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Empowering Women Farmers with Digital Advisory Tool: Assessing the Impact of Rice Crop Manager on Rice Productivity in Odisha

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ABSTRACT

Odisha's agrarian economy depends heavily on rice production, which plays a central role in determining farm incomes and sustaining rural livelihoods. Although information and communication technologies are increasingly used to strengthen agricultural extension services in the state, women farmers remain underserved by digital advisory systems despite their substantial contribution to rice cultivation. This study examined the impact of a site-specific nutrient management approach delivered through the Rice Crop Manager (RCM), a digital decision support tool, on rice productivity among women farmers in rural Odisha. The study involved two groups, namely a treatment group (RCM) and a control group, each consisting of fifty farmers. The findings revealed that women farmers in the treatment group who received Rice Crop Manager advisories achieved higher yields (compared to those in the control group who followed conventional nutrient management practices. Higher levels of participation and adoption were observed among younger and educated women farmers, indicating persistent gaps in digital access and literacy. The results highlight the importance of gender responsive digital agriculture policies that emphasise improved access to smartphones, targeted capacity building, and advisory services tailored to the needs of women farmers. Expanding such inclusive digital interventions through public extension systems has the potential to enhance productivity, improve input use efficiency, and promote more equitable agricultural growth in Odisha.

Keywords: *Digital tools, Digital extension, Gender equality, Women's empowerment.*

Introduction

Information and Communication Technologies (ICT) and its use in agriculture have been instrumental in improving access to timely information and thereby increasing awareness and knowledge of farmers on innovative and effective crop management practices [1,2]. ICT has strengthened the linkages of farmers with markets, suppliers and institutions [3]. It acts as a bridge between improved technologies at research stations and laboratories and the farmers at grass root level. Many ICT interventions like mobile phones, short message services (SMS), interactive voice response (IVR), mobile applications, and digital advisory services are complementing the traditional extension system of extension personnel [4]. Last-mile delivery faces serious challenges because extension systems are heavily understaffed, with one officer handling about 1,162 farmers instead of the recommended 750 in India [5]. With the shortage in extension personnel, it becomes extremely difficult for farmers to get their queries answered when needed. Farmers, especially in remote areas, are often left behind when it comes to information on new technologies, be it varieties or crop management practices [6]. ICT tools are providing the exposure to innovations, real-time information on weather forecasts, remedies for insect-pest and disease attack, alerts on stress-conditions and so on. Use of these digital advisories has proven to improve the production, productivity and ultimately income and livelihood of the farmers [6].

Odisha is an agrarian State with 60 % of its rural population dependent on agriculture for livelihood [7].

The main crop grown by the farmers in Odisha is rice with 69% of the cultivated area [8]. Despite rice being the major crop, the rice yield is lower than the national average [9]. There is also a large yield gap among the state's different districts, indicating a gap in resources, technology diffusion and adoption, and knowledge sharing. Further, Odisha's growth rate is more volatile than the all-India rate. This high volatility is partially explained by the impact of weather and climatic variability on agricultural growth in Odisha [10]. The policy paper also urges Odisha to sustain agricultural growth, address challenges, harness markets, and prioritise farmers' welfare. The Government of Odisha has always recognised ICT as a strong means of information dissemination channel. Initiatives like Krushi Samrudhi Helpline, established by the Department of Agriculture and Farmers Empowerment (DA&FE) offer a toll-free helpline number to farmers to get their queries answered. The Government of Odisha has invested in digital agricultural platforms to strengthen Extension and Advisory Services (EAS). The Krushak Odisha Portal represents a major ICT intervention aimed at creating a centralised digital ecosystem for farmers. The platform facilitates farmer registration, creation of verified digital farmer profiles, access to scheme-related information, beneficiary tracking, and dissemination of notifications and advisories [7]. The Odisha government partners with many research institutes to strengthen the agriculture sector of the state.

