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From Innovation to Implementation: A Qualitative Study of Kushinagar District Sugarcane Farmers' Technological Experiences

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HIGHLIGHTS

- Research-driven technical advancements and the real-world experiences of sugarcane farmers differ significantly.
- Because of poor digital literacy and inadequate extension assistance, the advantages of digital tools which have increased efficiency and transparency remain unequal.
- Local agroclimatic, irrigation, and farm-size realities are not taken into account by universally applicable research solutions.
- Sustainable sugarcane development requires research that is context-specific, participatory, and has stronger institutional and feedback links.

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ABSTRACT

As information and communication technologies and precision agriculture instruments are integrated, agricultural management techniques are being enhanced. Through improved input applications, communication across various hardware and datasets, and reduced production costs, this integration intends to improve the sustainability of the sugarcane crop production system. Many sugarcane farmers, especially smallholders, continue to face low profitability, increased input prices, labour shortages, and limited benefits from institutional and digital innovations despite consistent research investment and technical advancements. The research tried to understand sugarcane-growing farmers' viewpoints and experiences about digitalization and challenges in sugarcane farming. In the Kushinagar district of Uttar Pradesh, exploratory-descriptive qualitative research was carried out at the Deoria Sugarcane Committee's Jaura Bazar Centre "A" between October 2023 and January 2025. A pre-tested semi-structured guide was used to conduct in-depth, in-person interviews with purposively recruited twenty-four sugarcane producers. Interviews were audio recorded, verbatim transcribed, and subjected to thematic analysis using NVivo 15. Results show significant discrepancies between farmers' lived experiences, extension services, and agricultural research. Technical innovations like online slip generation, digital payment systems, and digitization have increased operational efficiency and transparency. Adoption was hampered by low digital literacy, limited access to advanced technology, insufficient extension assistance, and poor institutional coordination.

INTRODUCTION

The cultivation of sugarcane has changed significantly in recent decades as a result of institutional, technological, and economic advancements. Sugarcane continues to be one of India's most significant commercial crops and is essential to rural lives and agro-based businesses, especially in the state of Uttar Pradesh. To improve agricultural operations and marketing procedures, tools

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including mobile phones, digital advising platforms, online cane slips, and direct bank payment methods have been implemented. ICT is crucial to modern agriculture, according to Devi et al. (2025), since it gives farmers fast and precise information that improves production, farm management, market access, price, and income while lowering agricultural hazards. Mukhamedova et al. (2022) state that modern digital information systems are necessary for the effective use of precision farming, particularly when utilising complete Farm Management Information Systems. However, the use of digital technology in agriculture is still unequal, especially among small and marginal farmers who frequently encounter issues with infrastructure, financial resources, and digital literacy. Udisha et al. (2023) discovered issues such as a lack of understanding regarding digital agriculture, a lack of enabling legislation, and poor internet connectivity. The authors recommend creating supportive laws, increasing digital literacy, and modernizing infrastructure to promote the use of digital agriculture. Awan et al. (2019) claim that the lack of local information centers and the high percentage of illiteracy are the primary barriers keeping farmers from utilizing modern information systems. Due to their limited exposure to modern technology, many farmers still employ traditional methods and lack familiarity with contemporary agricultural practices. Information and communication technologies have become a crucial part of contemporary agricultural extension operations. Farmers are using ICT tools like smartphones, social media, and digital advisory services more frequently to get timely agricultural information, weather forecasts, and market updates (Mukherjee & Jha, 2024). Singh and Mathur (2024) found that ICT platforms offer tremendously more potential for providing rural communities with agricultural information and enhancing farmers' ability to manage their farms more effectively. According to the report, farmers are depending more and more on ICT tools to get crop-related information, advisory services, and technology advancements that help them make agricultural decisions. Increasing use of digital devices, such cellphones, in obtaining agricultural information has also been highlighted by recent study. According to a research by Singh et al. (2025), most farmers utilized cellphones to get information about market pricing, pest control, and weather predictions. However, the study also showed that farmers' use of advanced digital services is still modest and is impacted by variables including knowledge level, landholding size, and education level. Research has shown how crucial it is to increase farmers' access to and understanding of ICT for successful digital agriculture. According to Kumar (2025), even though farmers are becoming more aware of the advantages of ICT tools, the majority of farmers still only have a medium level of ICT understanding. This suggests that more digital literacy and extension help are necessary to increase technology adoption.

