



RESEARCH ARTICLE

Estimating the farmers' acceptance of phygital services under the mobile agri support services (MASS) initiative: A difference-in-differences approach

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Abstract

Effective agricultural transformation in India requires inclusive models that can connect small and marginal farmers to timely knowledge, tools and services. Despite growing digital infrastructure, last-mile delivery remains a major challenge due to socio-economic and infrastructural barriers. This study evaluates the mobile agri support services (MASS) intervention of a phygital model integrating physical and digital extension tools to improve farmer engagement and adoption of agri-technologies in selected aspirational districts of Telangana. Mobile agri support services is a unique 'phygital' (physical + digital) platform tested for a period of one year (2nd June 2023 to 31st July 2024). A quasi-experimental research design with treatment and control groups was adopted. A total of 1000 farmers were selected from three aspirational districts of Telangana: Kumuram Bheem Asifabad, Jayashankar Bhupalpally and Bhadradi Kothagudem. A difference-in-difference (DID) approach and fixed-effects regression measured changes in farmers' attitudes before and after the intervention. Results showed that before the intervention, over 85 % of farmers in both groups exhibited a low attitude toward phygital services and had little awareness of digital agricultural platforms. After the MASS intervention, 80–90 % of beneficiary farmers shifted to the high-attitude category, whereas 88–92 % of farmers in the control group remained in the low-attitude category. The DID analysis indicated a net increase of 78.11 units in attitude scores, with the interaction effect statistically significant ($p < 0.01$). Regression results further revealed that education, extension participation, media exposure, risk-taking ability and decision-making behaviour significantly influenced the adoption of phygital services. By combining mobile field demonstrations, expert interaction, soil testing, drone demonstrations and digital advisory platforms, the intervention effectively bridged the last-mile gap in agricultural extension. The findings highlight that phygital service delivery systems can serve as scalable and inclusive models for strengthening agricultural extension, improving technology adoption and supporting digital transformation in rural agriculture.

Keywords: behavioural change; digital agriculture; farmers' attitude; hybrid service delivery; smallholder farmers; technology adoption

Introduction

Agriculture in India serves as the socio-economic foundation for over half the population, particularly in rural regions. Despite its pivotal role in ensuring food security and livelihood, the sector continues to face structural challenges ranging from limited access to real-time information, weak market linkages, fragmented extension systems and growing disparities in the adoption of technology, especially among small and marginal farmers.

To address these challenges, the concept of phygital service delivery, a hybrid of physical and digital engagement, has gained traction. In agriculture, phygital models combine on-ground support, such as demonstrations and diagnostics, with the scalability of digital tools like mobile apps, e-platforms, weather advisories and remote sensing. While India is witnessing rapid rural digitisation, trust-building and capacity enhancement through human interaction remain essential, making phygital approaches

both practical and contextually appropriate. In agriculture, phygital extension services combine field-based demonstrations, farm visits and interpersonal communication with ICT-based advisories, video conferencing, mobile apps and social media tools (1–3). They emphasised that farmers trust physical demonstrations and peer learning, but digital platforms enable scalability, timeliness and reduced transaction costs. Integrating both approaches ensures that farmers not only receive accurate information but also develop confidence to apply innovations through experiential learning.

Mobile-based agricultural service units, often equipped with soil testing labs, demonstration tools and digital connectivity, represent a practical example of the phygital concept (Fig. 1). Studies on mobile agro-advisory vans reveal their effectiveness in reaching remote farmers, providing real-time diagnostic services and strengthening trust in extension agents (4, 5). The mobile agricultural service system (MASS) intervention adopted a similar model,

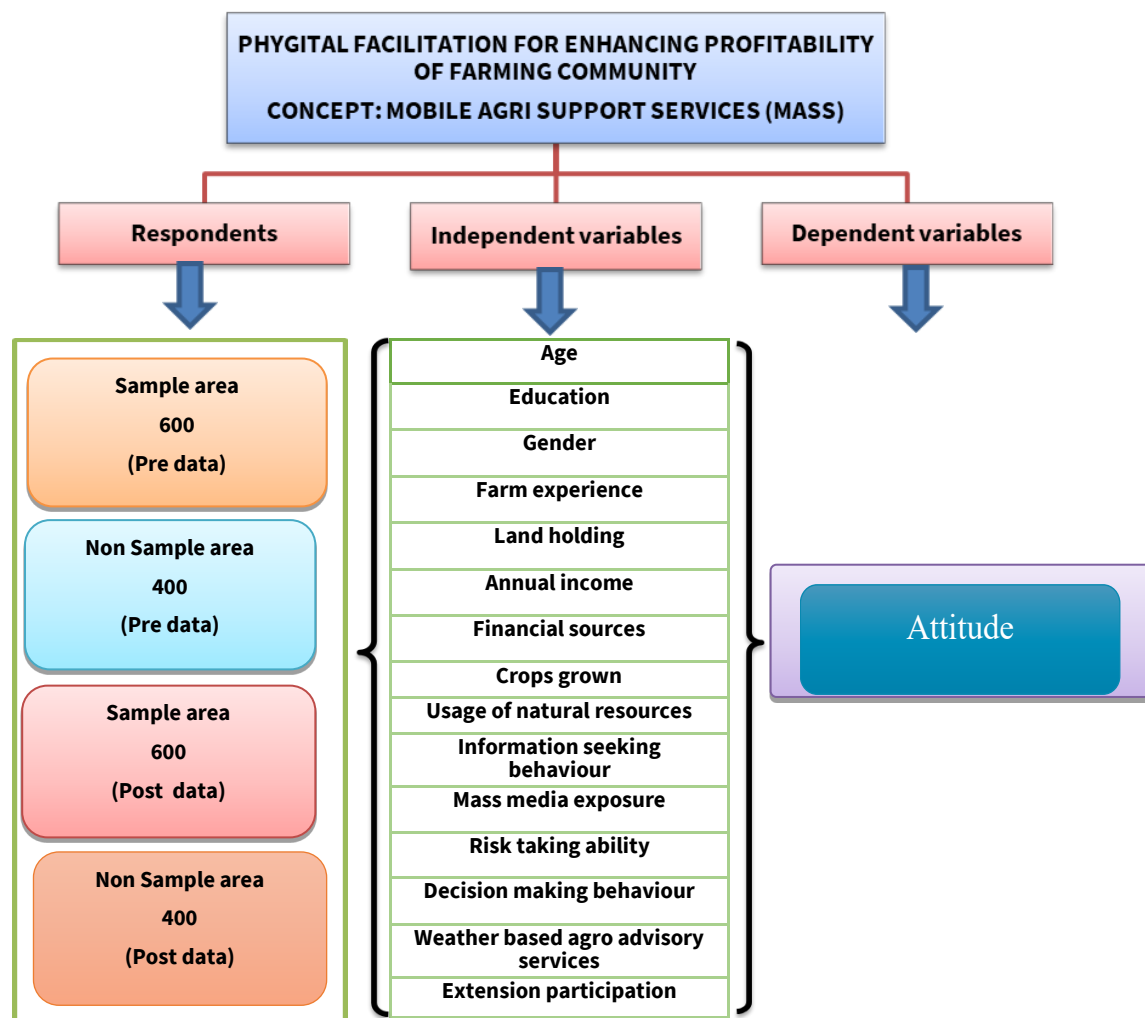


Fig. 1. Conceptual model of the study.

