable	Definition.
(Harshbarger *et al.*, 2021, p. 4)	Tailored Digital Content	Refers to digital information or material that is customised or personalised to meet the specific needs, preferences, or characteristics of a particular user or audience, designed to be more relevant and engaging to the target audience, leading to increased user engagement and satisfaction
(Friha *et al.*, 2022, p. 83)	Interaction with Digital Ecosystem in Digital Agriculture	involves the use of digital tools, platforms, and data-driven solutions to enhance and optimise different aspects of agricultural activities, including Access to Information, Mobile Apps and Platforms, Financial Inclusion, E-commerce and Market Access, Training and Extension Services, Social Networking, and Usage of DSA.
(Mathew and Soliman, 2021, pp. 1-3)	Access to digital content	encompasses the capability and opportunity for individuals to obtain and retrieve digital information from various sources, such as the internet, databases, or digital libraries and platforms, including physical access to digital content, the availability of the appropriate software, and the degree to which the structural information of the content is accessible for processing by other applications
(Qin *et al.*, 2022, p. 8-12)	Ability to create or add to digital content	refers to the capacity and skill of individuals to generate, produce, or contribute new digital information, material, or media, including the creation of digital content in various forms, such as text, images, videos, and multimedia, and the incorporation of this content into digital platforms or systems

2.5. Conceptual Framework

The conceptual framework for this study is modelled using the simple concept of independent versus dependent variables. The independent variables are tailored digital content, access to digital content, and the ability to create and add to content, whereas the dependent variable leverages the developmental benefits of DSA. This paper operationalised tailored digital content for DSA with eleven Tailoring aspects of digital content for smallholder farmers, as shown in Figure 2. This set of eleven constructs includes Farming Practices, Crop Diseases & management, Animal diseases and management, Weather information, Market Information and Price Analysis, Suppliers of agricultural inputs, Buyers and markets of agricultural produce, E-commerce (selling and buying online), Agricultural Education and Training content, financial services and Research and Development. This paper also argues that this content and services should be provided to smallholder farmers in a bundle.

For the objectives of this dependent variable, interaction with the digital ecosystem in DSA (IDE-DSA) was operationalised by measuring the strategic interaction and use of a selected set of digital ecosystem tools, platforms and services. This set comprised Access to Information, Mobile Apps and Platforms, Financial Inclusion, E-commerce and Market Access, Training and Extension Services, Social Networking, and Usage of DSA.

Finally, Quality Tailored Digital Content was operationalised by measuring its dimensions, including Farming Practices, Crop Diseases and management, Animal diseases and management, Weather information, Market Information and Price Analysis, Suppliers of agricultural inputs, Buyers and markets of agricultural produce, E-commerce (selling & buying online), Agricultural Education and Training content, and financial services. Research and Development

Independent Variables **Dependent Variables**

Quality Tailored Digital Content **Interaction with Digital Ecosystem**

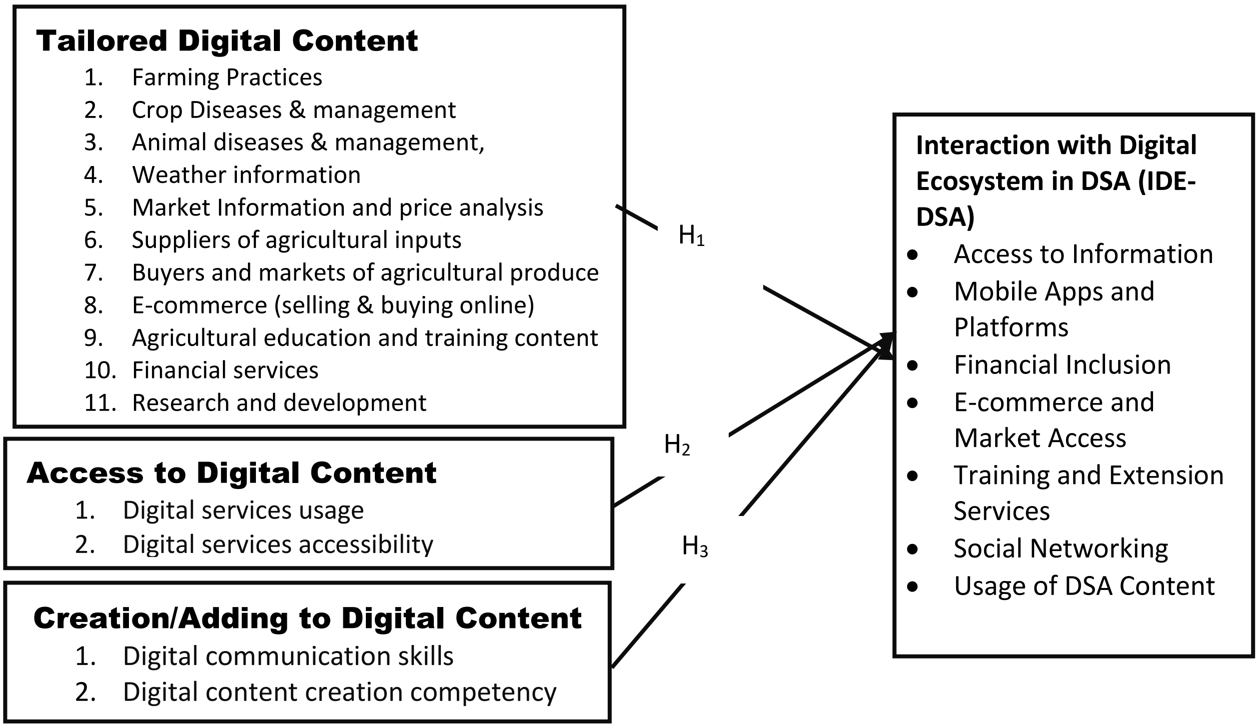

Figure 2: Research Conceptual Framework

3.0 METHODOLOGY

3.1 Research Design

This study was part of more considerable action research on digital services for enhanced agricultural productivity, improved livelihoods, and social inclusion of farmers in three sub-counties in Laikipia County in Kenya- Digital Services in Agriculture (DSA III) project. This paper adopted a descriptive survey design and used an assisted questionnaire to obtain data from a representative sample of smallholder farmers who received the interventions.

