RESEARCH ARTICLE Agricultural Reviews, Volume 47 Issue 2: 331-336 (April 2026)

Assessing the Impact of Smart Farming Technology on Small-Scale Farmers: A Case Study of Jangoan Mandal, Telangana State

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10.18805/ag.R-2762

ABSTRACT

Background: Smart Farming Technology (SFT) employs advanced tools and techniques to enhance agricultural productivity and quality. Despite its potential, the acceptance and understanding of SFT among farmers are influenced by factors such as geographical location, education level, income and awareness. This study focuses on small-scale farmers in Jangoan mandal, Telangana State, to explore their perspectives and practices concerning SFT. Given the digital technology gap in agriculture, this research is crucial for enhancing food availability, promoting rural development and providing valuable insights for policymaking.

Methods: The study employed a descriptive analysis method, interviewing a sample of 252 out of 18,465 farmers using a semi-structured interview schedule. Spanning from 2022 to 2024. The interview schedule included semi-structured and structured questions to assess farmers' knowledge, practices and understanding of SFT. The topics covered SFT techniques, awareness of SFT's benefits and challenges, sources of information and training and perceptions of SFT's impact. Data analysis was conducted using SPSS software to provide insights into SFT adoption among farmers.

Result: Focusing on socio-economic and technological aspects. Results show that 79% of farmers believe SF reduces harvesting time and reliance on synthetic pesticides, while 72% assert that relevant regulations enhance biodiversity. Despite 82% recognizing the adverse effects of excessive chemical fertilizer use on soil and water quality and 80% willing to adopt alternative methods, only 6% report substantial annual incomes from agriculture. While 74% view SFT as strategic for crop management, many face storage and implementation challenges. This research highlights the need for comprehensive support from governments and agricultural institutions to bridge the digital technology gap, enhance food availability and promote sustainable agricultural development.

Key words: Agricultural technology adoption, Economic impact, Smart farming, Small-scale farmers, Socio-sustainable farming techniques.

INTRODUCTION

Smart farming technology (SFT) is a pioneering approach designed to minimize the use of unnecessary resources while ensuring the optimal use of materials, equipment and labour in agricultural practices. SFT techniques allow for the early detection of crop diseases, the prevention of crop wastage through efficient harvesting and the monitoring and tracking of livestock behaviour both within and outside the farm (Idoje *et al*., 2021). Integrating SFT into supply chain management simplifies operations (Pivoto *et al*., 2018). Farmers' knowledge and interest influence the adoption and effectiveness of SFT (Balafoutis *et al*., 2017). Currently, SFT technology is user-friendly and highly beneficial to agriculture. Younger farmers are more likely to adopt SFT compared to their older counterparts (Jithin Das *et al*., 2019). However, the increasing use of SFT and the Internet of Things (IoT) brings susceptibility to cyber threats and security issues (Gupta *et al*., 2020). There is also a lack of confidence among farmers regarding SFT's potential (Kernecker *et al*., 2020).

Recent technological advancements have significantly impacted real-time data evaluation and automated farming operations (Wolfert *et al*., 2017). Despite the potential benefits, the high cost of SFT is a significant barrier for small farmers, who often believe that only large farms can afford to implement SFT (Lieder and Schröter-Schlaack, 2021). Government support and subsidies are crucial for assisting small farmers (Raja and Reddy, 2012). Additionally, farmers require specialized knowledge and improved access to SFT-related information, training, advisory services and reliable digital infrastructure (Knierim *et al*., 2019). SFT offers a path to sustainable agriculture by

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How to cite this article: Katherasala, S. and Thaduru, S. (2026). Assessing the Impact of Smart Farming Technology on Small-Scale Farmers: A Case Study of Jangoan Mandal, Telangana State. *Agricultural Reviews.* **47(2):** 331-336. doi: 10.18805/ag.R-2762.

Submitted: 24-08-2024 **Accepted:** 17-12-2024 **Online:** 11-02-2025

diversifying technologies for crop production and livestock management and by connecting stakeholders to enhance food security mechanisms (Walter *et al*., 2017). Currently, SFT technology significantly improves crop productivity, real-time decision-making and crop management (Sharma *et al*., 2022). It also reduces the environmental impact of hazardous farming practices by minimizing the use of synthetic chemicals and lowering fuel, water and electricity costs (Javaid *et al*., 2022). To enhance productivity and resource efficiency, government and agricultural extension services should focus on helping small farms adopt this technology (Meena *et al*., 2024). Adoption of SFT reduces farm labour hours, stress levels and accident rates (Balafoutis *et al*., 2020; Said Mohamed *et al*., 2021).