METHODOLOGY

This study used an exploratory-descriptive qualitative research technique to give a thorough understanding of farmers' perspectives, challenges, and experiences with digitalization and technological transformation in sugarcane farming. The study was guided by the Consolidated Criteria for Reporting Qualitative Research) checklist Tong et al. (2007) to ensure methodological quality, rigor, and transparency. Between October 2023 and January 2025, in depth, face-to-face interviews were carried out at participants' homes or farms, based on their preferences. The research team adhered to the COREQ standards in order to ensure the transparency, validity, and dependability of the qualitative data. Since the Jaura Bazar Center "A" within the Deoria Sugarcane Development Committee in Kushinagar district had the greatest sugarcane output under the Cooperative Sugarcane Development Committee Limited, Deoria, the current study was purposefully carried out there in 2024. According to government statistics, Kushinagar district has become one of Uttar Pradesh's top producers of sugarcane. Approximately 3.62 million metric tons of sugarcane were grown on 68,739 hectares, yielding roughly 52.69 quintals per hectare (KVK Kushinagar). Twenty-four sugarcane growers participated in the study. Three participants were selected by each of the eight villages out of sixteen villages. An appropriate sample size for qualitative analysis was maintained while balanced geographic representation was ensured by choosing three farmers every village. Participants were chosen on the basis of their willingness to take part in the study, marketing their crop through the sugar mill system, and having at least five years of experience growing sugarcane. Farmers from a variety of age groups between 31 and 40, between 41 and 50, and above 50 were included in the sample. Capturing intergenerational disparities in opinions toward the adoption of digital technology in agriculture was made easier by include a variety of age groups, levels of education (from primary school to higher secondary and graduate school). This variance made it easier to comprehend how farmers' knowledge and use of digital agricultural technology are influenced by their level of education. Farm sizes (less than two hectares, two to four hectares, and more than four hectares). This classification made it easier to examine how the availability of resources affects the use of technology in sugarcane growing. With the participants' informed consent, the interviews were audio recorded, lasted 30 to 40 minutes, and were conducted in Hindi, the native language. Coded labels (R-1, R-2, etc) were used to identify the respondents and to protect participant privacy. Data saturation was reached at 14 interviews. In order to preserve sample uniformity throughout the chosen villages and to strengthen the reliability and credibility of the results, the researchers still carried out all 24 scheduled interviews. Following Braun et al. (2022) six-step methodology (Familiarization with the data, generating initial codes, Searching for themes, Reviewing themes, Defining and naming themes, Reporting the findings) thematic analysis has been used to analyze the data Ahmed et al. (2025). NVivo version 15 was used to manage, code, and arrange the qualitative data. Themes were cross-checked against raw data to verify consistency and reliability, and coding selections were revisited frequently to improve rigor.

RESULTS

Theme and sub-theme based on the interview questionnaire as per the responses

Theme 1- *Changing sugarcane production techniques*

Farmers claim that chemical-based farming practices have definitely replaced traditional organic farming methods. In order to meet manpower limits and meet production demands, the prior

reliance on organic fertilizer has progressively been replaced with chemical fertilizers. Similar changes have been observed in the expanding sugarcane systems of northern India, where productivity demands are driving an increase in the usage of external inputs. Adopting better planting techniques, especially trench sowing, was generally considered as beneficial due to wider spacing, moisture retention, and higher yields, supporting research indicating improved agronomic approaches raise sugarcane output under smallholder settings.

Shift from traditional to chemical-based farming

Instead of employing organic manures like cow dung, farmers reported using chemical fertilizers. Rather than being a decision, this shift was a response to the growing need for higher yields, shorter crop cycles, and the paucity of organic inputs. While chemical fertilizers boosted yield, farmers expressed worries about rising costs and declining soil health. "When chemical fertilizers were not available, we used to cultivate sugarcane by adding cow dung manure. Gradually, developed chemical fertilizers came." (R-5)

Adoption of improved planting methods

Improved planting techniques, particularly trench sowing, were viewed by farmers as a significant advancement. Farmers highlighted greater moisture retention, better plant spacing, and observable production enhancement, which promoted wider implementation of this technique despite the need for initial technical support. "Now the same is being sown at a distance of one foot by trench method, and the yield is good." (R-7)

Theme 2- *Economic stress and inequitable allocation of resources*

Respondents commonly cited rising input costs as their primary concern. Fertilizers, pesticides, manpower, and mechanization have all contributed to a sharp increase in agricultural costs, which has reduced profit margins. These rising costs disproportionately affected small and marginal farms, expanding the gap between resource-rich and resource-poor farmers. This trend is in line with other studies showing that larger farmers often benefit more from capital-intensive agriculture than smallholders.