3.2. Population, Sample Design and Sample Size

The Digital Services in Agriculture (DSA) Project I -2020/2021 and DSA Project II -2021/2022 delivered several interventions to 38,026 farmers. These interventions included DSA benefits awareness creation, digital skills literacy training, locally relevant digital content, reliable and affordable intent access, DSA platforms, DSA bundled services, and access to champion farmers. In 2023, DSA Project III used stratified random sampling to obtain a sample of 1,510 farmers selected to represent the population of 38,026 farmers. Each stratum was assigned a proportional sample size relative to the entire population, as shown in Table 2. Since the more significant the sample, the better, in this paper, the sample size was deliberately made to be four times that calculated by the formula provided (Cochran, 1977, pp. 77-85).

3.3. Instruments and Data Collection

This paper defines digital services for agricultural (DSA) smallholder farmers as individuals engaged in activities along agricultural value chains with access to computing devices and the internet or basic data connectivity. In constructing the survey instrument, the study used a 5-point Likert scale where '1' was used for strongly disagreed and '5' for strongly agreed. The design drew insights from literature synthesis and the researchers' experience in the application of digital technologies in digital services for agriculture. However, validated construct items were unavailable from the literature for adaptation, so the researchers innovated almost all of the survey items. The researchers further used the feedback from the pilot test and inputs from agriculture and digital services experts, including county agricultural officers, to refine the instrument. The instrument was then deployed on the Kobo Collect online platform, where some of the resulting refinements included simplifications for online quality and presentation adapted from prior research, including those on digital skills training (Carretero, Vuorikari and Punie, 2017, p. 1-40).

Table 2: The Stratum and Respective Sample Proportions

Target Population				**Sample**	
Sub-county Name	**Strata count**	**Percentage of the target population**		**Sample count**	**Percentage of sample respondents**
Laikipia East	15,150	40%		638	42.25%
Laikipia North	5,840	15%		253	16.75%
Laikipia West	17,036	45%		619	40.99%
Total	**38,026**	**100%**		**1,510**	100.00%

3.4 Research Procedure

The farmers who participated in the study had their roles clarified and gave informed consent. The field research assistants were trained to assist the farmers and aid them in responding to the survey. A pilot test of the survey questionnaire was done on ten farmers not included in the final survey. Participatory workshops and meetings in each sub-county involving local farmers and stakeholders were conducted. Additionally, meetings with all stakeholder engagement and support were done to educate them on their roles and delivery time in the project. The study utilised three approaches to test reliability: internal reliability, achieved when the Cronbach's alpha value is 0.6 or higher (Ahmad, Zulkurnain and Khairushalimi, 2016, p. 3); composite or construct reliability, achieved when a composite reliability value of CR ≥ 0.6 (Ahmad, Zulkurnain and Khairushalimi, 2016, p. 3); and the average variance extracted (AVE); which is the average percentage of variation explained by the items in a construct and requires that AVE ≥ 0.5 (Ahmad, Zulkurnain and Khairushalimi, 2016, p. 3). The study measured the validity of the constructs' measurements using three approaches: convergent validity, achieved when all items in a measured model are statistically significant and also measured using AVE; construct validity, realised when the fitness indices achieve the level of acceptance; and discriminant validity realised when the measurement model is free from redundant items, the correlation between each pair of the latent exogenous construct is less than 0.85, and the square root of AVE for the construct is higher than the correlation between the respective constructs (Jian, Yin and Awang, 2020, p. 935). The instrument was implemented on the Kobo Collect platform, with refinements made based on online quality and presentation, drawing from previous research and digital skills training materials(Carretero, Vuorikari and Punie, 2017a, pp. 1-40).

The study used diagnostic tests to measure whether the assumptions on regression analysis are sample adequacy and multicollinearity (Kothari, 2004, pp. 283-314). The study ensured that participating farmers provided informed consent and that their roles in the research were clearly explained and voluntary. The technical research proposal received ethical approval from the USIU Institutional Review Board (IRB). The research utilised a structured questionnaire aligned with the study objectives. Field research assistants underwent training to aid farmers in completing the survey. A pilot test of the questionnaire was conducted with ten farmers not included in the final survey. Participatory workshops and meetings involving local farmers and stakeholders took place in each sub-county. Furthermore, comprehensive meetings were held with all stakeholders to educate them on their roles and the project's delivery timeline.

3.5 Data Analysis Methods and Tools

The collected data was coded, cleaned, and analysed using the SPSS version 27. The study applied an existential abduction approach using exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) to determine the underlying factor structure. Multivariate linear regression was used to test the hypotheses of the study objectives. Descriptive and inferential statistics were used to analyse data for the study.

4.0 RESULTS

4.1. Demographics

Results showed that most respondents were female (67.2%), while males constituted 32.8% (Table 3). The most critical decision-makers were the farmers themselves, involved in 98.9% of decisions. Most of the farmers were non-houses with ages>35 years. At the same time, 72.7% were self-employed in farming. On the other hand, 75.8% have either primary or secondary education. Additionally, 83.8 % of the farmers were married.

Table 3: Demographic of Respondents

Variable	Categories	Frequency	Percent	Mean
Gender	Male	496	32.8	
	Female	1014	67.2	
Age(Years)	18-24	7	0.5	
	25-35	297	19.7	
	>35	1206	79.9	
Education	No certificate	196	13.0	
	Primary certificate	568	37.6	
	Form four Certificate	578	38.3	
	College Certificate	141	9.3	
	University Certificate	27	1.8	
Marital Status	Single	130	8.6	
	Married	1266	83.8	
	Separated	36	2.4	
	Widowed	62	4.1	
	Divorced	16	1.1	
Farm Size(acres)				2.73
Annual Earnings (Before Project) Ksh				61,217.85
Annual Earnings After Project) Ksh				79,799.05

Source: Field survey data

4.2 Diagnostics Tests

Based on the guidance of scholars (Nichols and Edlund, 2023, pp. 286-484)**,** this study asserts the importance of adhering to specific assumptions when conducting comprehensive analysis. The assumptions help maintain the integrity of the study's conclusions by ensuring the provided data does not distort the overall findings. The study employed various tests to validate these assumptions and facilitate the interpretation of results at each phase of the regression analysis. Specifically, this study evaluated sample adequacy and multicollinearity, reliability, and validity assumptions.