In 2015, DA&FE signed an MoU with the International Rice Research Institute (IRRI) to promote and accelerate the expansion and dissemination of improved research technologies and packages of practices to enhance the livelihood of poor farmers in a mission-mode approach. Subsequently, the project "Improving Productivity of Rice-based Farming Systems and Farmers' Income in Odisha" was launched (2016-17) to promote cooperation in the fields of rice research, development and training, and improvement of production technologies. RCM was selected to disseminate site-specific nutrient management recommendations to the farmers of Odisha. RCM has proven to improve crop productivity, nutrient use efficiency and promote balanced fertiliser application in the rice-based cropping system [11]. Extension staff were trained to use RCM and provide advisories to the farmers. However, it was seen that women farmers' participation was limited towards the use of ICT tool. Women in Odisha play a central role in crop cultivation, livestock management, and post-harvest activities, yet they frequently face constraints related to limited access to information, training, and institutional support [12]. Gender disparities in land ownership, education, income, and access to extension services often limit women's participation in technology-driven agricultural interventions, despite their substantial contribution to agricultural production and allied activities [13].

Recent studies indicate that ICT adoption in agriculture is positively associated with socio-economic factors such as education, age, landholding size, and access to mobile devices [14]. Women farmers with better access to smartphones and digital literacy are more likely to engage with ICT-based advisory services, while younger and relatively better-educated women tend to exhibit higher levels of participation [15]. Nevertheless, challenges such as the digital gender gap, limited control over mobile phones, language barriers, and inadequate digital skills continue to restrict the full realisation of ICT benefits among women farmers, particularly those from marginalised and resource-poor households [16].

Against this backdrop, understanding the impact of ICT interventions on women farmers in Odisha is crucial for designing inclusive and gender-responsive agricultural policies and programs. Examining how ICTs influence access to information, adoption of improved agricultural practices, and participation in extension services can provide valuable insights into their role in enhancing women's empowerment and agricultural outcomes. This study seeks to contribute to the existing literature by analysing the role of ICT in agriculture and its impact on women farmers in Odisha, with a focus on participation patterns, socio-economic determinants, and potential pathways for improving the effectiveness of digital agricultural interventions.

Materials and Methods

Study area

The study was conducted during the kharif season 2025 in Dighapahandi block of Ganjam district, Odisha. The block and district were purposively selected due to the presence of a Farmer Producer Company (FPC), namely "Bhuvikash Women Farmers' Producer Company", which operates across five villages in the study area. These villages provided an appropriate setting for evaluating the impact of digital agro-advisory services, as the FPC actively works with women farmers and supports technology-based interventions. The selected area represents uniform agro-ecological conditions suitable for rice cultivation, enabling a fair comparison between treatment and control groups.

Survey design

The study adopted a quasi-experimental research design involving two groups: treatment and control, to assess the impact of smartphone-based agro-advisories (Rice Crop Manager, i.e. RCM) on rice production and productivity. Farmers were assigned to either group based on predefined selection criteria to ensure comparability in terms of socio-economic status, soil characteristics, cropping history, rice variety, and irrigation conditions. Treatment group (RCM group): Farmers received smartphone-based, crop-stage-specific nutrient management advisories. Control group: Farmers followed their usual cultivation practices without receiving digital advisories during the study period.

Selection of farmers

Treatment group: A total of 50 women farmers were selected, with 10 farmers from each of the five villages. Selection criteria included regular access to a smartphone, ability to use the device, willingness to attend training sessions, and readiness to follow RCM advisories throughout the season.

Control group: 50 farmers were selected from the same villages to maintain similar agro-ecological conditions. These farmers did not receive RCM training or advisories and continued their conventional practices.