Increasing cost of cultivation

Farmers stated a significant rise in the cost of inputs, such as labour, machinery, herbicides, and fertilizers. Although sugarcane is still grown, producers are increasingly susceptible to institutional and market delays since the profit margins are decreasing. "The cost of sugarcane inputs has increased. Earlier the cost was not so much, therefore there was inclination towards sugarcane cultivation." (R-12)

Resource disparity among farmers

Inequality in access to machinery, quality inputs, and digital services was frequently highlighted. Farmers with better financial resources were able to adopt modern technologies, while small and marginal farmers struggled to keep pace, leading to unequal benefits from technological progress. The only farmers who can benefit from new technologies are still farmers with adequate resources. Those with limited resources can't even access or use 10% of these facilities. (R-2).

Theme 3- *Farmers' experiences with agricultural digitalization*

Digital initiatives such as online slips and direct bank payments are well received by farmers. Digital technology improved payment process transparency, reduced the need for intermediaries, and reduced in-person visits to government offices. These findings support other studies that demonstrate how digitalization enhances the efficacy, accountability, and confidence of agricultural marketing systems.

Access to digital information and online slips

Farmers admitted that their reliance on intermediaries and frequent visits to organization offices has decreased, "thanks to digital technologies like online slips". These methods made it easier to obtain timely information on cane supply management and harvesting schedules. Harvesting programs used to be manually organized by supervisors, and farmers had to visit the society office frequently. Thanks to developments in online technology, this process is now more effective and requires less frequent physical coordination. (R-2)

Digital transactions and financial transparency

Direct bank payments or digitalization of payments were viewed as a major improvement as it ensure timely and transparent transactions. Farmers appreciated reduced corruption and easier payment processing, which boosted their trust in governmental procedures. "Now the bank has made the payment, the money in the account will go to the farmer's account, he will be able to withdraw his money easily." (R-10)

Theme 4- *Digital divide and limited access to technology*

Despite technological developments, there is still a significant digital divide. Low digital literacy hindered the efficient use of mobile phones and applications, particularly among older and less educated farmers. Additionally, most farmers said they had limited firsthand experience with cutting-edge technologies like drones. This unequal access reflects broader concerns in the literature on the uneven adoption of digital agriculture technologies in rural areas.

Limited digital literacy

According to some of the respondents, older and less educated farmers found it difficult to use mobile devices and apps. Due to their lack of digital literacy, farmers were more reliant on others and had less trust in their ability to adopt new technologies. "Many farmers do not know how to use a mobile because old farmers are not educated, so they have to face problems." (R-12)

Lack of exposure to advanced technology

Farmers claimed to have little to no familiarity with advanced machinery such as drones. Lack of training, demonstrations, and local availability hampered the adoption and understanding of precision technology. Farmers said they had little to no direct

experience with advanced agricultural technologies, such as GPS-enabled tractors, sensor-based soil testing devices, automated irrigation systems (drip and sprinkler systems with digital controllers), drones for crop monitoring and spraying, and mobile-based decision support apps. The lack of field demonstrations, training programs, and local availability of these technologies limited farmers' awareness and practical comprehension of precision agricultural equipment. "I have not seen a drone. There is no drone here in our area. We have not seen how a drone works." (R-8). "Drones are not available or demonstrated locally; we have only heard about them and have not seen any in our area." Precision sprayers, digital crop monitoring tools, sensor-based irrigation systems, drones, and other cutting-edge technologies are not available or demonstrated locally. They have just heard about these technologies, they haven't really seen or used them locally. (R-14)

Theme 5- *Crop shift and economic dependence on sugarcane*

This theme captures the broader structural transformation of regional agricultural systems, as livelihood possibilities are more influenced by market integration and institutional frameworks rather than agronomic variation. Sugarcane's growing dominance is a reflection of farmers' alignment with crops connected to legitimate procurement channels and trustworthy payment mechanisms. This change, which has reoriented farming toward income stability and commercial production while simultaneously decreasing crop choice flexibility and increasing reliance on sugar mills and legal frameworks, has made farm households more vulnerable to institutional disruptions.