4.2.1 Sample Adequacy Test

The Kaiser-Meyer-Olkin (KMO) test assessed the sampling adequacy for factor analysis. KMO value usually ranges from 0 to 1. In this study, the KMO result was 0.961. This KMO value closer to 1 indicates that the data is very suitable for factor analysis since, by rule of thumb, KMO values above 0.6 are considered acceptable, and values above 0.8 are considered good. Additionally, the significance level associated with this KMO test is 0.000 (<0.05), which suggests that the research data are suitable for factor analysis.

4.2.2 Multicollinearity Test

A Variance Inflation Factor (VIF) more significant than ten signals adverse multicollinearity, as the error terms for different observations are assumed to be uncorrelated. Commonly recommended threshold values of VIF should be 3.3 in the context of SEM (Kock and Lynn, 2012, p. 552), and the absence of collinearity is explained when VIF is less than 10 (Hair *et al.*, 2018). Using the VIF value threshold of 3.3 as indicative of collinearity, this study verified that multicollinearity was absent, as all values were below the threshold of 3.3. Table 6 shows the results of the VIF values ranging from 1.082 to 1.287.

4.2.3 Reliability Results

Internal reliability was achieved using Cronbach's Alpha values; All Cronbach alpha values are more significant than the criteria: 0.6 (Ahmad, Zulkurnain and Khairushalimi, 2016, p. 3). Composite reliability was used to assess construct reliability. This was achieved by CR= (∑Li)^2/((∑Li)^2+ ∑(1-(Li^2))) where i varies from 1 to n (the number of items measuring that construct), and L is the factor loading of every item, n = the number of items in a model. In this paper, the measure of reliability and internal consistency of the measured variables representing a latent construct, construct reliability, also known as composite reliability, had all values CR ≥ 0.6 as required (Ahmad, Zulkurnain and Khairushalimi, 2016, p. 3). Further Average Variance Extracted (AVE) is the average percentage of variation explained by the items in a construct. AVE ≥ 0.5 is required, which was satisfied in this paper. AVE was assessed using $\Sigma Li^2 / n$ (Ahmad, Zulkurnain and Khairushalimi, 2016, p. 3).

T**able 4: Reliability Results**

	Items	Cronbach Alpha	Composite Reliability	Average Variance Extracted
Tailored Digital Content	37	0.992	0.991	0.753
Access to Digital Content	48	0.962	0.991	0.687
Ability to create and add to content	11	0.886	0.964	0.708
Interactions with the Digital Eco System	15	0.92	0.983	0.792

4.2.4 Validity Analysis Results

Validity helps ensure a measurement or research instrument accurately and appropriately measures the intended construct or variable. Validity is crucial for research, ensuring the inferences drawn from data are meaningful and accurate.

This paper used three measures to assess validity. These are Convergent validity, Construct validity and Discriminant validity. Convergent validity is achieved when all items in the measurement model are statistically significant. This validity was verified through average variance extracted (AVE). The value of AVE was greater or equal to 0.5 to realise this validity. Construct validity was realised when the fitness indices achieved the level of acceptance. Discriminant validity was realised when the correlation between each pair of the latent exogenous constructs should be less than 0.85. Aside from that, the square root of AVE for the construct should be higher than the correlation between the respective constructs (Jian, Yin and Awang, 2020, p. 935). These were all satisfied accordingly (Ahmad, Zulkurnain and Khairushalimi, 2016, p. 3).

Table 4: Validity Analysis Results

	AVE	SQRT (AVE)	Tailored Digital Content	Access To Content	Add To Content	Interactions with Digital Eco-System
Tailored Digital Content	0.753	0.867	1			
Access To Content	0.687	0.829	.215**	1		
Add To Content	0.708	0.842	.197**	.455**	1	
Interactions with Digital Eco-System	0.792	0.890	.803**	.564**	.414**	1

***. Correlation is significant at the 0.01 level (2-tailed).*

*. Correlation is significant at the 0.05 level (2-tailed).

4.3 Regression Analysis

4.3.1 Model Summary

The high R-value (0.903) indicates a strong positive linear relationship between the predictors and the dependent variable. The R Square value (0.815) suggests that the model effectively explains 81.5% of the variability in the dependent variable. This relatively high percentage indicates that the combination of Tailored Digital Content, Access to Digital Content, and Ability to Create/Add to Digital Content is a good predictor of Interaction with Digital Content by Smallholder farmers and excluded communities. The Adjusted R Square value being the same as R Square suggests that the model is not penalised for having multiple predictors, and the model's fit remains strong.

4.3.2 ANOVA[a]

The SPSS ANOVA (Analysis of Variance) results provide information about the overall significance of the regression model. The low p-value (0.000) indicates that the overall model, including the predictors (Tailored Digital Content, Access to Digital Content, Ability to Create/Add to Digital Content), is statistically significant. In other words, the model significantly improves the explanation of the variance in interaction with digital content by smallholder farmers and excluded communities compared to a null model with no predictors. The F-statistic of 2217.459 is relatively high, supporting the conclusion that the model is significant. This high F-statistic suggests that the variance explained by the model is much greater than what would be expected by chance.

