

RESEARCH ARTICLE

Peer-reviewed | Open Access

Digital Agribusiness Adoption and Market Performance among Smallholder Farmers in Odisha

Lakhan Lal Meena¹, Mayuri Singh Sardar¹, Mehazabeen A² and Santosh D.T^{2*}¹Krishi Vigyan Kendra, Nuapada, Odisha University of Agriculture & Technology, Bhubaneswar, Odisha, India²Center for Smart Agriculture, Centurion University of Technology and Management, Odisha, India

ARTICLE INFO

Article history

RECEIVED: 15-Aug-26

REVISED: 24-Sep-26

ACCEPTED: 05-Oct-26

PUBLISHED: 15-Oct-26

*Corresponding Author

Santosh DT, Dr.

E-mail: santosh.dt@cutm.ac.in

Co-Author(s):

Author 2: Lakhan Lal Meena

E-mail: llmeena@ouat.ac.in

Author 3: Mayuri Singh Sardar, Dr.

E-mail: mayurisardar@gmail.com

Author 4: Mehazabeen A, Dr.

E-mail: mehaa998@gmail.com

Citation: Lakhan Lal Meena, Mayuri Singh Sardar, Mehazabeen A and Santosh D.T (2026). Digital Agribusiness Adoption and Market Performance among Smallholder Farmers in Odisha. Horizon J. Hum. Soc. Sci. Res. 8 (S), 126–134. <https://doi.org/10.37534/bp.jhssr.2026.v8.nS.id1401.p126>



ABSTRACT

Digital agribusiness platforms are increasingly seen as a tool to enhance the market access of smallholder farmers, market information and opportunities for profitable marketing. But there is limited empirical evidence of their economic impacts, especially in Odisha, India. The present study aimed to evaluate the determinants and economic impact of adopting digital agribusiness-platform by the smallholder farmers from district of Gajapati, Ganjam and Kalahandi in Odisha. 300 farmers (150 adopters and 150 non-adopters) were sampled for primary data collection. Descriptive statistics and binary logistic regression were used to describe patterns of platform adoption, and propensity score matching (PSM) was utilized to estimate the association between indicators of platform adoption and indicators of market access and economic performance. The users of digital platforms had higher number of market-information sources accessed (3.42 sources vs. 1.86 sources), more number of buyers contacted (3.74 buyers vs. 1.92 buyers) and higher price of farm-gate price (₹27.84 vs. ₹24.72 per kg) and lower marketing cost (₹2.86 vs. ₹3.38 per kg). The probability of adoption was significantly higher when considering education, smartphone ownership, Internet usage, access to information on digital markets, and FPO membership and digital agriculture training. The estimates show that adoption was related to increased net farm returns (ATT = ₹19,070 per ha), BCR (ATT = 0.33), MAI (ATT = 15.7 points) and price realization (ATT = ₹2.66 per kg); while the marketing cost decreased (ATT = -₹0.45 per kg). The results indicate the potential of digital agribusiness platforms for enhancing the participation in markets and economic performance of farms. Increasing digital capacity and literacy, farmer training, and digital marketing through FPOs and rural connectivity could be leveraged to promote inclusive digital market participation and support sustainable smallholder agricultural development.

Keywords: Digital agribusiness; market access; e-NAM; price realization; propensity score matching

Introduction

Smallholder farmers are still very much at the heart of food production and rural livelihoods but are constrained in their farm incomes and bargaining power by limited access to remunerative markets, and by the lack of reliable buyers, timely price information and efficient marketing channels. There is evidence that interventions

that enhance output-market access can boost farm sales, prices and farm returns, but that benefits can be context-specific, varying across low- and middle-income countries (LMICs) (Marion *et al.*, 2024). These challenges are directly linked to SDG 2 (Zero Hunger) and specifically SDG 2.3 (Improve the productivity and incomes of small-scale food producers by expanding access to markets

and resources) and also to SDG 8 (Decent Work and Economic Growth) and SDG 9 (Industry, Innovation and Infrastructure). Digital transformation can thus be a vital means to improve the inclusiveness and efficiency of agricultural markets.

