ROLE OF DIGITAL TOOLS FOR SUSTAINABLE AGRICULTURE – OPPORTUNITIES AND CHALLENGES

Purushothama Bhat N

Associate Professor
Department of Economics, Govt. First Grade College, Belthangady, Dakshina Kannada District. Karnataka

ABSTRACT

Agriculture is a dominant occupation in India where, the vast majority of people make their living from farming. However, low production, restricted market access, inadequate infrastructure, and climate change susceptibility are just a few of the many issues that traditional agricultural methods frequently confront. This research investigates how digitalisation of agriculture is propelling the conversion of rural regions into smart villages by utilising secondary data from scholarly publications, official documents, and international development agencies. Evidence that digital technologies including data analytics, mobile advisory services, and precision farming boost agricultural productivity, raise incomes, and support rural socioeconomic development is compiled in this study. According to the findings, digital agriculture has a lot of potential to promote equitable and sustainable rural growth, but its widespread adoption is constrained by issues including low digital literacy, weak digital infrastructure, and sociocultural hurdles.The report emphasises that to fully realise the potential of digital agriculture, integrated regulatory frameworks, investments in rural digital infrastructure, and capacity building are required. By overcoming these obstacles, digital agriculture can be a key component of the larger smart village project, fostering sustainability, resilience, and an enhanced standard of living in rural areas.

Keywords: Smart Villages, Digital Agriculture, Rural Areas, Information and Communication Technology, SWOC Analysis.

1. INTRODUCTION

Agriculture continues to be the foundation of rural economies, especially in developing nations where the vast majority of people rely on farming as their primary source of incomeChowdhury et al., (2023). Traditional farming methods, however, frequently encounter a number of difficulties, such as low output, restricted market accessibility, inadequate infrastructure, and climate change susceptibility. In response to these problems, digital agriculture, the application of digital technologies to agriculturehas become a potent force for change and growth in rural areas. Xie et al., (2021). To improve each step of the agricultural value chain—from production and processing to distribution and marketing—digital agriculture uses information and communication technology (ICT), data analytics, the Internet of Things (IoT), drones, and mobile applications.Digital agriculture offers a special chance to address systemic inefficiencies in rural areas by facilitating data-driven decision-making, optimising resource use, and enhancing market accessPatnaik et al., (2020). By encouraging the application of creative solutions to enhance rural communities' sustainability, economic well-being, and quality of life, the idea of "smart villages" builds on this potential. By utilising digital tools in agriculture, education, health, government, and infrastructure, smart villages seek to close the gap between rural and urban areas. This study investigates how digital agriculture is propelling the creation of smart villages.It looks at how implementing technology can improve food security, promote equitable and sustainable

growth, empower rural communities, and create job possibilities. In order to shed light on how digital agriculture can be a key component of rural transformation in the twenty-first century, the study will examine existing trends, obstacles, and success stories Emerllahu& Bogataj (2024).

2. LITERATURE REVIEW

Kareska, (2024) summarised in their study that digital agriculture as a transformative force capable of modernising rural economies and contributing to the development of smart villages. Numerous studies emphasise how technologies such as precision farming, remote sensing, drones, and mobile-based platforms improve agricultural efficiency, productivity, and market access for farmers. Malik et al., (2022). Study recognises the potential of digital agriculture to enhance rural livelihoods by facilitating financial inclusion, knowledge dissemination, and sustainable resource management. However, the study also points to significant challenges, including infrastructural deficits, limited digital literacy, and socio-cultural barriers that affect technology adoption in rural areas. Shankar & Natrajan,(2023). Study described the integrated strategies that guarantee comprehensive rural transformation by fusing digital agriculture with other smart village elements, including government, healthcare, and education. Even with increased research, there are still unanswered questions about how to scale these technologies inclusively and sustainably in a variety of rural situations, especially in developing nations.

3. RESEARCH GAPS

Regardless of whether digital agriculture is becoming more and more popular as a rural development accelerator, there are still a lot of unanswered questions about how it can completely change rural regions into smart villages. Previous research has tended to ignore the socioeconomic and infrastructure issues specific to rural areas in favour of concentrating on productivity gains and technology adoption. The ways that digital agriculture interacts with more general smart village projects, such as governance, healthcare, education, and energy systems, are not well supported by actual data.The contribution of gender dynamics, community involvement, and local knowledge to promoting sustainable digital transformation is also not well understood. Furthermore, especially in low-income areas, research rarely discusses the scalability and flexibility of digital solutions across various rural contexts. Developing inclusive, context-sensitive policies and technology that can successfully use digital agriculture to promote comprehensive smart village development requires closing these gaps.

4. Research Questions

1. How does digital agriculture impact agricultural productivity and income levels in rural areas?

2. What are the main barriers and facilitators for adopting digital agricultural technologies in rural communities?

3. In what ways do socio-cultural factors, including gender roles and community participation, affect the implementation and success of digital agriculture?