integrating soil health testing, drone demonstrations, video conferencing and digital app-based linkages. This combination aligns with emerging literature advocating for hybrid extension ecosystems that merge personal interaction with technological innovation for sustainable impact. Over the past two decades, the integration of information and communication technologies (ICTs) into agricultural extension has been recognised as an important pathway for improving information dissemination and knowledge access among farmers (6, 7). However, the digital divide continues to persist in rural areas due to socio-economic constraints, limited infrastructure and varying levels of digital literacy among farmers (8).

Furthermore, several studies highlight that farmers' adoption of digital agricultural services is influenced by factors such as perceived usefulness, ease of use, social influence and access to information networks (9, 10). Impact evaluation studies using experimental and quasi-experimental methods also show that mobile-based advisory services significantly improve farmers' knowledge, decision-making and technology adoption (11). Studies have shown that digital agricultural advisory services can significantly improve farmers' knowledge and adoption of improved farming practices when supported by appropriate institutional mechanisms (12). However, despite rapid technological advancements, the digital divide continues to limit the effective use of digital agriculture among smallholder farmers, particularly in developing countries where access to digital infrastructure, digital literacy and institutional support remain inadequate (13, 14). To address these challenges, hybrid extension approaches that integrate physical interaction with digital platforms, commonly referred to as phygital extension systems, have emerged as

promising solutions for improving last-mile service delivery (15). These approaches combine the strengths of traditional face-to-face advisory services with digital communication technologies to enhance farmers' engagement and access to agricultural innovations. Recent studies also emphasise that bundling multiple innovations and services can significantly enhance the transformation of agri-food systems and accelerate the adoption of new technologies among farmers (16).

The mobile agri support services initiative is one such innovative phygital model, designed by the Extension Education Institute (EEI), Southern Region, Professor Jayashankar Telangana Agricultural University (PJTSAU), in collaboration with Evergreen Energy Enterprises Pvt. Ltd. (EEEIPL), implemented in the study area. The MASS unit is a mobile extension platform equipped with soil testing kits, drones, expert advisory and ICT-enabled services that directly engage with farmers in remote villages. Governmental and non-governmental efforts to modernise agricultural extension have seen progress, yet large segments of the farming population remain disconnected from these services due to the last-mile gap, the critical interface where policy and innovation must reach farmers at the grassroots. This gap is particularly stark in aspirational and remote districts, where poor connectivity, low digital literacy and inadequate human resources hinder access to timely and actionable agricultural services. The objective of the present study is to assess the attitude of the farmers towards the MASS initiative. The findings are intended to inform both academic discourse and extension policy by offering an evidence-based, scalable model for integrating physical and digital agri-extension aligned with India's broader goals of digital India, climate resilience and inclusive rural transformation. H_0 : There is no

significant difference in farmers' attitudes and access to extension services among farmers across the selected villages. H₁: Significant differences exist in farmers' attitudes and access to services among farmers across the selected villages due to variations in advisory services, institutional support and socio-economic factors.

Materials and Methods

Research design

The study adopted a quasi-experimental research design with an experimental-control group framework to evaluate the effectiveness of the mobile agri support services (MASS) intervention in transforming farmers' attitudes toward phygital service delivery. The difference-in-differences (DID) approach was employed as the primary impact evaluation method, as it allows for causal inference by comparing the change in outcomes for the treatment group (beneficiaries) before and after the intervention, with the change in the control group (non-beneficiaries) over the same period. Additionally, fixed-effects regression modelling was used to account for unobserved heterogeneity and time-invariant individual effects.

Sampling procedure

A multi-stage purposive and random sampling technique was used for the selection of state, districts, mandals, villages and respondents: Telangana was selected purposively as the site of MASS implementation. Three aspirational districts, Kumuram Bheem Asifabad, Jayashankar Bhupalapally and Bhadradi Kothagudem, were chosen based on their backwardness index. Two mandals per district were randomly selected. One representative village from each mandal was chosen, totalling six sample villages. 600 farmers were selected randomly from intervention villages to form the experimental group and 400 farmers were selected from nearby non-intervention villages to serve as the control group. The final sample comprised 1000 respondents, ensuring adequate power for statistical analysis. Data were collected from the 600 respondents using participatory rural appraisal (PRA) techniques, focused group discussion (FGD) and a well-structured interview schedule. Socio-economic profile included farmer demographics and behavioural factors: age, gender, education, landholding, farming experience, income, risk-taking ability, mass media exposure, extension participation, decision-making behaviour and use of agro-advisories. All respondents were trained under the MASS initiative to avail digital services. The sample size was determined to ensure adequate statistical power for detecting meaningful program effects. A priori power calculations indicate that a sample of approximately 1000 respondents (600 treatment and 400 control) provides sufficient power (≥ 0.80) to detect moderate effect sizes at a 5 % level of significance in a difference-in-differences framework. This sample size also aligns with recommended practices in impact evaluation studies involving quasi-experimental designs, where balanced treatment and comparison groups improve the robustness and reliability of causal inference.

Variables and measurement

The study measured changes in the dependent variable as:

Attitude towards phygital services

Independent variables included farmer demographics and behavioural factors: age, gender, education, landholding, farming experience, income, risk-taking ability, mass media exposure, extension participation, decision-making behaviour and use of agro-advisories. Measurement scales were developed specifically for this

project and pre-tested. Attitude items were captured through structured schedules and categorised using class interval and arithmetic mean methods.

Farmers' attitude toward phygital agricultural services was measured using a 20-item Likert-type attitude scale developed for this study. The items captured farmers' perceptions regarding usefulness, accessibility, reliability and decision-making support provided by phygital advisory services. Responses were recorded on a five-point scale ranging from 1 (strongly disagree) to 5 (strongly agree). Negatively worded statements were reverse-coded. The overall attitude score was obtained by summing the item scores, resulting in a possible range of 20–100, where higher scores indicated a more favourable attitude toward phygital services. The scale was pre-tested for clarity and its internal consistency reliability was confirmed using Cronbach's alpha ($\alpha = 0.84$). Content validity was ensured through expert review.

Tools for data collection

A structured interview schedule was developed in English, translated into Telugu and validated through expert review.