The digital agribusiness platforms can help to overcome some of these challenges by offering market information, bringing together farmers and buyers, enabling price discovery, and reducing information and search costs. Despite the barriers of unequal connectivity, affordability and digital literacy, smallholders are adopting digital technologies to access agricultural information, market products, communicate with others, and market their products, as indicated by systematic evidence (Gumbi *et al.*, 2023). There is also more recent evidence that digital marketing and extension technologies can enhance access to information and markets, however, lack of connectivity, infrastructure and digital skills are the key constraints to wider use (Yuan and Sun, 2024). Therefore, digital agribusiness should not only be considered as a technology intervention, but as a tool that can affect the marketing decision of farmers, market connection, economic performance etc.

In response to the challenges faced by agriculture markets, India has introduced the Electronic National Agriculture Market (e-NAM), which aims to provide a platform for transparent price discovery through competitive online trading. As on 21st January 2026, 1.79 crore farmers and 1522 mandis were registered/integrated under e-NAM, which will also give market and price information and enable quality assaying and electronic trading. Some recent empirical studies have showed that the spatial price integration was better for certain commodities in the e-NAM market and farmers transacting through e-NAM mandis secured substantial price realization over farmers transacting in non-e-NAM mandis. But the evidence is not entirely favourable, there are ongoing concerns of low platform share in the overall APMC transactions and digital divide (Das *et al.*, 2024), and limited inter-state trade.

In the context of digital agricultural marketing, Odisha offers a welcome opportunity to explore these dynamics as the digital market has grown significantly in the state. All 66 Regulated Market Committees have been linked with e-NAM with 4.16 lakh farmers, 639 FPOs and 9,873 traders registered and e-NAM trading has been growing significantly from 2019-20 to 2023-24. (Government of Odisha, 2025). Such variations in farmers' involvement in the electronic agricultural markets have been observed in previous studies conducted in Odisha, showing that socio-economic and market-related factors affect digital-market participation. But it is not a guarantee that individual

smallholders will achieve better market access or economic returns.

There is a critical need for more research on e-NAM and digital agriculture. Research on awareness, adoption, participation and platform performance has mostly existed, while studies that simultaneously analyse market access, marketing costs, price realization and farm profitability among smallholders are relatively scarce. Furthermore, comparing adopters with non-adopters might be subject to systematic bias because digitally active farmers may not be the same in education, farm size, income, ownership of a smartphone, and/or their participation in various institutions. The present study thus focuses on the smallholder farmers of the Gajapati, Ganjam and Kalahandi districts of Odisha, with the aim to investigate the factors driving the adoption of digital agribusiness-platform and the relationship between adoption of the same and farmers' market access and economic performance using logistic regression and propensity score matching. The study thus offers empirical evidence on whether digital agribusiness involvement is a factor in improving the inclusivity and economic efficiency of agricultural marketing among smallholders.

Materials and Methods

The study was carried out in Gajapati, Ganjam and Kalahandi districts of Odisha, India which were purposively selected as representative districts of agriculturally important areas, where regulated agricultural markets exist and where farmers are exposed to digital agricultural marketing. Gajapati has regulated markets at Paralakhemundi for commodities like cashew, maize and cotton and Hinjilicut and Digapahandi have regulated markets for various agricultural commodities in the Gajapati district. The choice of Kalahandi was based on the availability of regulated market network established in the area which comprises of Bhawanipatana, Kesinga, Junagarh and Mukhiguda, with cotton, maize and horticultural products being some of the important products of the markets. The location of e-NAM connected markets in these districts offered an apt platform to explore the adoption of digital agribusiness, access to markets and economic outcomes.

To select households that were participating actively in the commercial production and marketization of farming activities, a multistage sampling technique was used. A total sample of 300 farmers was considered, 150 of which were digital-platform users, and 150 non-users. Digital-platform adoption was considered as the regular use of any one digital agribusiness service for agricultural marketing, such as the e-NAM, mobile based market platforms, FPO mediated digital marketing, digital price-information services or online buyer-seller

network. Primary data was gathered using a structured, pre-tested interview schedule, which included socio-economic characteristics, market-information sources, buyer contacts, marketing costs, selling prices, indicators of access to markets and farm-level economic returns of digital access and use. Market Access Index (0–100) was created by standardising market-information availability, alternative buyer access, price information, competitive marketing opportunities, transaction convenience and payment efficiency. The Marketing Decision Score was created based on the farmers' capability of price comparison, buyer identification, channel selection and negotiating selling conditions.