Shift from food crops to sugarcane

The switch to sugarcane is an example of farmers' adaptive reaction to market risk and economic uncertainty. Sugarcane is viewed as a more reliable source of revenue due to its well-organized procurement system and more steady profits. This shift implies a decrease in agricultural diversity and an increase in commercialization, which might improve short-term income stability but also increase reliance on institutional arrangements and susceptibility to changes in the market and in policy. "In the past, the area's main crops were wheat and mustard, but over time, farmers have increasingly switched to sugarcane cultivation." (R-1)

Sugarcane as a cash crop

Due to guaranteed procurement and consistent payments from sugar mills, sugarcane was widely acknowledged as a reliable cash crop, making it essential to household financial planning. "Sugarcane is a cash crop; the factory gets its bundle made and gives us cash for it." (R-3)

Theme 6- *Improved productivity and emerging production risks*

This theme highlights the growing discrepancy between the long-term durability of intensive agricultural methods and sugarcane production systems. Even while technological developments have altered production results, farmers still have to deal with increasing uncertainty regarding crop performance and input efficacy. These problems point to structural weaknesses in input control, agronomic support, and sustainability planning, suggesting that output growth alone cannot ensure stability or reduce risk in sugarcane production.

Yield improvement through technology

Farmers observed notable yield improvements through methods such as trench planting and improved land preparation. These benefits reinforced positive attitudes toward technological interventions. "We had grown more sugarcane by the Trench method; we had bought it one year. We had grown a lot of sugarcane." (R-5)

Pest, disease, and inputs quality issues

Farmers voiced grave worries about insect infestations, disease outbreaks, and poor crop protection inputs despite output increases. Production hazards were increased by a lack of timely and efficient responses. "Sometimes we face huge loss because crops are get affected from diseases… But there is no cure for it." (R-11)

Theme 7- *Institutional and policy related constraints*

One significant limiting element was found to be an organizational challenge. Farmers complained about stringent subsidy requirements, ongoing middlemen's participation, and factory delays in sugarcane procurement, which resulted in financial losses. These limitations have been well documented as obstacles to the development of inclusive agriculture.

Subsidy restrictions and middlemen

Farmers expressed dissatisfaction about restrictive subsidy conditions and the continued involvement of intermediaries, which restricted their access to government assistance and increased their reliance. "This year they have also put a binding that means only the sugarcane of those who have sown sugarcane variety 9301 will be sown and subsidy will be given to that sugarcane only." (R-2)

Procurement Delays in Sugar Mills

Delays in procurement by sugar mills were a major problem that often led to production loss, quality degradation, and financial pressure. "Many time factory does not take the sugarcane on time, then the farmer suffers a loss." (R-3)

Inadequate extension support

Farmers frequently said that their capacity to implement and oversee new technologies in sugarcane production was hampered by a lack of field-level support, technical advice, and extension services. In contrast, frequent field demonstrations, seasonal training programs, pest advisories, soil health services, and mobile-based information via Krishi Vigyan Kendras and state agencies were seen as more systematic forms of extension support for food crops like rice and wheat. Farmers pointed out that sugarcane does not have the same emphasis on crop-specific expansion. Regular field inspections, stage-by-stage technical recommendations, mechanization demonstrations, and prompt assistance with pest and disease control were all anticipated. "The government does not provide us with sufficient assistance. We are compelled to handle everything ourselves without institutional support, and there are no observable advantages. (R-3)