Data collection

Data collection for the study focused on capturing both the implementation of smartphone-based advisories and the resulting crop management practices and yield outcomes. Farmers in the treatment group were provided with timely, crop-stage-specific nutrient management advisories through the Rice Crop Manager (RCM) digital tool. The advisories, presented in simple Odia language using tabular and pictorial formats, guided farmers on the type, dose, and timing of fertilizer application for their specific rice varieties. To generate recommendations, farmers inputted plot-specific information, including sowing date, crop establishment method, variety duration, prior fertiliser use, expected water availability, straw management, and harvesting practices. The RCM algorithm processed this data and delivered location-specific nutrient and crop management guidelines within 3–5 minutes. These guidelines included basal NPK recommendations, split nitrogen applications aligned with critical crop stages, zinc requirements if needed, and reminder messages for top-dressing.

Treatment farmers were trained to use the RCM tool, interpret advisories, and apply fertilisers according to the recommended timeline and doses. In contrast, control farmers continued with conventional practices, applying uniform doses of nitrogenous, phosphatic, and potassic fertilisers based on local norms without reference to crop stage, soil nutrient supply, or yield targets. Crop yield, the primary outcome of interest, was measured using crop cutting experiments (CCEs) conducted at harvest. For each sampled plot, a 5 × 5 m^2 area was randomly selected while avoiding border effects. The crop within this area was harvested, threshed, cleaned, and weighed, and the grain yield was converted to tonnes per hectare at 14% moisture content. In addition, structured interviews were conducted with all farmers to document fertiliser and weedicide use, adherence to advisories (for the treatment group), and socio-economic and demographic characteristics.

This combined approach allowed the study to capture both the process of implementing digital advisories and their effects on rice crop management and productivity.

Data processing and data analysis

After data collection, all field and survey data were compiled, cleaned, and organised for analysis. Grain yield data obtained from crop cutting experiments were processed to calculate the mean and variance for both the treatment and control groups. To evaluate the impact of smartphone-based advisories, the study compared average yields between the groups and analysed differences in fertiliser use, including the amount and timing of nitrogenous, phosphatic, and potassic fertilizers, as well as the number of split applications. Given that the treatment and control groups were independent and exhibited unequal variances, a Welch two-sample t-test was employed to test the null hypothesis that there was no difference in mean yield between the RCM and control farmers. The analysis was conducted using Microsoft Excel's "t-Test: Two-Sample Assuming Unequal Variances" procedure at a significance level of $\alpha = 0.05$. This approach enabled the study to quantify the effects of digital advisories on rice crop productivity while accounting for variability in field conditions and management practices, ensuring a robust assessment of treatment impacts.

Results

Socio-demographic characteristics of respondents

Age group

The age distribution of women farmers in the treatment (RCM) and control groups was analysed to identify the most active age categories (Fig. 1). In the treatment group, the majority of women farmers belonged to the 25–40 years age group, followed by the 41–55 years category. In contrast, the control group was predominantly composed of women farmers aged 41–50 years. Participation of women below 25 years and above 55 years of age was minimal in both groups.

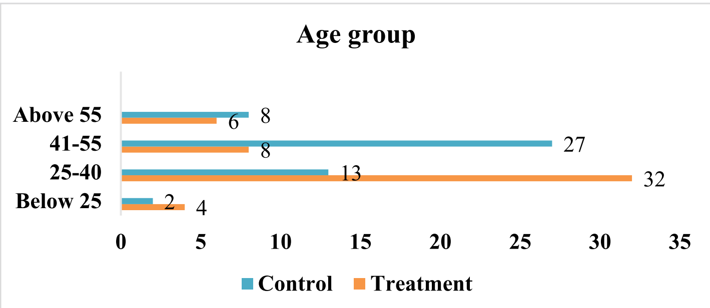

Fig. 1. Age group of women farmers

Education level of respondents

Distinct differences were observed in the education levels of women farmers between the treatment and control groups (Fig. 2). No illiterate respondents were present in the treatment group, whereas a small proportion of illiterate women farmers was observed in the control group.

Women with primary education (up to class 5) constituted a larger share of the control group compared to the treatment group. The treatment group was dominated by women with secondary education (class 6–10), followed by senior secondary and graduate-level education. At all higher education levels, representation was greater in the treatment group than in the control group.