Future technological advancements are set to significantly transform agricultural practices, from planting to harvesting (Bacco *et al*., 2019). SFT can help preserve biodiversity, encourage early adoption and enhance farm revenue (Dayananda *et al*., 2022). However, legal and regulatory challenges related to data sharing may arise, necessitating clear and comprehensible terms and conditions for data licensing (Wiseman *et al*., 2019). A lack of understanding of technical advancements could hinder the development of new agricultural automation capabilities (Sharma *et al*., 2022). It is essential for government bodies, agricultural research institutions, commercial organizations and non-governmental organizations to support farmers in adopting and utilizing smart farming technologies on a large scale (Eastwood *et al*., 2019). These stakeholders play crucial roles in the adoption of SFT from the farmers' perspective and governments should create effective policies and regulations to support farmers (Riungu *et al*., 2021). Anticipating governance is critical for comprehensive environmental management, as decision-making will shape the agriculture sector's development in the coming years and decades (Regan, 2019).

Importance and objective of study

This study aims to examine the impact of Smart Farming on small-scale farmers in Jangoan mandal of Telangana State. The specific objectives are to assess the level of adoption, analyse the economic benefits and challenges, investigate changes in crop management practices, identify knowledge gaps and provide recommendations to policymakers and agricultural extension services to encourage the adoption of these technologies and address the obstacles faced by smallholder farmers. The study holds significant importance in reducing the digital technology gap in agriculture, enhancing food availability, promoting rural development, providing valuable insights for policymaking and fostering sustainable agricultural practices. By addressing the challenges and opportunities related to the adoption of SFT, this research can offer crucial assistance to policymakers, agricultural extension agencies and farmers, ultimately contributing to a more sustainable and equitable agricultural sector.

MATERIALS AND METHODS

Smart Farming employs advanced tools and techniques to enhance agricultural productivity and quality. However, the acceptance and understanding of Smart Farming Techniques (SFT) among farmers vary according to factors such as geographical location, education level, income and awareness. This study was conducted in three mandals, namely Bachannapeta, Palakurthi and Raghunathpalli of Jangaon district, Telangana State, to explore farmers' perspectives and practices. Using a descriptive analysis method, 252 out of 18,465 farmers were selected through simple random sampling methods. The data were collected through a semi-structured interview schedule. The study, spanning from 2022 to 2024, was designed and reviewed by the Department of Sociology and Social Work at Osmania University, Hyderabad. The interview schedule comprised both semi-structured and structured questions with a statement scale to understand farmers' knowledge, practices and comprehension of sustainable farming methods. Topics included the types of smart farming techniques adopted, awareness of the advantages and disadvantages of SFT, challenges associated with SFT, sources of information and training and farmers' perceptions of the impact of SFT on their daily practices. Farmers' perceptions and expertise levels were assessed using a five-point Likert scale, ranging from strongly disagree to strongly agree and the data were analysed using SPSS version 22 software. The responses from farmers were included with percentages within the tables. This study scrutinized the collected data to provide valuable insights into the current state and future potential of SFT adoption and knowledge among farmers.

RESULTS AND DISCUSSION

Socio-economic aspects

The age group analysis shows that 33% of participants are aged between 25 and 35, 26% are between 36 and 45 and 41% are 45 and above. This indicates a predominant inclusion of younger farmers, making up 59% of the total participants aged between 25 and 45 (Table 1).

An examination of annual incomes reveals that only 12% of farmers earn between 300,000 to 400,000 rupees, followed by 6% earning 500,000 and above. The majority, 51%, have an annual income ranging from 100,000 to 200,000 rupees, while 31% of farmers earn below 100,000 rupees per annum. This suggests that most farmers have an annual income below 200,000 rupees, with a significant portion earning below 100,000 rupees per year, excluding all investment-related costs in their cultivation processes.

The size of the farmers' landholdings significantly impacts their limited incomes. Specifically, 72% of farmers

possess 1 to 4 acres of dry land and 71% own 1 to 4 acres of wet land. Only 2% of the farmers have 11 acres or more of dry land and none have over 11 acres of wet land. Thus, small landholdings, particularly those ranging from 5 to 10 acres, which account for 28% of dry land and 29% of wet land holdings, reflect their agricultural legacy.

Productive aspects

The implementation of innovative technologies in agriculture presents a diverse range of perspectives among farmers. A significant majority, 79%, use new fertilizers on their fields and 88% employ advanced pesticides and other synthetic chemicals to optimize land productivity. Innovation extends beyond these practices, involving a comprehensive conceptual framework aimed at enhancing all aspects of agricultural production.