5. Research Objectives

1. To evaluate the impact of digital agriculture on agricultural productivity and income levels in rural areas.

2. To identify the main barriers and facilitators influencing the adoption of digital agricultural technologies in rural communities.

3. To analyse the effects of socio-cultural factors, including gender roles and community participation, on the implementation and success of digital agriculture.

6. SWOC ANALYSIS

a. Strengths:

Utilising cutting-edge technology like IoT, AI, and data analytics, digital agriculture improves farming production, sustainability, and efficiency. These developments make it possible to manage resources precisely, monitor them in real time, and make smarter decisions—all of which can greatly increase crop yields while lowering expenses. Digital agriculture is a major force behind modernising rural economies, generating new job opportunities, and expanding market accessibility in the framework of smart villages. Its capacity to link farmers with supply chains, financial services, and information enhances rural resilience and self-sufficiency and lays the groundwork for a more extensive digital revolution in rural regions (Doloi, 2025).

b. Weaknesses:

Digital agriculture has many potential applications, but its efficacy in rural areas is constrained by a number of intrinsic flaws. Poor digital infrastructure, such as erratic internet access and restricted access to electricity, plagues many rural locations, making it difficult to implement and utilise digital technology. Furthermore, farmers frequently lack the technical know-how and digital literacy necessary to properly embrace and profit from these advancements. The lack of smallholder farmer-specific solutions and the high upfront expenditures of digital tools also prevent widespread adoption, which could exclude disadvantaged populations and result in unequal gains (Ikbal et al., 2025).

c. Opportunities:

Opportunities for rural development expand when digital agriculture is integrated into smart village projects. Because it empowers small-scale farmers, enhances food security, and reduces rural poverty, it can foster inclusive growth. Digital platforms have the potential to improve access to financial products such as loans and insurance, agricultural extension services, and knowledge sharing. Furthermore, digital agriculture can have a synergistic effect with other smart village elements like healthcare, education, and renewable energy, elevating living conditions in rural areas overall. The growing focus on sustainability and climate-smart agriculture worldwide opens more avenues for finance and innovation to support digital agriculture in rural transformation (Somwanshi et al., 2016).

d. Challenges:

A lot of challenges need to be addressed before digital agriculture can completely turn rural areas into smart villages. Participation and acceptance in the community might be hampered by sociocultural obstacles like gender inequity and opposition to change. Risks to the ethical use of digital technology include issues with data privacy, security, and a lack of regulatory policies. Furthermore, the diversity of rural environments necessitates flexible and expandable solutions, which can be challenging to develop and execute. In order to bridge the digital divide and ensure the long-term sustainability and upkeep of digital systems, governments, the commercial sector, and civil society must work together(Majumdar, 2020).

7. SMART VILLAGE OVERVIEW

Zhao, et al. (2022) summarised that the Innovation with the use of digital agriculture has raised agricultural output, which has greatly helped farmers' financial circumstances. This helps solve issues like inadequate living conditions, education, and health care that rural areas face. The smart village concept focuses on rural communities and areas by creating new opportunities and leveraging existing assets and capabilities. These findings require validation and comparison through additional empirical research comparing the implementation and results of smart villages in various regions, especially from reputable and updated journal papers. Gerli et al., (2022). In the smart village concept, improved digital technology is used to improve new services, networks, and traditions. Utilising social innovation and information and communication technology (ICT) to address the issues that rural communities face is the goal of Smart Village. Smart water, smart education, smart transit, smart healthcare, and smart energy are all seen as crucial strategies. telecommunications, creativity, and knowledge application for the good of rural companies and communities. Kaur& Parashar,(2022). Innovation and digital technology can increase living standards, improve inhabitants' quality of life, improve resource utilisation, reduce environmental impact, and open up new chances for rural value chains to produce better goods. Fatimah et al., (2020) explained that Smart villages are constructed on the idea of an autonomous ecosystem that can generate resources to aid in human growth and adjust to shifting governmental regimes.

Wang et al., (2022) said that regional sensitivity is used to create smart villages, taking into account the potential and demands of each area. The strategy is backed by either new or pre-existing territorial strategies. Technology is crucial in a smart village for economic development, infrastructure investment, and building up the human resource capability of the community. By using technology to uphold traditions and encourage sustainable development, rural communities may meet the challenges of modernity by embracing the smart village model. Ilham et al., (2023) highlighted that this strategy offers a chance to restore resilient and sustainable rural communities while also opening the door for innovation and rejuvenation. Even if there are still numerous ways to interpret the smart village concept, its execution is centred on information technology. Jayanthi et al. (2022).Elaborated: Depending on the capabilities of village components, different smart village implementations are used in different communities. In addition to implementing the use of information technology, a smart village concept may also expand the potential of the village, boost the economy, and improve the community's quality of life.