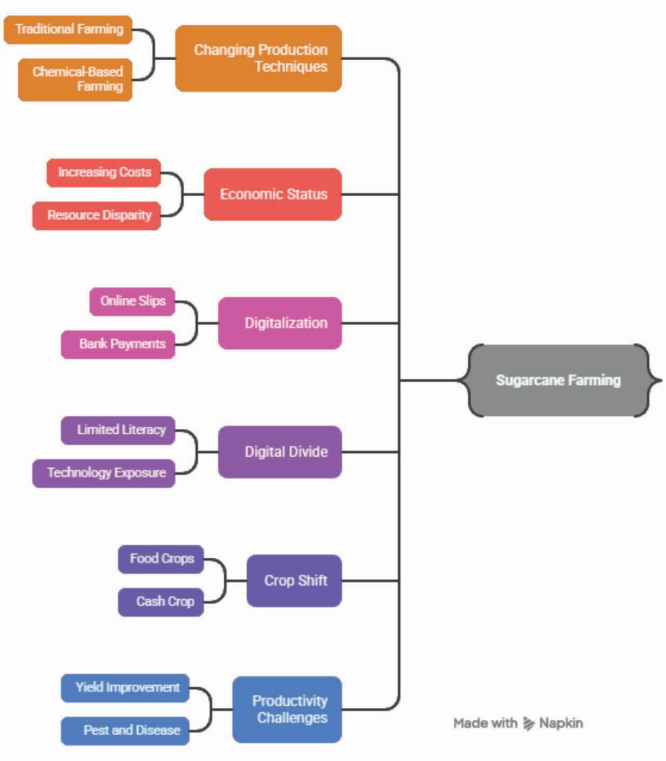

Figure 1. Challenges and opportunities in sugarcane farming

Water scarcity and irrigation issues

The absence of a steady supply of water throughout critical growth phases was highlighted by farmers, and irrigation seemed to be a major barrier. Water scarcity was considered a major obstacle to crop survival and productivity. "There is a need for improvement in water availability by the government, suppose we plant sugarcane in 5 acres, now if water is not available in May, June, then everything will become useless." (R-5)

DISCUSSION

The study's conclusions are consistent with larger structural changes in Indian sugarcane farming, where middle-aged and smallholder farmers continue to be the key players influencing production choices. The prevalence of smallholder profiles in cane belts is reinforced by empirical data that sugarcane producers frequently operate on tiny landholdings with restricted access to finance and credit (Singh, 2025). Across agro-ecological areas, national trends of small-scale farming and land fragmentation continue to limit production and the uptake of new technologies (Roy et al., 2020). According to socioeconomic studies conducted in Uttar Pradesh, the majority of farm households are small and marginal farmers, and land fragmentation affects agricultural methods and livelihood strategies (Kashyap et al., 2022). The respondents' preference for chemical fertilizers over organic inputs is consistent with earlier studies that demonstrate commercial crop agricultural intensification. This intensification has led to short-term improvements in output, but it has also increased cultivation costs and caused problems with soil, particularly for smallholders (Pingali, 2012; Jat et al., 2016). Farmers viewed digital interventions favourably because they increased transparency and decreased reliance on middlemen, especially online slips and direct bank payments. Studies looking at digital governance and mobile-based services in agriculture have shown similar results, emphasizing improvements in efficiency and confidence in institutional systems (Aker, 2011; Fabregas et al., 2019). Kremer and Houngbo's (2021) claims on the transformative possibilities of digital agriculture are supported by the substantial improvements in information availability, transparency, and fraud reduction brought about by digital interventions like online slips, mobile phones, and direct bank payments. Farmers' assessments of reduced dependency on intermediaries and greater payment predictability imply positive institutional change. However, the unequal distribution of these advantages as a result of low digital literacy is consistent with research on rural technology adoption, which warns that if capacity building is insufficient, digitalization may worsen inequality (Trendov et al., 2019; Emeana et al., 2020). Satapathy et al. (2024) reported that lack of ICT knowledge, financial support, and reliance on traditional information sources significantly restricted ICT adoption in Odisha. While basic ICT tools like televisions and cell phones were widely available, their use for informed farm decision-making remained superficial (Panda et al., 2019; Singh & Mathur, 2024). The analysis reveals a significant digital disparity despite these advancements. The wider advantages of digitalization are limited by poor exposure to cutting-edge technology like drones, insufficient knowledge of agricultural uses, and limited digital literacy. This result is consistent with the observations of Harris and Achora (2018) and Emeana et al. (2020) that uneven access to digital tools may exacerbate rather than lessen already-existing inequities. Insufficient exposure to cutting-edge technologies, such as drones, exposes persistent shortcomings in prolonged efforts and localized demonstrations. Research on smart and precision agriculture often shows that without strong extension assistance, smallholders cannot access new technologies (Wolfert et al., 2017; Shitu et al., 2018; Klerkx et al., 2019). Organisational obstacles, including strict subsidy rules, delayed sugar mill procurement, and poor extension services, continue to erode farmers' faith. Furthermore, the argument that technical adoption alone is insufficient in the absence of suitable physical infrastructure and climate-resilient planning is supported by irrigation-related challenges and water scarcity (Shirsath et al., 2017: Barman et al., 2026).