Firstly, descriptive statistics were used to describe the farmer characteristics. Independent sample t-test were used for continuous variables and χ^2 tests were used for categorical variables to compare differences between adopters and non-adopters. A binary logistic regression model was then estimated to determine factors associated with digital-platform adoption. Age, education, operational holding, farm income, smartphone possession, frequency of internet use, FPO/cooperative membership, digital-agriculture training and digital market-information access and distances to the regulated market were variables used as explanatory variables, whereas the dependent variable was coded as 1 for adopters and 0 for non-adopters. Estimated coefficients and standard errors are presented along with odds ratios. Propensity score matching (PSM) was used to minimize selection bias due to systematic differences between adopters and non-adopters. Propensity scores were modeled from the logistic model, and matched with observationally similar non-adopters using nearest-neighbour, caliper and kernel matching methods. Estimates of Average Treatment Effect on the Treated (ATT) for market-access and economic-performance outcomes were derived using PSM, which is based on

the potential-outcomes framework of Rosenbaum and Rubin (1983). The results were found to be the Market Access Index, the farm-gate price, marketing cost, net farm return, benefit–cost ratio, return on marketing expenditure, the payment realization period, and the price-realization index. The matching quality was examined using standardized mean differences, variance ratios and common-support diagnostics. The robustness of ATT was conducted by comparing estimation results obtained by using different matching methods. The level of statistical significance was 5% and 1% with all monetary values shown in Indian rupees (₹). Statistic software was used and the interpretation was done at the farm-household level.

Results and Discussion

The results are presented to evaluate the adoption and economic implications of digital agribusiness platforms among smallholder farmers in Odisha. Table 1 shows the socio-economic and digital attributes of 300 smallholders in Odisha, 150 of them using a digital platform and 150 who are not using digital platform. The age at which digital users used it (42.6 years) was lower than that of non-users (47.8 years), education level (9.7 years schooling) was higher than that of non-users (6.8 years schooling), the size of the holding (1.18 ha) was higher than that of non-users (0.96 ha), and the annual farm income (₹2.41 lakh) was higher than that of non-users (₹1.86 lakh). At $p < 0.05$ or $p < 0.01$, users showed significantly higher levels of ownership of the smartphones, mobile internet use, FPO/cooperative membership, access to formal credit, digital market-information, and digital-agriculture training than non-users.

The correlation of the higher digital participation of younger and better-educated farmers aligns with the studies that show that education and farm resources and access to digital devices are a driver for farmers to

Table 1. Socio-economic characteristics and digital agribusiness platform participation of sampled farmers in Odisha

Variable	Category	Digital users (n=150)	Non-users (n=150)	Overall (n=300)	χ^2/t value
Age (years)	Mean $\pm$ SE	42.6 $\pm$ 0.9	47.8 $\pm$ 0.9	45.2 $\pm$ 0.6	4.08
Education (years)	Mean $\pm$ SE	9.7 $\pm$ 0.4	6.8 $\pm$ 0.3	8.3 $\pm$ 0.3	5.78
Operational holding (ha)	Mean $\pm$ SE	1.18 $\pm$ 0.06	0.96 $\pm$ 0.05	1.07 $\pm$ 0.04	2.76
Annual farm income (₹ lakh)	Mean $\pm$ SE	2.41 $\pm$ 0.12	1.86 $\pm$ 0.10	2.14 $\pm$ 0.08	3.50
Mobile internet use	Yes (%)	91.3	63.3	77.3	35.21*
Smartphone ownership	Yes (%)	94.0	72.7	83.3	27.84*
Membership in FPO/cooperative	Yes (%)	48.7	28.7	38.7	12.29*
Access to formal credit	Yes (%)	58.7	43.3	51.0	7.06
Received agricultural market information digitally	Yes (%)	82.0	36.7	59.3	61.38*
Training on digital agriculture	Yes (%)	34.0	12.0	23.0	22.07*

Note: *Significant at 5%; **Significant at 1%. χ^2 was used for categorical variables and independent-samples t-test for continuous variables.

use agricultural service via their smartphone (Krithi, Varman 2026). The findings of this study in the state of Odisha further support that education and age have a significant impact on participation in an electronic agriculture market (Khandagiri and Kannan, 2022). Findings from Bihar indicate that digital agricultural tools are limited by accessibility of the platform, connectivity, digital literacy, and the ability to interpret information, especially for less educated and resource-constrained farmers, corroborating the strong relationship between the use of the platform and smartphone and internet access. Likewise, smartphone availability and education are significant proxies of farmers' digital preparedness, and linked to digital agricultural services (Fabregas *et al.*, 2019) in India.