This study examines the latest fertilizers, incorporating both inorganic and organic elements and explores advancements in seed varieties, including hybrid and "*Bacillus Thuringians"* (BT) types. Furthermore, it analyses farmers' perceptions of recent technological breakthroughs that enhance agricultural practices in various ways. A notable drawback highlighted is that 13% of farmers lack the capability to store their agricultural products in warehouses, which presents a significant challenge in the effective management of their yields (Table 2).

This study evaluated farmers' understanding of recent technological advancements and the challenges they face on their farms, using a Likert scale. It also included aspects of creative adaptation, such as the use of new technologies, the spread of innovations within and across regions and the benefits of technology in agriculture. The analysis of the Likert scale data focused on comparing the median and mode.

Results showed that 73% of farmers reported a decrease in crop illnesses due to the implementation of innovative practices. Additionally, 60% of farmers believed that modern technology would help protect soil. However, influenced by social media and other platforms, these farmers had a theoretical rather than practical understanding of these methods. The concept of new technology encompassed multiple dimensions, with farmers primarily emphasizing the introduction of synthetic fertilizers as a significant advancement. They hypothesized that combining insecticides with innovative methods would reduce fungal infections in crops. Interestingly, 49% farmers reported reducing pesticide use to control fungus, which is a prudent decision. Moreover, 81% of farmers indicated that they might further reduce insecticide usage in the future due to advancements in agriculture. However, it was observed that many farmers were still excessively using pesticides and insecticides.

Table 1: Socio-economic conditions: Age, Income and Land Landholdings of farmers.

Variables	Category	C	%
Age	25-35	83	33%
	36-45	66	26%
	45 and above	103	41%
Income	Below 100,000	78	31%
	100,000-200,000	129	51%
	300,000-400,000	30	12%
	500,000 and above	15	6%
Land Holdings in acres	Dry land: 1-4	181	72%
	Wet land: 1-4	179	71%
	Dry land: 5-10	71	28%
	Wet land: 5-10	73	29%
	Wet land: Above 11	0	0%
	Dry land: Above 11	5	2%

C- Count of farmers, % - Percentage of farmers.

Table 2: Farmers perspectives on technology aspects.

Statements	C	%
Implementation of innovative practices decreases crop illnesses	184	73%
Modern technology provides soil protection.	151	60%
Adoption of innovative methods reduces fungal infections.	123	49%
Utilizing innovative methods decreases insecticide usage.	204	81%
New technologies shorten harvesting times.	199	79%
Compliance with laws and regulations in technology use protects biodiversity.	181	72%
Synthetic chemicals degrade soil quality.	207	82%

C- Count of farmers, % - Percentage of farmers.

Table 3: Farmers perspectives on technology and adoption.

Statements	C	%
Adoption of smart farming techniques improves irrigation.	189	75%
Technological use alters current agricultural practices.	209	83%
Willingness to adopt new technologies increases with government support.	202	80%
Diffusion of innovation enhances crop yield.	171	68%
Cultivation of new crop varieties boosts farmers' economic status.	164	65%
Smart farming techniques improve crop management.	186	74%
Smart farming enhances and protects biodiversity and natural resources.	192	76%
Adoption of smart farming methods reduces pollution.	129	51%

C- Count of farmers, % - Percentage of farmers.

According to a study, 79% of farmers indicated that implementing technological advancements in agriculture would shorten harvesting times and reduce dependency on synthetic pesticides. Additionally, 72% of respondents believed that complying with relevant laws and regulations for using new technologies would promote biodiversity. Notably, 82% of the farmers were aware that excessive use of chemical fertilizers could degrade soil quality and pollute water sources, highlighting their understanding of the adverse effects of soil degradation and environmental pollution. Several farmers had already observed these negative impacts in their local area (Table 3).

Perspective on technology and adoption

The attitudes and knowledge of farmers toward innovative technologies on their fields were evaluated. Results show that 75% of farmers believe innovation has improved irrigation and the use of "high-yield varieties" (HYV) to boost agricultural production. However, 71% think that adopting new technical methods would necessitate altering their current practices. Furthermore, 83% expressed doubts about reducing chemical pesticide use, as they believe chemicals are essential for high crop yields. Nonetheless, 80% acknowledged the detrimental effects of their long-term practices and showed a willingness to adopt improved or alternative methods if supported by the government, agricultural research institutions, or other relevant organizations. Additionally, they highlighted the need for guidance and education on these concepts. The farmers' positive response may pave the way for the adoption of more sustainable and resource-efficient agricultural practices that enhance the environment.