Data analysis techniques

Data were coded and analysed using descriptive and inferential statistical methods. The following tools were applied: Frequencies and percentages for distribution analysis, class interval method for categorisation of aspirations, arithmetic mean for central tendency estimation, Z-test for significance testing between groups, as the sample size ($n = 1000$) is large, the Z-test is statistically appropriate and aids in strengthening the interpretability of results, though causal attribution is derived exclusively from the DID estimates. Difference-in-difference estimator to measure net effects of the MASS intervention, fixed effects models to control for unobserved heterogeneity in longitudinal data. SPSS statistical software was used for the analysis of the data.

Difference-in-difference analysis is a quasi-experimental, longitudinal analysis method used to estimate causal effects by comparing the changes in outcomes over time between a treatment group and a control group. By calculating the difference in trends (rather than just levels) before and after an intervention, it accounts for time-invariant unobserved confounding factors, making it a robust alternative when randomised experiments are not feasible. The method computes the difference in differences by taking the change in the treatment group (PostT - PreT) and subtracting the change in the control group (PostC - PreC).

$$DID = (Y_{T,post} - Y_{T,pre}) - (Y_{C,post} - Y_{C,pre}) \quad (\text{Eqn. 1})$$

It isolates the effect of an intervention (MASS initiative) by assuming that in the absence of the treatment, the difference between the treatment and control groups would have remained constant over time. The DID model evaluated differences in attitude changes between beneficiaries and non-beneficiaries before and after intervention, using the following formula:

The basic DID model can be estimated using a linear regression (Ordinary least squares (OLS)):

$$Y_{it} = \beta_0 + \beta_1 \text{Group}_i + \beta_2 \text{Time}_t + \beta_3 (\text{Group}_i \times \text{Time}_t) + \epsilon_{it} \quad (\text{Eqn. 2})$$

Here, β_3 represents the net effect of the MASS intervention.

The DID approach assumed parallel trends between groups prior to intervention and adjusted for time-invariant unobserved factors using a fixed effects regression model where applicable.

Data interpretation and reporting

Data were systematically tabulated, analysed and interpreted to assess the pre- and post-intervention changes in farmers' aspirations. The findings were presented in both descriptive and analytical formats to draw meaningful conclusions and policy recommendations regarding the MASS intervention.

Results

Attitude of the sample farmers on phygital services before the implementation of the MASS intervention

Results from Table 1 present that the distribution of sample farmers' attitudes towards phygital services before the implementation of

MASS. The results show that 80.00–95.00 % of farmers expressed a low attitude, indicating little awareness or inclination towards such services. Only 5.00–20.00 % exhibited medium attitude, while none of the respondents indicated high attitude levels.

It is also evident from Table 2 that the item-wise responses of the farmers highlight that among the physical services, agro advisory services showed moderate variation across villages. Only 1.00 % of farmers in Polaram reported access to agro-advisory services, whereas higher proportions were observed in Nayakapuguda (45.00 %), Sayanapalli (50.00 %), Nazrulnagar (37.00 %), Abbugudem (20.00 %) and Gunturpally (40.00 %). These results indicate an uneven distribution of advisory services among the study locations.

Table 1. Distribution of sample farmers according to attitude on phygital services before MASS intervention (n = 100 per village)

Response category	Polaram	Nayakapuguda	Sayanapalli	Nazrulnagar	Abbugudem	Gunturpally
Low attitude	88.00 (88 %)	88.00 (88 %)	95.00 (95 %)	80.00 (80 %)	86.00 (86 %)	80.00 (80 %)
Medium attitude	12.00 (12 %)	12.00 (12 %)	5.00 (5 %)	20.00 (20 %)	14.00 (14 %)	20.00 (20 %)
High attitude	0	0	0	0	0	0

Table 2. Item analysis of sample farmers according to the Attitude on phygital services before implementation of MASS intervention (n = 100 per village)

Physical services	Polaram		Nayakapugud		Sayanapalli		Nazrulnagar		Abbugudem		Gunturpally	
	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N
Agro Advisory services	1.00 (1 %)	99.00 (99 %)	45.00 (45 %)	55.00 (55 %)	50.00 (50 %)	50.00 (50 %)	37.00 (37 %)	63.00 (63 %)	20.00 (20 %)	80.00 (80 %)	40.00 (40 %)	60.00 (60 %)
Drone-based technology	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)
Agri products services	25.00 (25 %)	75.00 (75 %)	40.00 (40 %)	60.00 (60 %)	45.00 (45 %)	55.00 (55 %)	30.00 (30 %)	70.00 (70 %)	45.00 (45 %)	55.00 (55 %)	37.00 (37 %)	63.00 (63 %)
Manufacturing and marketing of the products	1.00 (1 %)	99.00 (99 %)	20.00 (20 %)	80.00 (80 %)	35.00 (35 %)	65.00 (65 %)	36.00 (36 %)	64.00 (64 %)	40.00 (40 %)	60.00 (60 %)	63.00 (63 %)	37.00 (37 %)
Climate change solutions	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)
Carbon credit solutions	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)
Sustainability solutions	25.00 (25 %)	75.00 (75 %)	30.00 (30 %)	70.00 (70 %)	48.00 (48 %)	52.00 (52 %)	17.00 (17 %)	83.00 (83 %)	25.00 (25 %)	75.00 (75 %)	19.00 (19 %)	81.00 (81 %)
Crop insurance	45.00 (45 %)	55.00 (55 %)	30.00 (30 %)	70.00 (70 %)	45.00 (45 %)	65.00 (65 %)	31.00 (31 %)	69.00 (69 %)	19.00 (19 %)	81.00 (81 %)	28.00 (28 %)	72.00 (72 %)
Multiple temperature and cold storage systems	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)
Agri inputs	40.00 (40 %)	60.00 (60 %)	20.00 (20 %)	80.00 (80 %)	10.00 (10 %)	90.00 (90 %)	45.00 (45 %)	55.00 (55 %)	37.00 (37 %)	63.00 (63 %)	10.00 (10 %)	90.00 (90 %)
Capacity building	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)
Digital services												
Smart crop digital platform	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)
e-commerce platform	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)
Weather station	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)
Digital trainings	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)
Digital farmer scientist interaction meeting	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)
Smart agriculture solutions	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)
WhatsApp groups	50.00 (50 %)	50.00 (50 %)	30.00 (30 %)	70.00 (70 %)	25.00 (25 %)	75.00 (75 %)	30.00 (30 %)	70.00 (70 %)	40.00 (40 %)	60.00 (60 %)	26.00 (26 %)	74.00 (74 %)
Agri Central app	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)
Kisan Sarathi	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)

The availability of agri-product-related services was relatively moderate. About 25.00 % of respondents in Polaram, 40.00 % in Nayakapuguda, 45.00 % in Sayanapalli, 30.00 % in Nazrulnagar, 45.00 % in Abbugudem and 37.00 % in Gunturpally reported receiving such services. Services related to the manufacturing and marketing of agricultural products showed considerable variation among villages. Only 1 % of farmers in Polaram reported access to these services, while 20.00 % in Nayakapuguda, 35.00 % in Sayanapalli, 36.00 % in Nazrulnagar, 40.00 % in Abbugudem and 63.00 % in Gunturpally reported availability, indicating relatively better access in Gunturpally.