4.3.3 Regression Coefficients

The regression analysis results in Table 5 provide information about the coefficients (b), t-values, and p-values for each predictor (Constant, Tailored Digital Content, Access to Digital Content, Ability to Create/Add to Digital Content) about the dependent variable (Interaction with Digital Content by Smallholder farmers and excluded communities). Let us interpret the findings:

Table 5: Regression Coefficients

Model		Unstandardised Coefficients		Standardised Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	.401	.037		10.967	.000		
	TailoredDigitalContent2	.513	.008	.704	61.652	.000	.941	1.062
	AccessToContent2	.324	.011	.363	28.862	.000	.777	1.287
	AddToContent2	.081	.009	.111	8.843	.000	.783	1.277

a. Dependent Variable: Interactions with Digital Eco-System

The constant term represents the predicted value of the dependent variable when all predictor variables are zero. In this case, the constant has a coefficient (b) of 0.401. The t-value of 10.977 is associated with a very low p-value of 0.000, indicating that the constant term is statistically significant. This suggests that the dependent variable has a significant expected value even when all predictors are zero. All the predictors (Tailored Digital Content, Access to Digital Content, Ability to Create/Add To Digital Content) are statistically significant, as evidenced by their low p-values. This indicates that each predictor significantly contributes to predicting Interaction with Digital Content by Smallholder farmers and excluded communities.

Tailored Digital Content has the highest coefficient, suggesting it has the most substantial impact on the dependent variable among the predictors. The overall model, including the constant and all predictors, appears robust and statistically significant in predicting the dependent variable. While the statistical significance is established, the practical significance and the magnitude of the effects should also be considered in the study context.

Thus, the regression equation model can be written as:

Interaction with Digital Content=0.401+0.513×Tailored Digital Content+0.324×Access to Digital Content+0.081×Ability to Create/Add To Digital Content+ Error term

Here, the coefficients (b-values) represent the change in the dependent variable for a one-unit change in the corresponding predictor variable, holding other predictors constant. The Constant (b = 0.401): This is the intercept term. It represents the expected value of the dependent variable (Interaction with Digital Content) when all predictor variables (Tailored Digital Content, Access to Digital Content, and Ability to Create/Add To Digital Content) are zero.

4.4. Hypothesis Testing Results:

The hypotheses testing results are presented in summary form in Table 6.

Table 6: Summary of Hypotheses Test Results

Study Hypotheses	p	Results
H_1: Quality Tailored Digital Content has a positive and significant influence on the interaction with the digital eco-system by smallholder farmers,	**0.000**	**Accept H_1**
H_2: Access to Digital Content has a positive and significant influence on the interaction with the digital eco-system by smallholder farmers and	**0.**000	**Accept H_2**
H_3: The ability to Create/Add Digital content has a positive and significant influence on the interaction with the digital ecosystem by smallholder farmers.	**0.000**	**Accept H_3**

The hypotheses testing results provide sufficient evidence that the three independent variables, Tailored Digital Content, Access To Digital Content, and Ability to create/ add to digital content, measured, have a positive and significant influence on the interaction with the digital ecosystem by Smallholder Farmers and Excluded or Underserved Communities.

5. DISCUSSION

5.1 Influence of Quality Tailored Digital Content

The hypothesis that "Quality Tailored Digital Content has a positive and significant influence on the interaction with the digital ecosystem by smallholder farmers and underserved communities" is supported by various studies. For instance, Manda et al., (2021, p. 1-3) smallholder farmers' participation in single and multiple commodity markets was positively associated with household income (Manda *et al.*, 2021, p. 1-3). Additionally, Rajkhowa and Qaim, (2021, pp. 3-4) it demonstrated that personalised digital extension services are positively associated with input intensity, production diversity, crop productivity, and crop income (Rajkhowa and Qaim, 2021, pp. 3-4). The findings agree with prior research by Onyeneke *et al.*, (2023, p. 1) reviewing accredited journals from 2007 to 2021. He confirms that prior studies point to the benefit of tailored digital content overcoming the information barrier, facilitating increased interactions among stakeholders in the digital ecosystem. (Gandhi *et al.*, 2009, pp. 1-3) Undertakes a 13-month trial involving 16 villages (eight villages were the control group, and the other eight were the experimental villages). By providing quality, tailored content under the digital green initiative, the researchers observed a seven-fold increase in adopting certain agricultural practices. The accessibility of localised content, tailored to the needs of farmers and packaged in a way that promotes education and training, helped the farmers personally connect with the content. The results from this study are preliminary but promising.

5.2 Access to Digital Content

The hypothesis that "Access to Digital Content has a positive and significant influence on the interaction with the digital ecosystem by smallholder farmers and underserved communities" is supported by various studies Sekabira et al. (2023, pp. 1-7) that highlighted the empowerment of smallholder farmers through digital services, especially in the context of COVID-19 experiences, which informed brilliant Integrated Pest Management (IPM) practices (Sekabira *et al.*, 2023, pp. 1-7). Additionally, prior studies have emphasised the importance of making smartphone-based agricultural advice apps attractive through insights from a choice experiment in Mexico, indicating the potential for a positive influence on smallholder farmers' interaction with the digital ecosystem (Molina-Maturano *et al.*, 2021, p. 3). The insights from these studies underscore the potential of digital services and content in empowering smallholder farmers, particularly in resilience-building and risk management.

5.3 Ability to Create or Add to Digital Content

The ability to create or add to digital content has been shown to positively and significantly influence smallholder farmers and underserved communities' interaction with the digital ecosystem. Moreover, the study by Devkota et al., (2020, pp. 1-23) evaluated the effectiveness of picture-based agricultural extension lessons developed using participatory testing and editing with smallholder women farmers in Nepal, demonstrating the efficacy of creating and tailoring digital content to enhance comprehension and effectiveness of agricultural extension services (Devkota *et al.*, 2020, pp. 1-23). Collectively, these studies provide compelling evidence supporting the hypothesis that the ability to create or add to digital content has a positive and significant influence on the interaction with the digital ecosystem by smallholder farmers and underserved communities. The findings underscore the importance of creating and tailoring digital content to enhance information dissemination, improve inclusion in value chain partnerships, and increase the effectiveness of agricultural extension services for smallholder farmers.