Aziiza & Susanto. (2020) study said Smart city and smart district development will be aided by the creation of smart villages. In general, the smart village concept places a higher priority on technology systems in conjunction with the community's native genius. The primary foundation for a smart village's success is the socio-cultural approach, which includes the following key elements: the government's role as a facilitator, the community as a customer, the development process by raising awareness of the participation of all elements, and priority targets for middle-class and underemployed communities. The foundation of a smart village's success is a valid identification of the different values, characters, norms, and issues that exist in society. Ren et al., (2024) study explained that the goal of putting smart villages into practice is to use information technology to empower rural communities, strengthen institutions, and enhance their welfare. Through the use of smart agriculture and digital infrastructure that facilitates better access to markets and essential services, the smart village concept has impacted the enhancement of farmers' welfare. Rural communities can attain sustainable development and resilience to environmental or economic crises by putting smart

village concepts into practice. Hanninger et al. (2021) mentioned the idea of social change in a rural society,increasing access to technology, bolstering community autonomy through locally created and sustainable solutions, and fostering greater cooperation between village residents and outside parties to address particular issues faced by rural communities,isanexample of social change in the context of smart villages. To evaluate the effects of implementing technology and smart agricultural practices on the lives and livelihoods of farmers as village communities, it is essential to evaluate farmer welfare during the transition to a smart village. Smart villages are attempting to use the digital shift to enhance deteriorating local services.Modernising agriculture is a process that truly calls for information and expertise. For efficient agricultural management, farmers are increasingly turning to online resources, agricultural advice, and knowledge sources. Lacković& Ivanović, (2021) highlighted that the adoption of smart villages is frequently impeded by a lack of funding, unclear development plans, a lack of cooperation among stakeholders, and a lack of understanding of the concept. According to this study, smart water, smart energy, smart health, smart transportation, and smart education are crucial tactics in the creation of smart villages that have a direct impact on raising farmers' standards of living. Food security and household income have increased as a result of the implementation of climate-smart agriculture, underscoring the function of CSAs in maximising agricultural output.

Maliki, (2024) summarised the concept of a village, illustrating how social norms are formed within a community. Rural locations are associated with social development because of the genesis of local traditions. People are dynamic creatures in their daily lives. Social change certainly occurs in many different businesses, and one of its indications is human. Social change is defined as any modification of a society's social institutions that affects its social structure, including its values, attitudes, and collective behaviours (Muke& Nilesh, 2017) stated that the spectrum of social change includes both material and immaterial cultural components; the influence of material components on immaterial components is emphasised.Niewiadomska,(2023) study said Smart communities and smart agriculture highlight the value of smart sensor technologies in agriculture to minimise losses and optimise procedures for higher yields. This study recommends that the creation of smart villages should prioritise smart agriculture. Through the reduction of input consumption, the optimisation of agricultural processes to boost yields, and the creation of predictions that are helpful to farmers, the smart village program promotes the improvement of rural communities' well-being. Smart Villages'use of IoT facilitates the creation of secure and effective technology ecosystems.

8. FINDINGS AND SUGGESTIONS

The potential for increasing agricultural output and raising rural populations' standard of living has been demonstrated by digital agriculture. Precision farming, remote sensing, and mobile-based advising services are examples of technologies that enable farmers maximise resource use and obtain timely information, which improves yields and revenue. Additionally, digital agriculture promotes economic inclusion by facilitating connectivity between farmers, markets, and financial institutions. However, because of sociocultural issues, including gender inequities, inadequate digital literacy, and unequal access to digital infrastructure, the influence varies greatly.Lack of professional assistance and inadequate internet connectivity continue to be problems in many rural areas, which prevent digital agricultural technologies from being widely used. It is imperative to invest in enhancing rural digital infrastructure, such as dependable internet connectivity and electricity supply, to fully realise the potential of digital agriculture in converting rural areas into smart villages. Inclusive adoption requires capacity-building initiatives that improve farmers' digital literacy, particularly among women

and underrepresented groups. Public-private partnerships should be promoted by policymakers in order to provide digital solutions that are affordable, relevant to local communities, and suited to small holder farmers. Integrating digital agriculture with other smart village components such as education, healthcare, and governance, will create synergistic benefits. Emphasising community participation and leveraging local knowledge can further ensure that digital initiatives are culturally appropriate and sustainable in the long term.

9. CONCLUSION

In conclusion, by increasing agricultural output, raising living standards, and promoting equitable economic growth, digital agriculture is essential to the conversion of rural communities into smart villages. Digital technology adoption has many potential advantages, but its success hinges on resolving important issues such gaps in digital infrastructure, sociocultural hurdles, and the requirement for customised, situation-specific solutions. Stakeholders can fully realise the potential of digital agriculture by making investments in digital literacy, infrastructure development, and community participation, as well as by encouraging integrated approaches that link agriculture with other facets of rural life. In the end, this will make it possible for rural communities to become more self-sufficient, resilient, and sustainable—a major step towards the realisation of smart villages and comprehensive rural development.

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