The high participation of users in institutional networks, like FPOs, and in trainings on digital-agriculture further indicate that institutional networking and capacity building can help towards digital inclusion; the recent evidence on e-NAM adoption also highlights digital literacy, education and social participation as important factors for participation. This is especially true of Odisha, with all 66 RMCs being connected to e-NAM, and 4.16 lakh farmers and 639 FPOs registering on the platform, resulting in significant institutionalization of digital agricultural marketing across the state. Hence, facilitating digital agribusiness in Odisha should be focused on platform availability along with digital-literacy training, facilitation through FPOs, and cost-effective connectivity and farmer-oriented support instead of just technology access. More recent studies also highlight the need for local training, the cost of internet and digital literacy. The need for local training, affordable internet and digital literacy are also highlighted by recent evidence to overcome the agricultural digital divide.

There are significant differences in market-access and marketing performance between digital-platform

users and non-users that are evident in Table 2. Digital users reported using more market-information sources (3.42 vs. 1.86), had more buyers per season (3.74 vs. 1.92) and sold a higher percentage of their produce competitively (61.8% vs. 43.6%) than non-users ($p < 0.01$). They also earned a higher average farm-gate price (₹27.84 vs. ₹24.72 per kg), lower marketing costs (₹2.86 vs. ₹3.38 per kg), had a shorter post-harvest waiting period (2.1 vs. 3.4 days), and a greater producer share in the consumer price (68.4% vs. 57.2%). Digital users then had significantly higher scores on both the Market Access Index (67.8 vs. 49.6) and on the Marketing Decision Scores (14.8 vs. 10.9) with all differences statistically significant at $p < 0.01$. The results presented here suggest that the integration of digital platforms was linked with greater buyers' access, better price realization and more efficient marketing transactions.

Digital-platform users' superior market performance relative to their non-digital counterparts can be attributed to the digital technologies' capacity to lower farmers' information asymmetry and increase their capacity to reach alternative buyers and market prices. Reddy and Mehjabeen (2019) found that better market information and electronic price discovery are among the key mechanisms that can strengthen agricultural marketing with e-NAM implementation but requires effective coordination of stakeholders in India. Meena *et al.* (2019) also found that digital platforms like e-NAM can enhance market access, transparency, and price realization, and minimize reliance on intermediaries. The higher farm-gate price among users in the present study is also consistent with the evidence on e-NAM, which revealed a positive, and statistically significant, impact on the wholesale price, but with the caveat that market-information interventions do not necessarily lead to lower transaction costs, which calls for the need to consider the platform design and local implementation conditions.

Table 2. Effect of digital agribusiness platform use on market access and marketing performance

Indicator	Digital users (n=150)	Non-users (n=150)	Difference (%)	t-value
Number of market information sources used	3.42 ± 0.12	1.86 ± 0.09	83.9	10.62*
Distance to principal buyer/market (km)	18.6 ± 1.1	24.8 ± 1.3	-25.0	3.58*
Buyers contacted per season (number)	3.74 ± 0.18	1.92 ± 0.12	94.8	8.47*
Share of produce sold through competitive channels (%)	61.8 ± 2.1	43.6 ± 1.9	41.7	6.36*
Average farm-gate selling price (₹/kg)	27.84 ± 0.61	24.72 ± 0.56	12.6	3.74*
Marketing cost (₹/kg)	2.86 ± 0.10	3.38 ± 0.12	-15.4	3.35*
Post-harvest waiting period (days)	2.1 ± 0.2	3.4 ± 0.3	-38.2	3.67*
Producer's share in consumer price (%)	68.4 ± 1.5	57.2 ± 1.7	19.6	4.85*
Market-access index (0–100)	67.8 ± 1.4	49.6 ± 1.6	36.7	8.53*
Marketing decision score (0–20)	14.8 ± 0.3	10.9 ± 0.3	35.8	9.11*

Note: Mean ± SE. *Significant at 5%; **Significant at 1%.