CONCLUSION

The study highlights that while mechanization and digitalization have increased the production, efficiency, and transparency of sugarcane cultivation, their benefits are still not equitably distributed. For small and marginal farmers, issues including rising input costs, limited access to cutting-edge technologies, insufficient extension services, and water shortages persist. If digital agriculture is to significantly contribute to inclusive rural development, technological innovation must be combined with targeted policy changes, more institutional support, and investments in irrigation and digital literacy. Technology integration with equitable governance frameworks is necessary to achieve sustainable sugarcane development. Even while farmers utilize chemical fertilizers, trench sowing, mechanized ploughing,

smartphones, online slips, and direct bank payments more regularly, access to state-of-the-art technology such as drones, soil testing facilities, and agricultural mobile applications is still uneven. Small and marginal farmers in particular confront a number of obstacles, including rising input costs, labor shortages, water scarcity, limited extension services, and restricted access to subsidized machinery.

DECLARATION

Data availability statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Authors contribution: The study was conceptualized by PC, who also created the research design, carried out fieldwork, gathered qualitative data, completed data transcription and theme analysis, and wrote the initial report. In addition, she was in charge of creating tables and integrating the results with relevant research. LV oversaw the whole academic program, helped create the interview guide and study strategy, and critically examined and updated the work for intellectual substance. The final draft of the paper was read and authorized by both writers, who both agreed to take full responsibility for the work.

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Ethical consideration and consent to participate: Informed consent of the participants.

Conflicts of interest: The authors declare no conflicts of interest.

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REFERENCES

Ahmed, S. K., Mohammed, R. A., Nashwan, A. J., Ibrahim, R. H., Abdalla, A. Q., Ameen, B. M. M., & Khdhir, R. M. (2025). Using thematic analysis in qualitative research. *Journal of Medicine, Surgery, and Public Health*, *6*, 100198.

Awan, S. H., Ahmed, S., & Hashim, M. Z. (2019). Use of information and communication technology ICT in agriculture to uplift small scale farmers in rural Pakistan. *American Journal of Engineering and Technology Management*, *4*(1), 25-33.

Barman, B., Singh, R., Padaria, R. N., Nain, M. S., Quader, S. W., & Praveen K. V. (2026). A qualitative synthesis of barriers to agriculture 4.0 adoption: evidence from a systematic literature review. *Discover Agriculture, 4*, 34 https://doi.org/10.1007/s44279-026-00505-7

Braun, V., Clarke, V., & Hayfield, N. (2022). 'A starting point for your journey, not a map': Nikki Hayfield in conversation with Virginia Braun and Victoria Clarke about thematic analysis. *Qualitative Research in Psychology*, *19*(2), 424-445.

Devi, T., Sharma, K., Sharma, N., Sethi, D., Devi, N., & Ankita, K. (2025). Role of ICT in bridging the knowledge gap in rural agriculture. *International Journal of Agriculture Extension and Social Development*, *8*(1), 20-24.

Emeana, E. M., Trenchard, L., & Dehnen-Schmutz, K. (2020). The revolution of mobile phone-enabled services for agricultural development (m-Agri services) in Africa: The challenges for sustainability. *Sustainability*, *12*(2), 485.

Harris, C. G., & Achora, J. C. (2018, September). Designing ICT for agriculture (ICT4A) innovations for smallholder farmers: The case of Uganda. In *Proceedings of the XIX International Conference on Human Computer Interaction*, pp 1-9.

Jat, M. L., Gathala, M. K., Saharawat, Y. S., Tetarwal, J. P., Gupta, R., & Singh, Y. (2016). Conservation agriculture in irrigated intensive cropping systems of South Asia. *Field Crops Research, 190*, 33–44.