6. CONCLUSION

The hypotheses test results provide empirical evidence supporting the importance of quality-tailored digital content, access to digital content, and the ability to create/add digital content as crucial factors influencing the interaction with the digital ecosystem by smallholder farmers and underserved communities (Sekabira *et al.*, 2023 , pp. 1-7). Policymakers and digital service providers should consider these factors when designing and implementing digital solutions for the agricultural sector. By providing relevant, reliable, and engaging digital content, ensuring affordable and accessible internet connectivity, and enabling user-generated content and feedback, they can enhance the digital literacy, empowerment, and participation of smallholder farmers and underserved communities. This can lead to improved productivity, profitability, and sustainability of the agricultural sector, as well as social and economic development of the rural areas. The study provides valuable insights into the potential of digital services in empowering smallholder farmers and the importance of personalised digital extension services in enhancing agricultural performance. This can lead to improved productivity, profitability, and sustainability of the agricultural sector, as well as social and economic development of the rural areas. These findings emphasise the need for policies and interventions that leverage digital technologies to support sustainable agriculture and improve the livelihoods of smallholder farmers and underserved communities. We also conclude that the country needs to develop and implement strategies and policies including those on digital agriculture, digital content and services in agricultures, and infrastructure in rural areas to support farmers and underserved communities.

8. **RECOMMENDATION**

Based on the accepted hypotheses test results, it is recommended that policymakers and digital service providers consider the factors of quality-tailored digital content, access to digital content, and the ability to create/add digital content when designing and implementing digital solutions for the agricultural sector. To enhance the digital literacy, empowerment, and participation of smallholder farmers and underserved communities, the following recommendations are proposed: Develop policies that will provide relevant and reliable digital content, affordable and accessible internet connectivity, enable user-generated content and feedback, environmental sustainability consideration, leverage traditional media channels, strengthen farmer associations/groups, tailor weather and climate information services, and strengthen access to agricultural information. These policies, when implemented, will, in return, contribute to improved productivity, profitability, and sustainability of the agricultural sector, as well as the social and economic development of rural areas. Further research is also recommended to establish other factors that may contribute to

REFERENCES

Abdulai, A.R. (2022a) ‘A New Green Revolution (GR) or Neoliberal Entrenchment in Agri-food Systems? Exploring Narratives Around Digital Agriculture (DA), Food Systems, and Development in Sub-Sahara Africa’, *Journal of Development Studies*, 58(8), pp. 1588–1604. Available at: https://doi.org/10.1080/00220388.2022.2032673.

Abdulai, A.R. (2022b) ‘Toward digitalization futures in smallholder farming systems in Sub-Sahara Africa: A social practice proposal’, *Frontiers in Sustainable Food Systems*, 6. Available at: https://doi.org/10.3389/fsufs.2022.866331.

Abdulai, A.R., Bahadur, K. and Fraser, E. (2022) ‘What factors influence the likelihood of rural farmer participation in digital agricultural services? experience from smallholder digitalization in Northern Ghana’, *Outlook on Agriculture*, 52(1), pp. 57–66. Available at: https://doi.org/10.1177/00307270221144641.

Ahmad, S., Zulkurnain, N. and Khairushalimi, F. (2016) ‘Assessing the Validity and Reliability of a Measurement Model in Structural Equation Modeling (SEM)’, *British Journal of Mathematics & Computer Science*, 15(3), pp. 1–8. Available at: https://doi.org/10.9734/bjmcs/2016/25183.

Aminullah, E. *et al.* (2022) *Interactive Components of Digital MSMEs Ecosystem for Inclusive Digital Economy in Indonesia*, *Journal of the Knowledge Economy*. Available at: https://doi.org/10.1007/s13132-022-01086-8.

Antony, A.P. *et al.* (2020) 'A review of practice and implementation of the internet of things (IoT) for smallholder agriculture', *Sustainability (Switzerland)*, 12(9), pp. 1–19. Available at: https://doi.org/10.3390/su12093750.

Awazi, N.P., Temgoua, L.F. and Shidiki, A.A. (2021) 'Examining Farmers' Resilience to Climate Change and Policy Ramifications in North-West Cameroon', *Current Research in Nutrition and Food Science Journal*, 16(1), pp. 46–60. Available at: https://doi.org/10.12944/cwe.16.1.06.

Beaunoyer, E., Dupéré, S. and Guitton, M.J. (2020) 'COVID-19 and digital inequalities: Reciprocal impacts and mitigation strategies', *Computers in Human Behavior*, 111(May). Available at: https://doi.org/10.1016/j.chb.2020.106424.

Beyene, W.M. (2017) 'Metadata and universal access in digital library environments', *Library Hi Tech*, 35(2), pp. 210–221. Available at: https://doi.org/10.1108/LHT-06-2016-0074.

Bhusal, K., Udas, E. and Bhatta, L.D. (2022) 'Ecosystem-based adaptation for increased agricultural productivity by smallholder farmers in Nepal', *PLoS ONE*, 17(6 June), pp. 1–16. Available at: https://doi.org/10.1371/journal.pone.0269586.

Campenhout, B. Van, Spielman, D.J. and Lecoutere, E. (2020) 'Information and Communication Technologies to Provide Agricultural Advice to Smallholder Farmers: Experimental Evidence from Uganda', *American Journal of Agricultural Economics*, 103(1), pp. 317–337. Available at: https://doi.org/10.1002/ajae.12089.

Carretero, S., Vuorikari, R. and Punie, Y. (2017a) *DigComp 2.1 The Digital Competence Framework for Citizens with eight proficiency levels and examples of use*. Edited by JRC. Available at: https://doi.org/10.2760/38842.

Carretero, S., Vuorikari, R. and Punie, Y. (2017b) *DigiCom2.1 -The Digital Competence Framework for Citizens With eight*.

Chamuah, A. and Singh, R. (2020) 'Securing sustainability in Indian agriculture through civilian UAV: a responsible innovation perspective', *SN Applied Sciences*, 2(1), pp. 1–10. Available at: https://doi.org/10.1007/s42452-019-1901-6.