With regard to sustainability-related services, 25 % of farmers in Polaram, 30.00 % in Nayakapuguda, 48.00 % in Sayanapalli, reported receiving such services, whereas lower levels were observed in Nazrulnagar (17.00 %), Abbugudem (17.00 %) and Gunturpally (19.00 %). Crop insurance services were available to a moderate proportion of farmers across villages. The highest coverage was observed in Polaram and Sayanapalli of about 45.00 % each, followed by Nazrulnagar (31.00 %), Nayakapuguda (31.00 %), Gunturpally (28.00 %) and Abbugudem (19.00 %). Similarly, agricultural input services were reported by Polaram (40.00 %), Nayakapuguda (20.00 %), Sayanapalli (10.00 %), Nazrulnagar (45.00 %), Abbugudem (37.00 %) and Gunturpally (10.00 %), indicating uneven distribution of input supply services among the villages. However, several important services were completely absent in all the study villages. None of the respondents reported access to drone-based technology, climate change solutions, carbon credit solutions, multiple temperature and cold storage systems or capacity building programs, suggesting a significant gap in advanced agricultural service delivery.

The analysis further revealed that most digital agricultural services were not available across the surveyed villages. Services such as smart crop digital platforms, e-commerce platforms, weather station services, digital training programs, digital farmer-scientist interaction meetings, smart agriculture solutions, Agri Central app and Kisan Sarathi were reported as unavailable by all respondents across the 6 villages. Among the digital communication tools, WhatsApp groups were the only service reported by farmers. Participation in WhatsApp-based agricultural information groups was observed among Polaram (50.00 %), Nayakapuguda (30.00 %), Sayanapalli (25.00 %), Nazrulnagar (30.00 %), Abbugudem (40.00 %) and Gunturpally (26.00 %).

Attitude of the non-sample farmers before the implementation of the MASS intervention

The results presented in Table 3 indicate that non-sample villages also show the same trend as the sample area. The majority (88.00–92.00 %) of farmers exhibited a low attitude, while only 8.00–12.00 % reported a medium attitude and none showed a high attitude. The item analysis in Table 4 again confirms that while physical services such as agro-advisory and crop insurance were recognised to an extent, digital services were completely unknown in non-sample villages. The majority of the farmers of the non-

sample area did not know about phygital services, whereas a few farmers had some knowledge of physical services through different extension units of Professor Jayashankar Telangana Agriculture University and state departments of agriculture and allied sectors. But none of the farmers had shown interest or knowledge in the digital services.

Attitude of the sample farmers after implementation of the MASS intervention

Following the implementation of MASS, a significant transformation in farmers' attitudes was observed (Table 5). Across all villages, the majority (80.00–90.00 %) of farmers expressed a high attitude, with (10.00–20.00 %) remaining at medium levels. The sharp increase in high attitude levels highlights the effectiveness of MASS interventions in building farmers' confidence in phygital services. Item-level analysis revealed substantial improvement in both physical and digital domains (Table 6). Farmers reported high acceptance of agro-advisory services, crop insurance, sustainability solutions and input support. Notably, unlike pre-intervention results, digital services such as smart crop platforms, e-commerce platforms, digital trainings, farmer-scientist meetings and WhatsApp groups also recorded strong positive responses of about 75.00–100.00 %. The majority (75.00–100.00 %) of the farmers had shown a positive attitude towards the phygital services due to its cost effectiveness, timeliness and solutions offered in the current scenario. Very few (10.00–25.00 %) of the farmers had a negative attitude due to doubts about the continuation of the project in their villages.

Attitude of the non-sample farmers after implementation of the MASS intervention

In contrast, non-sample farmers continued to show very little change in their attitudes even after the project (Table 7 and 8). Over 88.00–92.00 % remained in the low category, with only a few (8.00–12.00 %) indicating a medium attitude and none of the respondents expressed a high attitude. The absence of exposure to MASS services explains the negligible change in attitude among non-sample farmers. Whereas the few farmers showed a moderate increase in the attitude due to the spill-over effect (peer-to-peer relationships) from the sample area farmers.

Difference-in-difference (DID) analysis

The difference-in-difference (DID) analysis was conducted to assess the impact of the MASS intervention on the change in farmers' attitudes toward phygital agricultural services between the sample and non-sample areas. As shown in Table 9, the mean attitude score in the sample area increased substantially from 11.12 units during the pre-intervention to 90.41 units in the post intervention period, indicating a change of + 79.29 units. In contrast, the non-sample area recorded only a marginal increase, with the mean score rising from 18.00 to 19.18 units, reflecting a change of + 1.18 units. From the results, it is evident that the DID estimate was 78.11 units, suggesting a substantial positive impact of the MASS intervention on farmers' attitude toward phygital services in the sample area compared to the non-sample area.

Table 3. Distribution of non-sample farmers according to attitude on phygital services before MASS intervention

Response category	Mulugupally (n = 133)	Irakapally (n = 133)	Chinnavenkatapuram (n = 134)
Low attitude	121.00 (91 %)	123.00 (92 %)	118.00 (88 %)
Medium attitude	12.00 (9 %)	10.00 (8 %)	16.00 (12 %)
High attitude	0	0	0

Table 4. Item analysis of Non-sample farmers according to the attitude on phygital Services before implementation of MASS intervention