The dissemination of innovation in adopting agricultural technology by farmers. Approximately 49% of farmers strongly agreed on the necessity for the agricultural industry to engage in innovation through the introduction of new crop varieties. A majority, 68%, believed that the diffusion of innovation would increase their farm yields. Moreover, 65% expressed that early adoption and marketing of new crop varieties would improve their reputation within the farming community and their overall quality of life. However, 38% of farmers expressed doubts about the longevity and technological progress in agriculture, fearing that these innovations might eventually become obsolete.

Smart Farming represents a significant innovation in agriculture, employing cloud storage, big data, mobile devices, precision agriculture, artificial intelligence and geospatial technology to enhance crop management and increase production. The farmers' perspectives on the use of Sustainable of SFT in India's agricultural sector. Among those interviewed, 74% considered SFT a strategic innovation that could improve crop management and practices. Additionally, 67% said SFT could enhance biodiversity and natural resources, while 76% believed it could improve work culture and economic prospects for farmers. Furthermore, 51% felt that SFT could help reduce pollution.

The adoption of innovative technology in agricultural practices among Indian farmers reveals a complex landscape of both potential and challenges. While many farmers acknowledge that strategic innovation is essential for improving crop management and productivity, there are significant barriers to widespread adoption (Satyajeet *et al*., 2024). These barriers include scepticism about the effectiveness of new technologies, limited knowledge and experience and restricted access to markets and storage facilities.

This study's findings have several implications for the theory and practice of agricultural innovation. First, by highlighting the factors of knowledge, attitudes, perceptions and social networks influencing farmers' adoption decisions (Singh and Verma, 2023), it contributes to the body of research on innovation dissemination (Singh and Verma, 2023). Second, it provides insights into the challenges and opportunities of integrating smart agricultural technologies in the Indian context, emphasizing the need for more data, guidance, encouragement and support for farmers (Sharma and Tiwari, 2023). Third, it underscores the potential benefits of innovative techniques for farmers, the environment and natural resources, such as improved crop quality and yield, enhanced biodiversity, better soil health and reduced pollution and resource use (Kernecker *et al*., 2021).

Future research should address these limitations and deficiencies to expand understanding and support for technology adoption (Klerkx *et al*., 2010). Collaboration among key stakeholders, including the government, agricultural research institutions and other relevant organizations, is crucial for promoting and facilitating the acceptance of new ideas by farmers (Katherasala and Bheenaveni, 2024a). By working together, these actors can help farmers overcome challenges and realize the benefits of innovative agricultural practices, paving the way for a more sustainable and productive agricultural sector (Katherasala and Bheenaveni, 2024b).

The data highlights the necessity for targeted support and interventions to address these economic constraints. Enhancing access to markets, storage facilities and providing education and training on innovative technologies can empower farmers to improve their productivity and economic standing (Saikia and Saikia, 2022). Furthermore, fostering an environment where sustainable practices are accessible and economically viable will be crucial for the future of small-scale farming in the region.

CONCLUSION

This paper has explored the benefits and challenges of adopting innovative agricultural technologies for farmers, the environment and natural resources. The findings indicate that most farmers consider innovation essential for effective crop management and increased yields. However, they also recognize the negative impacts of prolonged use of synthetic chemicals and are open to alternative methods if supported by authorities. The study identifies several barriers to the adoption of new technologies, including scepticism about their long-term viability, a lack of training and education and limited access to markets and storage facilities. It underscores the need for comprehensive efforts from the government, educational institutions and other stakeholders to support farmers in adopting these innovations.

The research suggests enhancing farmers' awareness and acceptance of innovation by providing opportunities for knowledge exchange within the farming community, supporting early adopters and offering detailed information and guidance on the benefits and risks of new technologies. Ultimately, the study emphasizes that innovation in agriculture must address the farmers' needs, preferences and values and be approached as both a technological and socio-cultural issue. Future research should continue to explore these dynamics to support sustainable agricultural development.

ACKNOWLEDGEMENT

The authors express their gratitude to the Jangoan farmers for their invaluable information and active engagement in the research work. This research piece is a component of a Ph.D. study and the abstract of the work was presented at the 1st Asian conference on "Unfolding Emerging Issues in the Context of Changing Climate Scenario." The event took place at Dhaka University in Bangladesh and was hosted by the Centre for People and Environ (CPE). We express our gratitude to all the panellists for providing their invaluable feedback to enhance this article.

Disclaimer

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Conflict of interest

The authors, Srinivas Katherasala and Surender Thaduru, declare that they have no conflict of interest to publish this article. No funding has been provided for this research work by any institution or organization.

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