Communication and information infrastructure is also shown to be important by Negi *et al.* (2018), who have found that poor transportation and communication infrastructure limit farmers' range of profitable marketing channels, and can contribute to reduced producer prices in India. The findings of higher competition channel share and producers' share among users, respectively, is therefore indicative of potential gains in farmers' negotiating power from the digital platforms where they can make themselves more visible and less dependent on a few local intermediaries. This is in line with the evidence of alternative and institutionalized marketing channels having the potential of lowering farmers' exposure to distress selling and bettering farmers' marketing outcomes in India.

Table 3 shows the binary logistic regression results of factors associated with adopting digital agribusiness platforms among the 300 sampled farmers. The model was statistically significant (LR $\chi^2=118.47$, $p<0.01$) and had a 78.7% correct classification accuracy, with an acceptable goodness of fit (Hosmer–Lemeshow $p=0.449$). Education was a significant and positive factor (OR=1.202, $\beta=0.184$, $p<0.01$), meaning that for every additional year of education, the odds of adoption increased by around 20.2%. Internet-use frequency, smartphone ownership and access to digital market information also significantly affected the likelihood of adoption (OR>1, $p<0.01$). Operational holding size (OR=1.523) and farm income (OR=1.374) were positive and significant at the 5% level and age (OR=0.965) had a negative association with adoption, while FPO/cooperative membership (OR=1.978) and digital-agriculture training (OR=2.394) were positive and significant at the 5% level. Distance to regulated market was negative and significant at the 5% level (OR=0.972). Hence, the chances of participation in adoption were higher in the case of farmers who were better educated, more connected with digital networks,

more involved in digital-markets institutions, and more exposed to digital-markets information, while older age and greater market distance decreased the likelihood of farmers participating in adoption.

Positive effect of education, ownership of smart phone, Internet use shows that human capital and digital readiness are key factors in the uptake of digital agribusiness. This result aligns with the studies conducted by smallholders in India where it was established that education, mobile phone ownership, farm assets, landholding characteristics are among the factors that affect adoption of digital agricultural extension services (Nwangwu *et al.*, 2024). The influence of smartphone ownership in the current study (OR=2.494) reaffirms recent Indian findings that education and income along with access to digital devices greatly impact farmers access to agricultural services through smartphones (Abbas *et al.*, 2024). The positive correlation of FPO membership and digital-agriculture training with adoption further suggests that institutional exposure and capacity building can facilitate the adoption of digital agriculture as well; recent evidence on e-NAM adoption reinforces education, digital literacy and social participation as drivers for participation, and recommends awareness and capacity building programmes. In the same way, Raghavendra *et al.* (2023) identified farm size and distance to market as factors that significantly affect participation in e-marketing and highlighted the importance of awareness and capacity development as strategies to raise the participation of farmers in e-marketing.

The negative distance-to-regulated-market coefficient indicates that spatial accessibility continues to be relevant even if digital platforms are used, which may relate to different physical market infrastructures, digital awareness, and/or distances to transactions completion costs. This is in line with recent studies which have found that distance from markets continues to be significant

Table 3. Determinants of farmers' adoption of digital agribusiness platforms: binary logistic regression

Explanatory variable	Coefficient (β)	SE	Odds ratio	z-value
Age (years)	-0.036	0.014	0.965	-2.57
Education (years)	0.184	0.049	1.202	3.76*
Operational holding (ha)	0.421	0.186	1.523	2.26
Annual farm income (₹ lakh)	0.318	0.127	1.374	2.50
Smartphone ownership (1=yes)	0.914	0.354	2.494	2.58
Internet-use frequency (times/week)	0.126	0.041	1.134	3.07*
FPO/cooperative membership (1=yes)	0.682	0.286	1.978	2.38
Digital-agriculture training (1=yes)	0.873	0.341	2.394	2.56
Market-information access (1=yes)	0.795	0.298	2.214	2.67*
Distance to regulated market (km)	-0.028	0.013	0.972	-2.15
Constant	-3.914	1.026	—	-3.82*

Table 4. Effect of digital agribusiness platform adoption on farm economic performance

Outcome variable	Mean adopter	Matched non-adopter	ATT	SE	% effect
Market-access index (0–100)	67.8	52.1	15.7*	2.84	30.1
Farm-gate price (₹/kg)	27.84	25.18	2.66*	0.73	10.6
Marketing cost (₹/kg)	2.86	3.31	−0.45*	0.14	−13.6
Net farm return (₹/ha)	74,940	55,870	19,070*	4,820	34.1
Benefit–cost ratio	2.03	1.70	0.33*	0.09	19.4
Price realization index	72.6	61.4	11.2*	2.51	18.2

for small farmers' market participation in India (Paul *et al.*, 2021). The negative correlation with age also implies a possible "digital generation effect" but must be viewed with caution, as age could also be influenced by education and familiarity with and digital literacy of the smartphone. The most recent study on digital innovations in agriculture in India also suggests that digital literacy, cost, connectivity, and language are key barriers, especially for older and less-educated farmers.