Physical services	Mulugupally (n = 133)		Irakapally (n = 133)		Chinnavenkatapuram (n = 134)	
	Y	N	Y	N	Y	N
Agro Advisory services	80.00 (60 %)	53.00 (40 %)	53.00 (40 %)	80.00 (60 %)	101.00 (75 %)	33.00 (25 %)
Drone-based technology	0 (0 %)	133.00 (100 %)	0 (0 %)	133.00 (100 %)	0 (0 %)	134.00 (100 %)
Agri products services	27.00 (20 %)	106.00 (80 %)	47.00 (35 %)	86.00 (65 %)	40.00 (30 %)	94.00 (70 %)
Manufacturing and marketing of the products	53.00 (40 %)	80.00 (60 %)	47.00 (35 %)	86.00 (65 %)	60.00 (45 %)	73.00 (55 %)
Climate change solutions	0 (0 %)	133.00 (100 %)	0 (0 %)	133.00 (100 %)	0 (0 %)	134.00 (100 %)
Carbon credit solutions	0 (0 %)	133.00 (100 %)	0 (0 %)	133.00 (100 %)	0 (0 %)	134.00 (100 %)
Sustainability solutions	27.00 (20 %)	106.00 (80 %)	60.00 (44 %)	73.00 (56 %)	60.00 (45 %)	74.00 (55 %)
Crop insurance	20.00 (15 %)	113.00 (85 %)	53.00 (40 %)	80.00 (60 %)	40.00 (30 %)	94.00 (70 %)
Multiple temperature and cold storage systems	0 (0 %)	133.00 (100 %)	0 (0 %)	133.00 (100 %)	0 (0 %)	134.00 (100 %)
Agri inputs	27.00 (20 %)	106.00 (80 %)	51.00 (38 %)	82.00 (62 %)	63.00 (47 %)	71.00 (53 %)
Capacity building	0 (0 %)	133.00 (100 %)	0 (0 %)	133.00 (100 %)	0 (0 %)	134.00 (100 %)
Digital services						
Smart crop digital platform	0 (0 %)	133.00 (100 %)	0 (0 %)	133.00 (100 %)	0 (0 %)	134.00 (100 %)
e-commerce platform	0 (0 %)	133.00 (100 %)	0 (0 %)	133.00 (100 %)	0 (0 %)	134.00 (100 %)
Weather station	0 (0 %)	133.00 (100 %)	0 (0 %)	133.00 (100 %)	0 (0 %)	134.00 (100 %)
Digital trainings	0 (0 %)	133.00 (100 %)	0 (0 %)	133.00 (100 %)	0 (0 %)	134.00 (100 %)
Digital farmer scientist interaction meeting	0 (0 %)	133.00 (100 %)	0 (0 %)	133.00 (100 %)	0 (0 %)	134.00 (100 %)
Smart agriculture solutions	0 (0 %)	133.00 (100 %)	0 (0 %)	133.00 (100 %)	0 (0 %)	134.00 (100 %)
Agri Central app facilitation	33.00 (25 %)	100.00 (75 %)	40.00 (30 %)	93.00 (70 %)	37.00 (28 %)	97.00 (72 %)
WhatsApp groups facilitation	0 (0 %)	133.00 (100 %)	0 (0 %)	133.00 (100 %)	0 (0 %)	134.00 (100 %)
KisanSarathi intermediation	0 (0 %)	133.00 (100 %)	0 (0 %)	133.00 (100 %)	0 (0 %)	134.00 (100 %)

Table 5. Distribution of sample farmers according to attitude on phygital services after MASS intervention (n = 100 per village)

Response category	Polaram	Nayakapuguda	Sayanapalli	Nazrulnagar	Abbugudem	Gunturupally
Medium attitude	20.00 (20 %)	16.00 (16 %)	10.00 (10 %)	18.00 (18 %)	17.00 (17 %)	16.00 (16 %)
High attitude	80.00 (80 %)	84.00 (84 %)	90.00 (90 %)	82.00 (82 %)	83.00 (83 %)	84.00 (84 %)

Table 6. Item analysis of Sample farmers according to the attitude on phygital services after implementation of MASS intervention (n = 100 per village)

Physical services	Polaram		Nayakapuguda		Sayanapalli		Nazrulnagar		Abbugudem		Gunturupally	
	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N
Agro advisory services	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0
Drone based technology	80.00 (80 %)	20.00 (20 %)	100.00 (100 %)	0	90.00 (90 %)	10.00 (10 %)	100.00 (100 %)	0	80.00 (80 %)	20.00 (20 %)	100.00 (100 %)	0
Agri products services	90.00 (90 %)	10.00 (10 %)	80.00 (80 %)	20.00 (20 %)	90.00 (90 %)	10.00 (10 %)	100.00 (100 %)	0	90.00 (90 %)	10.00 (10 %)	80.00 (80 %)	20.00 (20 %)
Manufacturing and marketing of the products	75.00 (75 %)	25.00 (25 %)	75.00 (75 %)	25.00 (25 %)	75.00 (75 %)	25.00 (25 %)	75.00 (75 %)	25.00 (25 %)	75.00 (75 %)	25.00 (25 %)	75.00 (75 %)	25.00 (25 %)
Climate change solutions	90.00 (90 %)	10.00 (10 %)	90.00 (90 %)	10.00 (10 %)	80.00 (80 %)	20.00 (20 %)	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0
Carbon credit solutions	75.00 (75 %)	25.00 (25 %)	75.00 (75 %)	25.00 (25 %)	75.00 (75 %)	25.00 (25 %)	75.00 (75 %)	25.00 (25 %)	75.00 (75 %)	25.00 (25 %)	75.00 (75 %)	25.00 (25 %)
Sustainability solutions	90.00 (90 %)	10.00 (10 %)	80.00 (80 %)	20.00 (20 %)	90.00 (90 %)	10.00 (10 %)	100.00 (100 %)	0	90.00 (90 %)	10.00 (10 %)	80.00 (80 %)	20.00 (20 %)
Crop insurance	90.00 (90 %)	10.00 (10 %)	80.00 (80 %)	20.00 (20 %)	90.00 (90 %)	10.00 (10 %)	100.00 (100 %)	0	90.00 (90 %)	10.00 (10 %)	80.00 (80 %)	20.00 (20 %)
Multiple temperature and cold storage systems	75.00 (75 %)	25.00 (25 %)	75.00 (75 %)	25.00 (25 %)	75.00 (75 %)	25.00 (25 %)	75.00 (75 %)	25.00 (25 %)	75.00 (75 %)	25.00 (25 %)	75.00 (75 %)	25.00 (25 %)
Agri inputs	80.00 (80 %)	20.00 (20 %)	100.00 (100 %)	0	90.00 (90 %)	10.00 (10 %)	100.00 (100 %)	0	80.00 (80 %)	20.00 (20 %)	100.00 (100 %)	0
Capacity building	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0
Digital services												
Smart crop digital platform	75.00 (75 %)	25.00 (25 %)	75.00 (75 %)	25.00 (25 %)	75.00 (75 %)	25.00 (25 %)	75.00 (75 %)	25.00 (25 %)	75.00 (75 %)	25.00 (25 %)	75.00 (75 %)	25.00 (25 %)
e-commerce platform	75.00 (75 %)	25.00 (25 %)	75.00 (75 %)	25.00 (25 %)	75.00 (75 %)	25.00 (25 %)	75.00 (75 %)	25.00 (25 %)	75.00 (75 %)	25.00 (25 %)	75.00 (75 %)	25.00 (25 %)
Weather station	80.00 (80 %)	20.00 (20 %)	100.00 (100 %)	0	90.00 (90 %)	10.00 (10 %)	100.00 (100 %)	0	80.00 (80 %)	20.00 (20 %)	100.00 (100 %)	0
Digital trainings	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0
Digital farmer scientist interaction meeting	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0
Smart agriculture solutions	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0
Agri central app facilitation	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0
Whatsapp groups facilitation	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0
Kisan sarathi intermediation	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0	100.00 (100 %)	0