Chepape, R.M. and Maoba, S. (2020) 'Impact of agricultural developmental programmes on smallholder farmers of bronkhorstspruit region in Tshwane metropolitan municipality, Gauteng province', *South African Journal of Agricultural Extension (SAJAE)*, 48(1), pp. 1–4. Available at: https://doi.org/10.17159/2413-3221/2020/v48n1a524.

Cheruku, D.J.K. and Katekar, V. (2021) 'Harnessing Digital Agriculture Technologies for Sustainable Agriculture in India: Opportunities and Challenges', *Administrative Development 'A Journal of HIPA, Shimla'*, 8(SI-1), pp. 215–230. Available at: https://doi.org/10.53338/adhipa2021.v08.si01.13.

Cochran, W.G. (1977) *Sampling Techniques_*. 3rd edn. New York: John Wiley & Sons.

Coggins, S. *et al.* (2022) 'How have smallholder farmers used digital extension tools? Developer and user voices from Sub-Saharan Africa, South Asia and Southeast Asia', *Global Food Security*, 32(August 2021), p. 100577. Available at: https://doi.org/10.1016/j.gfs.2021.100577.

Dayioğlu, M.A. and Türker, U. (2021) 'Digital transformation for sustainable future-agriculture 4.0: A review', *Tarim Bilimleri Dergisi*, 27(4), pp. 373–399. Available at: https://doi.org/10.15832/ankutbd.986431.

Devkota, R. *et al.* (2020) 'Evaluating the effectiveness of picture-based agricultural extension lessons developed using participatory testing and editing with smallholder women farmers in nepal', *Sustainability (Switzerland)*, 12(22), pp. 1–28. Available at: https://doi.org/10.3390/su12229699.

Dugstad, J. *et al.* (2019) 'Towards successful digital transformation through co-creation: A longitudinal study of a four-year implementation of digital monitoring technology in residential care for persons with dementia', *BMC Health Services Research*, 19(1), pp. 1–17. Available at: https://doi.org/10.1186/s12913-019-4191-1.

Edet, O.G., Agbachom, E.E. and Uwah, E.D. (2019) 'The effect of microcredit on technical efficiency of smallholder rice farmers in Ikot Ekpene Agricultural Zone, Akwa Ibom State, Nigeria', *Global Journal of Agricultural Sciences*, 18(1), p. 73. Available at: https://doi.org/10.4314/gjass.v18i1.8.

Emeana, E.M., Trenchard, L. and Dehnen-Schmutz, K. (2020) 'The revolution of mobile phone-enabled services for agricultural development (m-Agri services) in Africa: The challenges for sustainability', *Sustainability (Switzerland)*, 12(2). Available at: https://doi.org/10.3390/su12020485.

Fabregas, R., Kremer, M. and Schilbach, F. (2019) 'Realizing the potential of digital development: The case of agricultural advice', *Science*, 366(6471). Available at: https://doi.org/10.1126/science.aay3038.

Fang, D. and Zhang, X. (2021) 'The protective effect of digital financial inclusion on agricultural supply chain during the covid-19 pandemic: Evidence from china', *Journal of Theoretical and Applied Electronic Commerce Research*, 16(7), pp. 3202–3217. Available at: https://doi.org/10.3390/JTAER16070174.

FAO and ITU (2022) *Status of digital agriculture in 47 sub-Saharan African countries*. FAO; ITU; Available at: https://doi.org/10.4060/cb7943en.

FAO and Worldbank (2021) *Digital Agriculture Profile • Kenya*. Available at: https://www.fao.org/documents/card/en/c/CB3958EN.

Fortner, N.D. (2022) *Bridging the Gap Between Research and Smallholder Farmers through Community-Based Development Organizations by*. University of Nebraska - Lincoln. Available at: https://digitalcommons.unl.edu/planthealthdoc/23%0A.

Friha, O. *et al.* (2022) 'Digital Agriculture Security: Aspects, Threats, Mitigation Strategies, and Future Trends', *IEEE Internet of Things Magazine*, 5(3), pp. 82–90. Available at: https://doi.org/10.1109/iotm.001.2100164.

Gandhi, R. *et al.* (2009) 'Digital Green: Participatory Video and Mediated Instruction for Agricultural Extension', *Information Technologies & International Development*, 5(1), pp. 1–15.

Glendenning, C.J. and Ficarelli, P.P. (2012) 'The Relevance of Content in ICT Initiatives in Indian Agriculture', *International Food Policy Research Institute*, (April), p. 40.

GoK (2019) *National Information & Communications Technology (Ict) Policy*. Nairobi Kenya. Available at: https://www.ict.go.ke/wp-content/uploads/2019/12/NATIONAL-ICT-POLICY-2019.pdf.

Government of Kenya (2017) *Kenya Climate Smart Agriculture Strategy-2017-2026*. Nairobi Kenya. Available at: http://www.mediaterre.org/docactu,cGV4aW5lZy9kb2NzL2tlbnlhLWNsaW1hdGUtc21hcnQtYWdyaWN1bHR1cmU=,11.pdf.

Gumbi, N., Gumbi, L. and Twinomurinzi, H. (2023) 'Towards Sustainable Digital Agriculture for Smallholder Farmers : A Systematic Literature Review'.

Hair, J.F. *et al.* (2018) *Multivariate Data Analysis*. Available at: https://doi.org/10.1002/9781119409137.ch4.

Harshbarger, C. *et al.* (2021) 'Challenges of and solutions for developing tailored video interventions that integrate multiple digital assets to promote engagement and improve health outcomes:

Tutorial', *JMIR mHealth and uHealth*, 9(3), pp. 1–12. Available at: https://doi.org/10.2196/21128.

Harvey, C.A. *et al.* (2018) 'Climate change impacts and adaptation among smallholder farmers in Central America', *Agriculture and Food Security*, 7(1), pp. 1–20. Available at: https://doi.org/10.1186/s40066-018-0209-x.

Jian, O.Z., Yin, K.Y. and Awang, M. (2020) 'Developing And Validating the Measurement Model for Employee Engagement Construct Using Confirmatory Factor Analysis', *International Journal of Academic Research in Business and Social Sciences*, 10(8), pp. 924–941. Available at: https://doi.org/10.6007/ijarbss/v10-i8/7662.