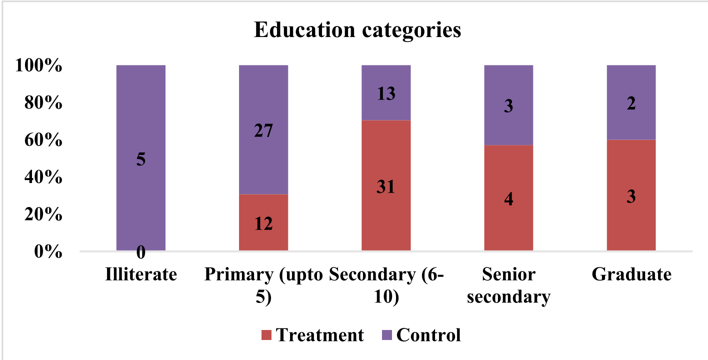

Fig. 2. Education levels of respondents in two groups (Treatment = RCM farmers)

Landholding of respondents

Landholding patterns differed notably between the two groups (Fig. 3). Marginal and small landholders constituted the majority of the control group, whereas the treatment group showed a relatively higher proportion of medium and large landholders.

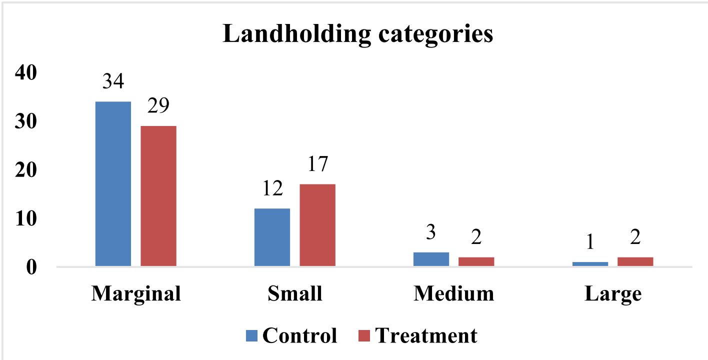

Fig. 3. Landholding categories of respondents in two groups (Treatment = RCM farmers)

Fertilizer application (amount and frequency)

Significant differences were observed in fertilizer application between RCM and control farmers (Table 1). The mean nitrogen application rate was significantly higher under RCM (113.6 kg ha^{-1}) than under farmers' conventional practices (92.2 kg ha^{-1}; $t(101)=8.30$, $p<0.001$). Conversely, phosphorus and potassium application rates were significantly lower in the RCM group (28.4 kg P ha^{-1} and 41.8 kg K ha^{-1}) compared with the control group (48.7 kg P ha^{-1} and 48.7 kg K ha^{-1}; $p<0.001$).

Table 1. Grain yield and fertilizer nutrient application (N, P and K, kg ha^{-1}) under RCM advisories and farmers' conventional practices among women rice farmers of Odisha

Particulars	RCM (Mean ± SD)	Control (Mean ± SD)	t value	Df (Welch)	P value (two-tailed)
Grain yield (kg ha^{-1})	5.01±0.54	4.24±0.44	8.09	101.2	< 0.001
Nitrogen (kg ha^{-1})	113.6 ± 12.6	92.2 ± 13.7	8.30	101.4	< 0.001
Phosphorus (kg ha^{-1})	28.4 ± 4.6	48.7 ± 9.9	−13.51	72.6	< 0.001
Potassium (kg ha^{-1})	41.8 ± 11.6	48.7 ± 8.4	−3.46	93.1	< 0.001

Note: Values are mean ± standard deviation; n = 50 for both RCM and control groups. Differences between groups were tested using Welch's independent samples t test assuming unequal variances. All tests were two-tailed.