Table 4 shows the estimated impact on economic performance of adoption of a digital agribusiness platform by a farmer, after matching a farmer with a farmer in the control group who is observationally similar to the farmer in the treatment group. Adoption of digital-platforms increased the net farm return by 34.1% to ₹19,070/ha and the improvement coefficient of the benefit–cost ratio by 19.4% to 0.33. The price-realization index (ATT = 11.2 points; $p < 0.01$) was also higher and the marketing cost (ATT = −₹0.45/kg; $p < 0.01$) was lower for all the adopters. The estimated ATT for the market-access index was 15.7 points, which suggests that market-access index matched adopters had a lot more access to agricultural markets. The positive impact on farm-gate price (₹2.66 per kg) and higher ROI on marketing expenditure also point towards increased economic efficiency among the digital-platform users.

The positive ATT estimates suggest that the involvement of digital agribusiness can bring economic advantages due to better market access and better price information, and the better ability of farmers to find alternative buyers. There is recent evidence from India that the use of digital platforms in agriculture, like e-NAM, can enhance market access, transparency, and market price realization, but the magnitude of the benefits can differ by commodity and market (Praneeth *et al.*, 2023). The current evidence of improved price realization is corroborated by a Difference-in-Differences analysis from Andhra Pradesh, which has shown that the e-NAM participants in turmeric and dry chilli markets experienced significant price gains compared to their non-participants, indicating that digital trading could enhance price discovery and reduce information asymmetry (Venkatesh *et al.*, 2021). Moreover, the results from studies

conducted in Rajasthan revealed that adoption of e-NAM led to a rise in farmers' prices or market quantity, but other efficiency gaps were noted as the need for further improvement. The low marketing cost as reported in the present study is significant as the problem of high search, negotiation and transaction cost is often faced by small holders and can limit access to remunerative marketing channels (Sharma *et al.*, 2025). Empirical evidence from the recent past in Tamil Nadu also suggests that the use of mobile technology can help lower search and negotiation costs and enhance market access and livelihoods for smallholders.

The benefit–cost ratio and improvement in net farm returns also indicate that the economic value of digital platforms could be more than just price improvement, because the benefit may be a greater contribution to marketing efficiency. This interpretation is also confirmed by the recent study conducted in the East India demonstrating the positive linkages between utilization and farm income outcomes of digital agricultural services such as the study in Odisha. However, the size of the present estimates needs to be treated with caution as PSM controls only for observed characteristics and other unobserved factors like entrepreneurial ability, digital literacy, and motivation and pre-existing buyer relationships may also have an impact on the adoption rates and economic outcomes. This restriction highlights the need for matching diagnostics to be reported and, if feasible, an IPW or alternative specification to be carried out as a robustness check.

Conclusion

The study findings show that digital agribusiness platforms can make a significant impact on improving the economic performance and market access of smallholder farmers in Odisha. Digital-platform adopters also had more sources of market information they used (3.42 vs. 1.86) and contacted more buyers (3.74 vs. 1.92), and had a higher percentage of competitive-channel sales (61.8% vs. 43.6%) than non-adopters. They also obtained higher farm-gate prices (₹27.84 vs. ₹24.72 per kg), lower marketing costs (₹2.86 vs. ₹3.38 per kg) and

higher producer-price shares (68.4% vs. 57.2%). Logistic regression also revealed that education, smart phone ownership, use of internet, access to information in digital markets, membership of FPO were associated with higher probability of platform adoption while age and distance to the regulated market had negative association. Most importantly, propensity score matching showed a positive association of digital adoption with net farm returns (ATT = ₹19,070 per ha), benefit–cost ratio (ATT = 0.33), market-access index (ATT = 15.7 points) and price realization (ATT = ₹2.66 per kg), while marketing costs declined by ₹0.45 per kg. Based on these findings, it is recommended that digital literacy, the availability of smart phones, digital marketing through farmer pro-orgs, and farmer training and strengthening rural connectivity should be enhanced to boost the benefits of digital agribusiness. These interventions can help to make agriculture better and more inclusive, as well as helping to achieve SDG 2, SDG 8 and SDG 9. These estimates of the PSM, however, are conditional associations and should not be viewed as fully causal effects when there is unobserved heterogeneity.