Kataike, J. *et al.* (2018) 'A parametric test evaluating smallholder farmers' training needs in Uganda: A case of dairy farmers in the Rwenzori region', *Journal of Agribusiness in Developing and Emerging Economies*, 8(3), pp. 537–553. Available at: https://doi.org/10.1108/JADEE-08-2016-0053.

Kieti, J. *et al.* (2022) 'What really impedes the scaling out of digital services for agriculture? A Kenyan users' perspective', *Smart Agricultural Technology*, 2(January), p. 100034. Available at: https://doi.org/10.1016/j.atech.2022.100034.

Kindon, S., Pain, R. and Kesby, M. (2007) *Participatory Action Research Approaches and Methods: Connecting People, Participation and Place*. Routledge.

Kirui, V.C., Ombati, J.M. and Nkurumwa, A.O. (2022) 'Sources, Nature and Characteristics of Agricultural Digital Content Accessed by Smallholder Farmers in Nakuru County, Kenya', *Asian Journal of Agricultural Extension, Economics & Sociology*, 40(10), pp. 557–564. Available at: https://doi.org/10.9734/ajaees/2022/v40i1031113.

Kock, N. and Lynn, G.S. (2012) 'Lateral collinearity and misleading results in variance-based SEM: An illustration and recommendations', *Journal of the Association for Information Systems*, 13(7), pp. 546–580. Available at: https://doi.org/10.17705/1jais.00302.

Kothari, C.R. (2004) *Research Methodology: Methods and Techniques*. 2nd Editio. New Age International Publishers.

Krell, N.T. *et al.* (2021) 'Smallholder farmers' use of mobile phone services in central Kenya', *Climate and Development*, 13(3), pp. 215–227. Available at: https://doi.org/10.1080/17565529.2020.1748847.

Krone, M., Dannenberg, P. and Nduru, G. (2016) 'The use of modern information and communication technologies in smallholder agriculture : Examples from Kenya and Tanzania', 32(5), pp. 1503–1512. Available at: https://doi.org/10.1177/0266666915611195.

Kuntke, F. *et al.* (2022) 'Resilience in Agriculture: Communication and Energy Infrastructure Dependencies of German Farmers', *International Journal of Disaster Risk Science*, 13(2), pp. 214–229. Available at: https://doi.org/10.1007/s13753-022-00404-7.

Kyaw, N.N., Ahn, S. and Lee, S.H. (2018) 'Analysis of the factors influencing market participation among smallholder rice farmers in Magway Region, Central Dry Zone of Myanmar', *Sustainability (Switzerland)*, 10(12). Available at: https://doi.org/10.3390/su10124441.

López-meneses, E. and Vázquez-cano, E. (2020) 'University students ' digital competence in three areas of the DigCom 2 . 1 model : A comparative study at three European universities', 36(3), pp. 69–88.

Manda, J. *et al.* (2021) 'Welfare impacts of smallholder farmers' participation in multiple output markets: Empirical evidence from Tanzania', *PLoS ONE*, 16(5 May), pp. 1–20. Available at: https://doi.org/10.1371/journal.pone.0250848.

Mapiye, O. *et al.* (2023) 'Information and communication technologies (ICTs): The potential for enhancing the dissemination of agricultural information and services to smallholder farmers in sub-

Saharan Africa', *Information Development*, 39(3), pp. 638–658. Available at: https://doi.org/10.1177/02666669211064847.

Mathew, V. and Soliman, M. (2021) 'Does digital content marketing affect tourism consumer behavior? An extension of technology acceptance model', *Journal of Consumer Behaviour*, 20(1), pp. 61–75. Available at: https://doi.org/10.1002/cb.1854.

MoALF (2017) 'Climate Risk Profile: Laikipia County'.

Molina-Maturano, J. *et al.* (2021) 'Understanding smallholder farmers' intention to adopt agricultural apps: The role of mastery approach and innovation hubs in Mexico', *Agronomy*, 11(2). Available at: https://doi.org/10.3390/agronomy11020194.

Morton, J.F. (2007) 'The impact of climate change on smallholder and subsistence agriculture', *Proceedings of the National Academy of Sciences of the United States of America*, 104(50), pp. 19680–19685. Available at: https://doi.org/10.1073/pnas.0701855104.

Munialo, S. *et al.* (2023) 'Gaps and opportunities in research on food systems; a micro-institutional analysis of the University of Nairobi', *Frontiers in Sustainable Food Systems*, 7(October). Available at: https://doi.org/10.3389/fsufs.2023.1125094.

Mushi, G.E., Serugendo, G.D.M. and Burgi, P.-Y. (2022) 'Digital Technology and Services for Sustainable Agriculture in Tanzania : A Literature Review', *Sustainability*, pp. 1–17.

Myeni, L. *et al.* (2019) 'Barriers affecting sustainable agricultural productivity of smallholder farmers in the eastern free state of South Africa', *Sustainability (Switzerland)*, 11(11), pp. 1–18. Available at: https://doi.org/10.3390/su11113003.

Nameere-Kivunike, F. *et al.* (2023) 'Assessing the contribution of the Adhoc crop health surveillance tool on the food security and livelihoods of smallholder farmers in Uganda', *Electronic Journal of Information Systems in Developing Countries*, 89(3), pp. 1–23. Available at: https://doi.org/10.1002/isd2.12249.

Nichols, A.L. and Edlund, J.E. (2023) *The Cambridge Handbook of Research Methods and Statistics for the Social and Behavioral Sciences*. Volume I. Cambridge University Press. Available at: https://doi.org/10.1017/9781009010054 ©.

Ogolla, K. (2019) *Digital Literacy Programme in Kenya; Developing IT Skills in Children to align them to the Digital World and Changing Nature of Work-Briefing Note,*. Available at: http://pubdocs.worldbank.org/en/967221540488971590/Kennedy-Ogola-Entry-Digital-Literacy-Kenya.pdf.