Kashyap, P., Prusty, A. K., Panwar, A. S., Paramesh, V., Natesan, R., Shamim, M., & Singh, M. P. (2022). Achieving food and livelihood security and enhancing profitability through an integrated farming system approach: a case study from western plains of Uttar Pradesh, India. *Sustainability*, *14*(11), 6653.

Klerkx, L., Jakku, E., & Labarthe, P. (2019). A review of social science on digital agriculture, smart farming and agriculture 4.0: New contributions and a future research agenda. *NJAS-Wageningen Journal of Life Sciences*, *90*, 100315.

Kremer, M., & Houngbo, G. F. (2021). Grow back better? Here's how digital agriculture could revolutionise rural communities affected by COVID-19. In *World Economic Forum*.

Krishi Jagran. (2021, September 13). Cash crops in Uttar Pradesh and their production status.

Kumar, S. (2025). Determining the knowledge level and accessibility of major ICT tools by farmers in Madhya Pradesh. *Indian Journal of Extension Education, 61*(4), 101–105.

KVK Kushinagar. (n.d.). District agricultural production statistics. Krishi Vigyan Kendra, Kushinagar, Uttar Pradesh.

Mukhamedova, K. R., Cherepkova, N. P., Korotkov, A. V., Dagasheva, Z. B., & Tvaronaviciene, M. (2022). Digitalisation of agricultural production for precision farming: A case study. *Sustainability*, *14*(22), 14802.

Mukherjee, S., & Jha, S. K. (2024). Utilization pattern of information and communication technologies among the farming community of West Bengal. *Indian Journal of Extension Education*, *60*(1), 7-13.

Panda, S., Modak, S., Devi, Y. L., Das, L., Pal, P. K., & Nain, M. S. (2019). Access and usage of Information and Communication Technology (ICT) to accelerate farmers' income. *Journal of Community Mobilization and Sustainable Development, 14*(1), 200-205.

Pingali, P. L. (2012). Green Revolution: Impacts, limits, and the path ahead. *Proceedings of the National Academy of Sciences, 109*(31), 12302–12308.

Roy, S., Singh, A. K., Bera, S. K., & Bhattacharya, S. (2020). Land structure and level of fragmentation in typical small-marginal

agricultural holdings in India. *The Indian Journal of Agricultural Sciences*, *90*(4), 699-703.

Satapathy, G. P., Das, S., Sahu, B. L., Dash, S., & Tripathy, M. (2024). Constraints of ICT adoption in agriculture in Khurda and Bargarh districts of Odisha. *Indian Journal of Extension Education*, *60*(3), 106-109.

Shirsath, P. B., Aggarwal, P. K., Thornton, P. K., & Dunnett, A. (2017). Prioritizing climate-smart agricultural land use options at a regional scale. *Agricultural Systems*, *151*, 174-183.

Shitu A. G., Nain M. S., & Singh R. (2018). Developing extension model for smallholder farmers uptake of precision conservation agricultural practices in developing nations: Learning from rice-wheat system of Africa and India. *Current Science, 114*(4), 814-825.

Singh, A., Doharey, R. K., Meena, N. R., & Sonu, K. (2025). Utilization of smartphones for accessing agricultural information by farmers in Bokaro district of Jharkhand. *Indian Journal of Extension Education, 61*(4), 9–13.

Singh, D., & Mathur, S. (2024). Consumption pattern of information and communication technology in agriculture: A study of Jaipur district. *Indian Journal of Extension Education*, *60*(1), 128-131.

Singh, G. (2025). Determinants of agricultural credit accessibility: A case study of sugarcane farmers in Muzaffarnagar district. *The Indian Journal of Agricultural Sciences*, *95*(11).

Tong, A., Sainsbury, P., & Craig, J. (2007). Consolidated criteria for reporting qualitative research (COREQ): a 32-item checklist for interviews and focus groups. *International Journal for Quality in Health Care*, *19*(6), 349-357.

Udisha, O., & Ambily Philomina, I. G. (2024). Bridging the Digital Divide: Empowering Rural Women Farmers Through Mobile Technology in Kerala. *Sustainability*, *16*(21), 9188.

Wolfert, S., Ge, L., Verdouw, C., & Bogaardt, M. J. (2017). Big data in smart farming–a review. *Agricultural Systems*, *153*, 69-80.