Grain yield of rice

Rice grain yield differed significantly between the two groups. Women farmers using RCM advisories achieved a mean grain yield of 4.96–5.01 t ha^{-1}, whereas control farmers recorded an average yield of 4.20–4.24 t ha^{-1} (Table 1). Welch's two-sample t-test confirmed that the yield difference was highly significant ($t \approx 8.10$, $p < 0.001$). The use of RCM advisories resulted in a yield advantage of approximately 0.76–0.77 t ha^{-1}, representing an increase of about 18% over conventional practices.

Economics

Economic analysis revealed higher returns for women farmers using RCM advisories (Table 2). Gross returns increased from ₹100,064 ha^{-1} in the control group to ₹118,236 ha^{-1} in the RCM group. Although the nutrient cost under RCM was slightly higher, the net economic advantage over the control group amounted to ₹18,172 ha^{-1}.

Table 2. Economic returns of women rice farmers under RCM advisories and farmers' conventional practice

Particulars	Unit	RCM farmers	Control farmers
Gross return (at MSP*)	₹ ha^{-1}	118,236	100,064
Nutrient value**	₹ ha^{-1}	6,255	5,849
Net advantage over control	₹ ha^{-1}	18,172	–

** MSP for paddy (common) = ₹2,369/quintal*
*** Calculated using NBS nutrient rates: N = ₹47.02 kg^{-1}, P = ₹28.72 kg^{-1}, K = ₹2.38 kg^{-1}*

Discussion

The comparative analysis demonstrates that access to ICT-based tools such as Rice Crop Manager (RCM) enhances informed decision-making among women farmers, particularly in nutrient management. Scientific nutrient management through RCM improved nutrient-use efficiency, leading to higher yields while promoting sustainability. Both over- and under-application of fertilisers were shown to adversely affect crop productivity, soil health, and the environment. The predominance of younger women (25–40 years) in the treatment group reflects greater access to smartphones and digital literacy within this age group, consistent with earlier findings [15]. Higher education levels among treatment farmers further facilitated the adoption of RCM advisories, suggesting that digital interventions are more readily embraced by educated farmers capable of interpreting fertiliser recommendations.

Differences in landholding size between the two groups indicate that women farmers with larger landholdings and better economic conditions were more likely to participate in the RCM intervention. Smartphone ownership, closely associated with economic status, further influenced participation in technology-based advisories [17]. The fertiliser application pattern under RCM reflects a shift towards site-specific nutrient management. Higher nitrogen application aligned with crop demand likely contributed to yield enhancement, while reduced phosphorus and potassium use suggest correction of habitual over-application under traditional practices. Such optimisation lowers input costs and mitigates risks of nutrient accumulation and environmental loss, particularly in rice-based systems.

The significant yield advantage observed under RCM can be attributed to timely and balanced fertiliser application during critical growth stages, improving tillering, panicle development, and grain filling [18,19]. Similar yield improvements under RCM and SSNM approaches have been reported earlier [11]. Economically, the higher yields under RCM translated into substantial income gains despite marginally higher nutrient costs. This confirms that digital nutrient advisories can enhance profitability without proportionally increasing fertiliser expenditure. Comparable improvements in agronomic efficiency and profitability using RCM and related tools have been documented in Asian rice systems [11, 20]. Overall, the findings indicate that digital advisory tools like RCM not only improve productivity and economic returns but also empower women farmers by strengthening their role in farm decision-making. Access to timely, reliable information enables women to move beyond labour roles and actively contribute to sustainable crop management strategies.

Conclusion

In the present investigation with 50 women rice farmers in Odisha, the use of Rice Crop Manager (RCM) advisories led to distinct changes in fertiliser use and productivity. RCM farmers applied more nitrogen but substantially less phosphorus and slightly less potassium than control farmers, yet achieved about 0.77 t ha^{-1} higher (18%) grain yield and much greater net returns than control. These results demonstrate that context-specific, digital nutrient recommendations can simultaneously enhance yield, optimise fertiliser use and improve economic resilience for women farmers in smallholder rice systems, supporting wider promotion of RCM within state extension programmes.

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Conflicts of interest

The authors declare no conflicts of interest.

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