Table 7. Distribution of non-sample farmers according to attitude on phygital services after MASS intervention (n = 100 per village)

Response category	Mulugupally (n = 133)	Irakapally (n = 133)	Chinnavenkatapuram (n = 134)
Low attitude	121.00 (91 %)	123.00 (92 %)	118.00 (88 %)
Medium attitude	12.00 (9 %)	10.00 (8 %)	16.00 (12 %)
High attitude	0	0	0

Table 8. Item analysis of non-sample farmers according to the attitude on phygital services after implementation of MASS interventions (n = 100 per village)

Physical services	Mulugupally (n = 133)		Irakapally (n = 133)		Chinnavenkatapuram (n = 134)	
	Y	N	Y	N	Y	N
Agro advisory services	80.00 (60 %)	53.00 (40 %)	53.00 (40 %)	80.00 (60 %)	101.00 (75 %)	33.00 (25 %)
Drone-based technology	0 (0 %)	133.00 (100 %)	0 (0 %)	133.00 (100 %)	0 (0 %)	134.00 (100 %)
Agri products services	27.00 (20 %)	106.00 (80 %)	47.00 (35 %)	86.00 (65 %)	40.00 (30 %)	94.00 (70 %)
Manufacturing and marketing of the products	53.00 (40 %)	80.00 (60 %)	47.00 (35 %)	86.00 (65 %)	60.00 (45 %)	73.00 (55 %)
Climate change solutions	0 (0 %)	133.00 (100 %)	0 (0 %)	133.00 (100 %)	0 (0 %)	134.00 (100 %)
Carbon credit solutions	0 (0 %)	133.00 (100 %)	0 (0 %)	133.00 (100 %)	0 (0 %)	134.00 (100 %)
Sustainability solutions	27.00 (20 %)	106.00 (80 %)	64.00 (48 %)	69.00 (52 %)	74.00 (55 %)	60.00 (45 %)
Crop insurance	20.00 (15 %)	113.00 (85 %)	53.00 (40 %)	80.00 (60 %)	94.00 (70 %)	40.00 (30 %)
Multiple temperature and cold storage systems	0 (0 %)	133.00 (100 %)	0 (0 %)	133.00 (100 %)	0 (0 %)	134.00 (100 %)
Agri inputs	27.00 (20 %)	106.00 (80 %)	51.00 (38 %)	82.00 (62 %)	63.00 (47 %)	71.00 (53 %)
Capacity building	0 (0 %)	133.00 (100 %)	0 (0 %)	133.00 (100 %)	0 (0 %)	134.00 (100 %)
Digital services						
Smart crop digital platform	0 (0 %)	133.00 (100 %)	0 (0 %)	133.00 (100 %)	0 (0 %)	134.00 (100 %)
e-commerce platform	0 (0 %)	133.00 (100 %)	0 (0 %)	133.00 (100 %)	0 (0 %)	134.00 (100 %)
Weather station	0 (0 %)	133.00 (100 %)	0 (0 %)	133.00 (100 %)	0 (0 %)	134.00 (100 %)
Digital trainings	0 (0 %)	133.00 (100 %)	0 (0 %)	133.00 (100 %)	0 (0 %)	134.00 (100 %)
Digital farmer scientist interaction meeting	0 (0 %)	133.00 (100 %)	0 (0 %)	133.00 (100 %)	0 (0 %)	134.00 (100 %)
Smart agriculture solutions	0 (0 %)	133.00 (100 %)	0 (0 %)	133.00 (100 %)	0 (0 %)	134.00 (100 %)
Agri central app facilitation	0 (0 %)	133.00 (100 %)	0 (0 %)	133.00 (100 %)	0 (0 %)	134.00 (100 %)
WhatsApp groups facilitation	33.00 (25 %)	100.00 (75 %)	40.00 (30 %)	93.00 (70 %)	37.00 (28 %)	97.00 (72 %)
KisanSarathi intermediation	0 (0 %)	133.00 (100 %)	0 (0 %)	133.00 (100 %)	0 (0 %)	134.00 (100 %)

Table 9. Difference-in-difference outcome summary

Group	Pre-intervention (units)	Post-intervention (units)	Change
Sample area	11.12	90.41	+ 79.29
Non-sample area	18.00	19.18	+ 1.18
Difference-in-difference			78.11

The DID regression results presented in Table 10 further confirm the significant impact of the intervention. The treatment-time interaction term ($T_r \times T_i$), which captures the causal impact of the MASS intervention, was positive and statistically significant ($\beta = 0.0052$, $SE = 0.0015$, $p < 0.01$). This indicates that the intervention significantly contributed to the increase in farmers' attitudes toward phygital services in the treatment area compared to the control area.

Among the socio-economic variables, age ($\beta = 0.0049$, $SE = 0.0015$, $p < 0.01$) showed a positive and significant relationship with farmers' attitude toward phygital services, suggesting that older farmers in the study area demonstrated relatively greater changes in attitude following the intervention. Education ($\beta = 0.0444$, $SE = 0.0015$, $p < 0.01$) also had a strong positive and highly significant influence, indicating that farmers with higher educational levels were more receptive to phygital agricultural services.

Similarly, landholding size ($\beta = 0.0221$, $p < 0.05$) was found to significantly influence attitude change, implying that farmers with larger landholdings were more likely to adopt or respond positively to phygital service interventions. Usage of natural resources ($\beta = 0.0308$, $p < 0.05$) also showed a positive and significant effect. Behavioural and communication-related variables played an important role in influencing farmers' attitudes. Information

seeking behaviour ($\beta = 0.0016, p < 0.05$), mass media exposure ($\beta = 0.0150, p < 0.05$), risk-taking ability ($\beta = 0.0408, p < 0.05$), decision-making behaviour ($\beta = 0.0226, p < 0.01$) and extension participation ($\beta = 0.0021, p < 0.05$) were all found to significantly influence farmers' attitude toward phygital services.

Table 10. Difference-in-difference regression on the increase in attitude of farmers (sample and non-sample) towards phygital services before and after MASS intervention

Variable	Coefficient	SE
Tr*Ti Interaction	0.0052**	0.0014
Age	0.0049**	0.0020
Gender	0.0052	0.0430
Farming experience	0.000	omitted
Education	0.0444**	0.0067
Land holding	0.0221*	0.0110
Annual income	0.0069	0.0257
Financial sources	0.0038	0.0112
Usage of natural resources	0.0308*	0.0148
Information seeking behaviour	0.0016**	0.0002
Mass media exposure	0.0150*	0.0073
Risk taking ability	0.0408**	0.0054
Decision making behaviour	0.0226**	0.0089
Extension participation	0.0021*	0.0010
n	1600	
F (13,1187)	2.45**	
F (399, 1187) ($\mu_i = 0$)	3.31**	

*Significant at 5 % level of significance, **Significant at 1 % level of significance.