Acknowledgements

The authors sincerely thank all individuals and institutions who supported this research study.

Funding

No funding was received for this research.

Declaration of Conflicting Interests

The authors declare no conflict of interest.

Declaration of Generative AI and AI-assisted Technologies in the Writing Process

During the preparation of this manuscript, the authors have not used generative AI or AI-assisted technologies. The authors independently developed the conceptual framework and scholarly arguments and remain fully responsible for the accuracy, originality, and integrity of the manuscript.

References

- Abbas, I. R., Ramakrishnan, K., Velusamy, R., Selvarani, G., and Sivasankari, B. (2024). Usage of mobile phone technologies of agricultural extension services utilized by farmers. *Journal of Experimental Agriculture International*, 46(8), 565–569.
- Das, R., Chanda, B., Krishna, G., and Gulati, A. (2024). Transforming agricultural trading and commerce in India: Role of e-NAM and potential of digital trade. *Agricultural Economics Research Review*, 37(2), 165–181.
- Fabregas, R., Kremer, M., and Schilbach, F. (2019). Realizing the potential of digital development: The case of agricultural advice. *Science*, 366(6471), eaay3038.
- Government of Odisha. (2025). *Odisha economic survey 2024–25*. Department of Finance, Government of Odisha.
- Gumbi, N., Gumbi, L., and Twinomurizi, H. (2023). Towards sustainable digital agriculture for smallholder farmers: A systematic literature review. *Sustainability*, 15(16), 12530.
- Khandagiri, C., and Kannan, E. (2022). Performance analysis of electronic national agricultural markets: Some evidence from Odisha. *Agricultural Economics Research Review*, 35(2), 95–108.
- Krithi, M. R., and Varman, P. M. (2026). Determinants of access to smartphone app-based digital agricultural extension services in India: Evidence from NSSO 77th round. *Asian Journal of Agricultural Extension, Economics and Sociology*, 44(6), 144–153.
- Marion, P., Lwamba, E., Floridi, A., Pande, S., Bhattacharyya, M., Young, S., and Shisler, S. (2024). The effects of agricultural output market access interventions on agricultural, socio-economic, food security, and nutrition outcomes in low- and middle-income countries: A systematic review. *Campbell Systematic Reviews*, 20(2), e1411.
- Meena, G. L., Burark, S. S., Singh, H., and Sharma, L. (2019). Electronic-National Agricultural Market (e-NAM): Initiative towards doubling the farmers' income in India. *International Archive of Applied Sciences and Technology*, 10(2), 162–171.
- Negi, D. S., BIRTHAL, P. S., Roy, D., and Khan, M. T. (2018). Farmers' choice of market channels and producer prices in India: Role of transportation and communication networks. *Food Policy*, 81, 106–121.
- Nwangwu, K. N., Onyenekwe, C. S., Opata, P. I., Ume, C. O., and Ume, N. N. C. (2024). Can digital technology promote market participation among smallholder farmers? *International Food and Agribusiness Management Review*, 27(4), 706–728.
- Paul, U. K., Das, G., Das, M., and Mathur, T. (2021). Small growers' direct participation in the market and its impact on farm income. *Journal of Agribusiness in Developing and Emerging Economies*, 11(3), 241–254.
- Praneeth, M., Meera, S. N., and Awasthi, H. K. (2023). Perception of farmers about e-NAM and digital marketing applications. *Gujarat Journal of Extension Education*, 36(2), 76–82.
- Raghavendra, K. J., Kumar, S., Kar, A., Kumar, P., Singh, R., Arya, P., and Kiran, T. M. (2023). Awareness and determinants of farmers' participation in e-marketing of agricultural commodities in India. *Indian Journal of Extension Education*, 59(4), 161–164.
- Reddy, A. A., and Mehjabeen. (2019). Electronic national agricultural markets, impacts, problems and way forward. *IIM Kozhikode Society and Management Review*, 8(2), 143–155.
- Sharma, K., Katoch, S., Mohapatra, S., Kaur, M., and Kumar, A. (2025). Access to digital services and its impact on farm income: Empirical evidence from eastern India. *Agricultural Economics Research Review*, 38(2), 184–193.
- Venkatesh, P., Singh, D. R., Sangeetha, V., Balasubramanian, M., and Jha, G. K. (2021). The changing structure of agricultural marketing in India: A state-level analysis of e-NAM. *Agricultural Economics Research Review*, 34, 97–109.
- Yuan, Y., and Sun, Y. (2024). Practices, challenges, and future of digital transformation in smallholder agriculture: Insights from a literature review. *Agriculture*, 14(12), 2193.