Onyeneke, R.U. *et al.* (2023) 'Information and Communication Technologies and Agricultural Production: New Evidence from Africa', *Applied Sciences (Switzerland)*, 13(6), pp. 1–30. Available at: https://doi.org/10.3390/app13063918.

Ouattara, N. *et al.* (2020) 'Determinants of smallholder farmers' access to microfinance credits: A case study in Sassandra-Marahoué District, Côte d'Ivoire', *Agricultural Finance Review*, 80(3), pp. 401–419. Available at: https://doi.org/10.1108/AFR-07-2019-0075.

Qin, T. *et al.* (2022) 'Digital Technology-and-Services-Driven Sustainable Transformation of Agriculture: Cases of China and the EU', *Agriculture (Switzerland)*, 12(2), pp. 1–16. Available at: https://doi.org/10.3390/agriculture12020297.

Quayson, M., Bai, C. and Osei, V. (2020) 'Digital Inclusion for Resilient Post-COVID-19 Supply Chains: Smallholder Farmer Perspectives', *IEEE Engineering Management Review*, 48(3), pp. 104–110. Available at: https://doi.org/10.1109/EMR.2020.3006259.

Rajkhowa, P. and Qaim, M. (2021) 'Personalized digital extension services and agricultural performance: Evidence from smallholder farmers in India', *PLoS ONE*, 16(10 October), pp. 1–23.

Available at: https://doi.org/10.1371/journal.pone.0259319.

Republic of Kenya (2020) *Digital Economy Blueprint*. Nairobi. Available at: https://www.ict.go.ke/wp-content/uploads/2019/05/Kenya-Digital-Economy-2019.pdf.

Republic of Kenya (2021) *Agricultural Policy-2021:"Food: Our Health, Wealth, and Security"*. Nairobi Kenya. Available at: https://kilimo.go.ke/wp-content/uploads/2022/05/Agricultural-Policy-2021.pdf.

Rusere, F. *et al.* (2019) 'Developing pathways to improve smallholder agricultural productivity through ecological intensification technologies in semi-arid Limpopo, South Africa', *African Journal of Science, Technology, Innovation and Development*, 11(5), pp. 543–553. Available at: https://doi.org/10.1080/20421338.2018.1550936.

Sekabira, H. *et al.* (2023) 'Are digital services the right solution for empowering smallholder farmers? A perspective enlightened by COVID-19 experiences to inform smart IPM', *Frontiers in Sustainable Food Systems*, 7. Available at: https://doi.org/10.3389/fsufs.2023.983063.

Shanmuka, A. *et al.* (2022) 'Factors Affecting Perception of Extension Agents Towards Effective Social Media Utilization Behaviour', *Indian Journal of Extension Education*, 58(3), pp. 88–92. Available at: https://doi.org/10.48165/ijee.2022.58319.

Tang, X., Ding, X.S. and Zhou, Z. (2023) 'Towards Equitable Online Participation: A Case of Older Adult Content Creators' Role Transition on Short-form Video Sharing Platforms', *Proceedings of the ACM on Human-Computer Interaction*, 7(CSCW2). Available at: https://doi.org/10.1145/3610216.

The Government of Kenya (2019) *The Agriculture Sector Growth and Transformation Strategy (ASTGS) : Towards sustainable agricultural transformation and food security in Kenya. 2019-2029*. Nairobi Kenya. Available at: https://www.agck.or.ke/Downloads/ASTGS-Full-Version-1.pdf.

Theodoridis, T. and Kraemer, J. (2018) *Digital Technologies for Agricultural and Rural Development in the Global South*. Edited by R. Duncombe. CABI Digital Library.

Timberlake, T.P. *et al.* (2022) 'A network approach for managing ecosystem services and improving food and nutrition security on smallholder farms', *People and Nature*, 4(2), pp. 563–575. Available at: https://doi.org/10.1002/pan3.10295.

Trivedi, T.M. (2022) 'Impact of Digital Content Marketing on Purchase Intentions for Online Shopping Post Covid-19 Pandemic', *International Journal of Management, Public Policy and Research*, 1(2), pp. 24–33. Available at: https://doi.org/10.55829/010204.

Tsinigo, E. and Behrman, J.R. (2017) 'Technological priorities in rice production among smallholder farmers in Ghana', *NJAS - Wageningen Journal of Life Sciences*, 83, pp. 47–56. Available at: https://doi.org/10.1016/j.njas.2017.07.004.

Vignola, R. *et al.* (2015) 'Ecosystem-based adaptation for smallholder farmers: Definitions, opportunities and constraints', *Agriculture, Ecosystems and Environment*, 211, pp. 126–132. Available at: https://doi.org/10.1016/j.agee.2015.05.013.

Vimal, K.E.K. *et al.* (2023) 'Barriers to the adoption of digital technologies in a functional circular economy network', *Operations Management Research*, 16(3), pp. 1541–1561. Available at: https://doi.org/10.1007/s12063-023-00375-y.

Wossen, T. *et al.* (2017) 'Impacts of extension access and cooperative membership on technology adoption and household welfare', *Journal of Rural Studies*, 54, pp. 223–233. Available at: https://doi.org/10.1016/j.jrurstud.2017.06.022.

Xie, X. *et al.* (2023) 'The Coupling Mechanism of the Digital Innovation Ecosystem and Value Co-creation', *Advances in Environmental and Engineering Research*, 04(01), pp. 1–9. Available at: https://doi.org/10.21926/aeer.2301013.

Zhang, X. and Fan, D. (2023) ‘Can agricultural digital transformation help farmers increase income? An empirical study based on thousands of farmers in Hubei Province’, *Environment, Development and Sustainability* [Preprint], (0123456789). Available at: https://doi.org/10.1007/s10668-023-03200-5.

Zhou, Z. *et al.* (2022) ‘The Impact of Environmental Regulation on China’s OFDI: From the Perspective of Home Country’, *Mobile Information Systems*, 2022. Available at: https://doi.org/10.1155/2022/3322324.