However, variables such as gender, annual income and financial sources were found to be statistically non-significant, indicating that these factors did not have a strong influence on the change in farmers' attitude in the context of the intervention. Additionally, farming experience was omitted from the model, likely due to multicollinearity or lack of variation in the dataset. The overall model was statistically significant, as indicated by the F-statistic ($F(13,1187) = 2.45, p < 0.01$) and the fixed effects test ($F(399,1187) = 3.31, p < 0.01$). The analysis was conducted on a sample size of 1600 observations, confirming the robustness of the regression results.

Discussion

Attitude of the sample farmers on phygital services before implementation of MASS intervention

The results indicate that the majority of farmers exhibited a low attitude toward phygital agricultural services before the implementation of MASS. This suggests limited awareness and exposure to integrated physical and digital agricultural services among farmers. Adoption of phygital agricultural extension services is often constrained by low digital literacy and limited access to extension systems in rural areas (1).

The item-wise analysis revealed an uneven distribution of physical agricultural services across villages. Agro-advisory services, agricultural product services, marketing-related services, sustainability services, crop insurance and input supply were available to varying degrees across the study villages, indicating disparities in extension outreach and institutional support. Which emphasises the need for stronger extension networks to improve service delivery to farmers. The findings further revealed that advanced agricultural services, including drone-based technology, climate change solutions, carbon credit services, cold storage facilities and capacity-building programs, were completely absent in the study villages. Similarly, most digital agricultural services were

unavailable, including smart crop platforms, e-commerce services, weather stations and digital training programs. Among digital communication tools, only WhatsApp groups were used by some farmers for sharing agricultural information. Overall, the results highlight low awareness, uneven access to agricultural services and limited penetration of digital technologies, indicating the need for integrated phygital extension models such as the MASS approach to strengthen agricultural service delivery and farmer engagement.

Attitude of the non-sample farmers before implementation of MASS intervention

Overall, the findings highlight that while farmers in non-sample villages have some exposure to traditional extension services, their knowledge and perception of digital and phygital agricultural services remain extremely limited. This underscores the importance of strengthening digital extension initiatives and promoting integrated phygital models to enhance farmers' awareness, access to information and adoption of modern agricultural technologies. The item-wise analysis further indicates that farmers in non-sample villages had some recognition of traditional physical services, particularly agro-advisory and crop insurance services. This may be attributed to the outreach efforts of institutions such as PJTSAU and various state departments of agriculture and allied sectors, which continue to provide conventional extension support to farmers. Previous studies have noted that public agricultural extension systems play a crucial role in disseminating information on crop management, input use and government schemes in rural areas (2).

Attitude of the sample farmers after implementation of MASS intervention

It is understood that there is considerable improvement in the attitude of the sample farmers towards phygital services offered through MASS intervention. The basic spirit and philosophy of the study is to orient the farmers on phygital (physical and digital) services offered through various information service providers of public, private and nongovernmental organisations like Ever Green Energy Enterprises Pvt Ltd., Kisan Link, Kisan Sarathi, IFFCO, Vyomic drones, scientists of PJTAU, NABARD officials, District Agri and Allied sector officials. Farmers were continuously trained at various growth stages of Paddy, Cotton and Redgram crops through various mobile agri support services (MASS) and acquired knowledge on climate resilient practices of these crops and skills on application of nano urea and DAP, adoption of integrated pest and disease management, usage of drones in spray fluid application etc.

Attitude of the non-sample farmers after implementation of the MASS intervention

The results show that farmers in the non-sample villages experienced very little change in their attitudes toward phygital services even after the project period. A large majority remained in the low attitude category, while only a small proportion exhibited a medium attitude and none reported a high attitude. This indicates that without direct exposure to the MASS intervention, farmers' perceptions toward phygital agricultural services remain largely unchanged.

The minimal change observed among a few farmers may be attributed to the spill-over effect through peer-to-peer interactions with farmers from the sample villages. Informal communication and social networks often enable limited diffusion of information and awareness about new agricultural practices (1). Farmers' attitudes toward digital and integrated extension services improve primarily

through direct participation in extension programs. Overall, the findings emphasise that direct involvement in interventions such as MASS is essential to significantly influence farmers' attitudes. While indirect exposure through social interaction results in only marginal changes.

Comparative analysis of sample and non-sample area

A comparative analysis of the sample area and non-sample area highlights that the sample farmers' attitude improved remarkably post-intervention. Farmers particularly valued doorstep agro-advisory services, climate change solutions, crop insurance, capacity building and drone-based technologies, reflecting their practical utility. In contrast, non-sample farmers showed no significant change, since they had no access to MASS facilities. The DID approach effectively isolates program effects by comparing treatment and control groups over time, accounting for unobserved heterogeneity. Recent studies emphasise that combining digital with physical delivery yields stronger behavioural and attitudinal changes than either mode alone, particularly among smallholders in low-connectivity regions (2, 4).

Over the last two decades, the shift from traditional, face-to-face extension approaches to digital and blended models has been widely documented (6, 7). However, despite several innovations, the digital divide in rural areas persists, primarily due to limited access, inadequate capacity and poor digital literacy among small and marginal farmers (8). To bridge these gaps, the concept of phygital service delivery, a hybrid model combining physical (in-person) and digital (technology-mediated) approaches, has emerged as a promising alternative for inclusive agricultural transformation.

The success of the intervention can be attributed to the mobile agri support services (MASS) trucks, which served as mobile hubs equipped with video conferencing tools, drones, soil testing units, weather stations, nano-fertiliser demonstrations and capacity-building facilities. These trucks operated directly in villages, bridging the knowledge and access gap and instilling confidence among farmers about the potential of phygital services. The MASS intervention aimed to transform farmers' outlook on accessing and utilising both physical and digital agricultural services. The results of the pre- and post-intervention survey clearly demonstrate the significant positive changes among the beneficiary (sample) group in contrast to the control (non-sample) group.

The DID model shows that the MASS intervention significantly increased the adoption and use of phygital services, confirming the value of such initiatives. Among individual factors, age, education, landholding size and resource use influence utilisation positively, as experienced, educated and resource-rich farmers are better placed to adopt new technologies. Behavioural traits such as information-seeking, media exposure, risk-taking, decision-making ability and extension participation also play a key role, as proactive and informed individuals are more open to innovations. Overall, the results highlight that both intervention involvement and individual characteristics strongly determine the effective use of phygital services.

Empirical studies confirm that perceived usefulness, ease of use, social influence and observability strongly influence technology adoption (9, 10). Randomised controlled trials (RCTs) and DID models have been widely used to assess causal impacts of digital advisories on farmers' knowledge, attitude and adoption behaviour (11).