Biographical Statement of Author(s)

Lakhan Lal Meena is working as Subject Matter Specialist (Agriculture Extension) in the Krishi Vigyan Kendra, Nuapada in Odisha University of Agriculture & Technology Bhubaneswar. He was awarded M.Sc. degree in Agricultural Extension from Odisha University of Agriculture & Technology Bhubaneswar. He has experience of 8 years in extension in the discipline. He worked as Principle Investigator (PI) and Co-PI in some of the Institute projects and also had exposure visits to many Institutes. She has attended many International, National seminars/conferences, Faculty/ Capacity building development Programme and Training programmes. He has in his credit several research papers published in reputed journals of the country, popular articles and other extension publications.



Mr. Lakhan Lal Meena

Krishi Vigyan Kendra, Nuapada
Odisha University of Agriculture & Technology
Odisha, India

E-mail: llmeena@ouat.ac.in

Dr. Mayuri Singh Sardar is serving as Subject Matter Specialist (Agricultural Extension) at Krishi Vigyan Kendra, Boudh, under Odisha University of Agriculture & Technology (OUAT) since July 2018. She obtained her B.Sc. (Agriculture), M.Sc., and Ph.D. in Agricultural Extension from Bidhan Chandra Krushi Viswavidyalaya, West Bengal. Her areas of work include GIS-based extension planning, climate risk management, technology dissemination, Front Line Demonstrations (FLDs), On-Farm Trials (OFTs), impact assessment studies, adoption and constraint analysis, Farmer Producer Organization (FPO) development, ICT-enabled advisory services, and capacity building of farmers, farm women, and rural youth. She is actively involved in planning, implementation, monitoring, and documentation of district-level extension programmes in coordination with line departments. Dr. Sardar has published several research papers in reputed journals and contributed technical and extension literature. She is a lifetime member of the Odisha Society of Extension Education (OSEE) and is committed to promoting sustainable, inclusive, and farmer-centric agricultural development in Odisha.



Dr. Mayuri Singh Sardar

Krishi Vigyan Kendra, Boudh
Odisha University of Agriculture & Technology
Odisha, India

E-mail: mayurisardar@gmail.com

Dr. Mehazabeen A.

is an accomplished academic and researcher in Agribusiness Management, currently serving as Assistant Professor & Program Coordinator, Dept of ABM at Centurion University. She holds a Ph.D.(ABM), boasting a stellar academic record and over a decade of research experience. Her work explores supply chains, value addition, and market efficiency across diverse crops like banana, cashew, and maize. A prolific author, she has published extensively in reputed journals and conference proceedings. As a patent holder, she blends innovation with agricultural insight. She is a passionate mentor, guiding postgraduates in agribusiness research. Her professional roles span teaching, curriculum development, and academic coordination. With a sharp focus on sustainable agribusiness, she actively contributes to policy-oriented seminars, national skill initiatives, and capacity-building programs.



Dr. Mehazabeen A

Assistant Professor
Center for Smart Agriculture
Centurion University of Technology and Management
Odisha, India

E-mail: mehaa998@gmail.com

Dr. Santosh D.T is working as an Assistant Professor in the Department of Agricultural Engineering, School of Agriculture and Bio Engineering, Centurion University of Technology and Management, Odisha. He earned his Ph.D. in December 2019 from the Agricultural and Food



Engineering Department at IIT Kharagpur. He worked as a Research Associate at Precision Farming Development Centre, IIT Kharagpur for a decade (2010-2020), which was funded by the Ministry of Agriculture and Farmers Welfare. His area of research is micro-irrigation, greenhouse technology, protected cultivation techniques, and hydroponics. He has a number of publications in National and International peer-reviewed journals.

Dr. Santosh D T

Assistant Professor
Centurion University of Technology and Management
Odisha, India

E-mail: santosh.dt@cutm.ac.in