Studies have shown that mobile-based advisory services and digital agricultural platforms can effectively enhance farmers' knowledge and decision-making when integrated with field-level extension support (17). The success of the MASS intervention further reinforces the importance of blended extension approaches, where digital tools complement traditional extension systems. Furthermore, global studies emphasise that the integration of digital innovations within agricultural advisory systems requires strong institutional collaboration and supportive policy frameworks (12, 14). Previous research also highlights that phygital extension models can play a crucial role in bridging the rural digital divide, particularly in regions with limited connectivity and digital literacy (13, 15). By combining physical outreach with digital technologies, such models help farmers overcome barriers related to information access and technology adoption.

Attitude transformation through MASS

The MASS initiative had a transformational impact on farmers' attitudes, particularly among those with no prior exposure to digital platforms. The mobile nature of the MASS unit ensured geographic inclusivity, reaching remote areas that traditional extension services often fail to serve. The use of drones, soil testing kits, video conferencing and live expert interaction helped overcome scepticism and created a tangible connection between innovation and on-ground farming realities. The shift in attitude was not superficial. It reflected an increase in confidence, willingness to experiment and capacity to engage with both public and private agri-tech services. Moreover, the success of the MASS model highlights the importance of delivering bundled services, including advisory services, training, input support and digital platforms, through a single integrated mechanism. Such bundled approaches have been recognised as effective strategies for transforming agri-food systems and promoting sustainable agricultural development (16).

Implications for policy and scaling

The findings of the study highlight that integrated phygital agricultural extension models, such as the MASS intervention, can significantly improve farmers' attitudes and engagement with modern agricultural services. The success of the intervention demonstrates that combining physical outreach with digital platforms helps overcome barriers related to awareness, access and digital literacy among rural farmers. The use of mobile service units, expert interactions and real-time digital advisories proved effective in bridging the gap between farmers and scientific institutions. Therefore, scaling up such initiatives through wider institutional collaboration among universities, government departments, agri-tech companies and development agencies can help extend these benefits to more villages. Expanding mobile-based phygital service delivery and strengthening digital capacity-building programs can play a key role in reducing the rural digital divide and enhancing the adoption of innovative agricultural technologies among smallholder farmers.

Conclusion

The study revealed that farmers initially had low awareness and limited access to phygital agricultural services in both sample and non-sample villages. However, after the implementation of the MASS intervention, a significant improvement in the attitude of sample farmers toward phygital services was observed, while non-sample farmers showed very little change. The difference-in-

difference analysis further confirmed the positive impact of the MASS intervention on farmers' attitudes. The results highlight that integrated phygital extension approaches combining physical outreach with digital platforms can effectively enhance farmers' awareness, confidence and engagement with modern agricultural services, thereby contributing to improved agricultural development and knowledge dissemination in rural areas.

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Authors' contributions

SD contributed to the conceptualisation of the study, participated in the study design and methodology, conducted data collection and field surveys, performed data analysis and interpretation, prepared visualisations (tables, figures and diagrams), drafted the original manuscript and contributed to its review and editing. JMRM contributed to the study design and methodology, conducted data collection and field surveys, assisted in manuscript review and editing and provided supervision, project administration and funding acquisition. PP provided supervision, project administration and funding acquisition. All authors have read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

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During the preparation of this work the authors used ChatGPT in order to summarise. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

References

- Chander M, Sulaiman RV. Phygital agricultural extension: the next frontier in knowledge delivery. *J Ext Syst.* 2021;37(2):1–10.
- Rao DUM, Reddy AA, Kumar PS. Integrating physical and digital extension mechanisms for sustainable technology dissemination. *Agric Ext Rev.* 2022;34(3):10–18.
- Nain MS, Singh R, Singh B. Digital and phygital innovations for last-mile agricultural extension: pathways and prospects. *Indian J Ext Educ.* 2023;59(1):1–9.
- Singh SP, Reddy GP, Ramesh V. Evaluation of mobile agro-

advisory vans for field-level extension delivery. *J Agric Ext Manag.* 2019;20(2):45–53.

- Rajkumar R, Rao DUM, Sreekanth K. Mobile agro-service units for bridging the last-mile gap in technology dissemination. *J Agric Ext Manag.* 2021;22(1):33–42.
- Meera SN, Jhamtani A, Rao DUM. Information and communication technology in agricultural development: a comparative analysis of three projects from India. *Agric Res Ext Netw Pap.* 2004;(135):1–56.
- Saravanan R. ICTs for agricultural extension: Global experiments, innovations and experiences. New Delhi: New India Publishing Agency; 2010. <https://doi.org/10.59317/9789389992816>
- Mittal S, Mehar M. Socio-economic factors affecting adoption of modern information and communication technology by farmers in India: analysis using multivariate logistic regression. *Agric Econ Res Rev.* 2016;29(2):265–74.
- Jain R, Singh M, Chauhan J. Determinants of farmers' intention toward mobile-based agricultural extension services: An application of UTAUT model. *J Agric Educ Ext.* 2020;26(2):175–88.
- Sharma P, Singh S, Joshi R. Factors influencing adoption of ICT-based agricultural information systems among farmers in Northern India. *Inf Technol Dev.* 2021;27(2):292–310.
- Cole S, Fernando AN. Mobileizing agricultural advice: technology adoption and knowledge gains from mobile phones. *Am Econ Rev.* 2020;110(10):3139–79.
- Fabregas R, Kremer M, Schilbach F. Realizing the potential of digital development: the case of agricultural advice. *Science.* 2019;366(6471):eaay3038. <https://doi.org/10.1126/science.aay3038>
- Klerkx L, Jakku E, Labarthe P. A review of social science on digital agriculture, smart farming and agriculture 4.0: New contributions and a future research agenda. *NJAS Wagening J Life Sci.* 2019;90–91:100315. <https://doi.org/10.1016/j.njas.2019.100315>
- Birner R, Daum T, Pray C. Who drives the digital revolution in agriculture? A review of supply-side trends, players and challenges. *Appl Econ Perspect Policy.* 2021;43(4):1260–85. <https://doi.org/10.1002/aep.13145>
- Trendov NM, Varas S, Zeng M. Digital technologies in agriculture and rural areas - status report. Rome: Food and Agriculture Organization of the United Nations (FAO); 2019.
- Barrett CB, Benton TG, Cooper KA, Fanzo J, Gandhi R, Herrero M, et al. Bundling innovations to transform agri-food systems. *Nat Sustain.* 2022;5:974–6. <https://doi.org/10.1038/s41893-020-00661-8>
- Aker JC. Dial A for agriculture: A review of information and communication technologies for agricultural extension in developing countries. *Agric Econ.* 2011;42(6):631–47. <https://doi.org/10.1111/j.1574-0862.2011.00545.x>

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