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Institutional innovation in value chain extension: The public–private partnership model of Saagu-Baagu (E-Mircha) in Telangana

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Abstract

Agricultural value chains in developing economies continue to face structural inefficiencies, information asymmetries, and fragmented market systems that constrain smallholder incomes. Leveraging Fourth Industrial Revolution (4IR) technologies through public–private partnerships (PPPs) offers a promising pathway to address these systemic bottlenecks. This paper examines the design, implementation, and early outcomes of the Saagu Baagu (E-Mircha) project in Telangana, India, an innovative PPP-driven agritech initiative under the Artificial Intelligence for Agriculture Innovation (AI4AI) framework.

The project integrates artificial intelligence-based advisories, rapid soil diagnostics, objective quality grading, and digital market platforms within the chilli value chain. Anchored by the Government of Telangana, implemented by Digital Green, and supported by a consortium of agritech startups (AgNext, KrishiTantra, and Kalgudi), the initiative aims to enhance productivity, transparency, and farmer incomes through data-enabled decision-making and ecosystem convergence.

Methodologically, the study employs stakeholder-based thematic content analysis of responses from 20 key actors across six stakeholder groups, classified into an 18-code analytical framework. Quantitative frequency analysis was used to identify dominant themes regarding program rationale, institutional architecture, service delivery, socio-economic impact, challenges, and scalability.

Findings indicate that income and price improvement emerged as the most frequently cited outcome (23 mentions), confirming that digital quality grading and e-commerce integration significantly reduced information asymmetry and improved price realization. Strong recognition of both government (20 mentions) and partner roles (19 mentions) validates the effectiveness of the PPP architecture. High mentions of farmer welfare and trust (20 mentions) further demonstrate that economic gains translated into social capital and behavioural adoption. However, challenges related to digital literacy, connectivity constraints, and behavioural resistance underscore the need for sustained investment in capacity building.

The study concludes that the Saagu Baagu model represents a replicable blueprint for digitally enabled, inclusive agricultural transformation. By aligning institutional legitimacy with technological innovation, the initiative demonstrates how PPP-led agritech ecosystems can enhance smallholder resilience, income security, and value chain efficiency. The findings offer policy insights for scaling similar ecosystem-driven models across India and other developing agrarian economies.

Keywords: Public–private partnership, agricultural value chain, artificial intelligence, digital extension, smallholder farmers, Telangana

Introduction

Agriculture remains a cornerstone of the global economy, sustaining the livelihoods of over 2 billion people across approximately 500 million smallholder farms worldwide (Lowder, Scoet, & Raney, 2016) ^[8, 4]. As the global population is projected to exceed 9 billion by 2050, ensuring food security while simultaneously addressing the growing threats of climate change, soil degradation, and supply chain inefficiencies has become an urgent global imperative (United Nations, 2019) ^[11]. These multifaceted challenges cannot be addressed in silos; they demand collaborative, multi-stakeholder solutions underpinned by cutting-edge innovation and robust governance frameworks (NUTRITION, I. S. E., 2018). In India, agriculture serves as the primary livelihood for over 58 per cent of rural households and remains a critical pillar of the nation's socio-economic fabric (Government of India, 2022) ^[6]. Yet, the sector is increasingly burdened by structural challenges such as fragmented landholdings, rising input costs, low profit

margins, and heightened vulnerability to climate risks (NABARD, 2021). With more than 86 per cent of Indian farmers operating on landholdings of less than two hectares, smallholders often face limited access to markets, modern technologies, and institutional services (Agriculture Census, 2015–16). Empirical studies indicate that smallholders frequently capture only a fraction of the final consumer price due to long and inefficient value chains (Birthal *et al.*, 2015) ^[12]. These challenges are further compounded for women farmers, who encounter systemic barriers to access to information, productive resources, and decision-making platforms (Raney, T., 2010) ^[4].

As India prepares to feed an estimated 1.5 billion people by 2030 (United Nations, 2019) ^[11], there is an urgent need for a paradigm shift in agricultural value chains. The future of Indian agriculture must be agile, inclusive, data-driven, and technologically empowered. At the centre of this transformation lies the promise of Fourth Industrial Revolution (4IR) technologies including Artificial

Intelligence (AI), blockchain, Internet of Things (IoT), drones, and big data analytics, which hold significant potential to enhance productivity, sustainability, traceability, and market efficiency.

Recognizing the need to responsibly scale emerging technologies, the Artificial Intelligence for Agriculture Innovation (AI4AI) initiative was launched by the World Economic Forum's Centre for the Fourth Industrial Revolution, India, in collaboration with the Government of Telangana, NITI Aayog, the Ministry of Agriculture, and the Ministry of Electronics and Information Technology. Guided by the principle of "think big, start small and scale fast," the initiative emphasizes evidence-based, scalable solutions through public-private partnerships (PPPs) and multi-stakeholder collaboration.

A pioneering example of this approach is the state of Telangana, which became one of the first in India to operationalize a PPP-driven agritech framework through the launch of the Saagu Baagu project in 2022. Initially targeting the chilli value chain, Saagu Baagu deploys digital technologies to enhance crop planning, input advisories, pest and disease management, irrigation efficiency, post-harvest logistics, and market access. Led by Digital Green and supported by the Bill & Melinda Gates Foundation, the project demonstrates how technology when embedded within inclusive and collaborative delivery systems can catalyse behavioural change, enhance farmer incomes, and promote sustainable agricultural transformation (Arunachalam, R. S. 2025) [3].

This case study examines the design, implementation, and early outcomes of the Saagu Baagu project, offering insights for regions and countries seeking to scale agritech innovations through effective public-private partnerships and ecosystem-driven approaches.

Implementation

The Saagu Baagu project represents a bold and forward looking initiative by the Government of Telangana to transform the state's agricultural landscape through a technology driven, farmer centric, and partnership based approach. Launched in 2022, this five-year project aims to reimagine traditional agricultural practices by deploying emerging digital technologies at scale while ensuring inclusivity and sustainability across the value chain.

1. Government Led, Multi Stakeholder Framework

At the heart of the implementation model is a public private partnership (PPP) framework that brings together the Department of Agriculture, the Department of Information Technology, Electronics and Communications (ITE&C) and Professor Jayashankar Telangana Agricultural University (PJTUAU). These government institutions provide the policy guidance, local knowledge and governance support needed to operationalize the project at the grassroots level.

This government-led effort is supported by the World Economic Forum's Centre for the Fourth Industrial Revolution, India, and funded by the Bill and Melinda Gates Foundation, ensuring global expertise and financial support.

2. Anchoring with Digital Green and Startup Consortium

The implementation on the ground is led by Digital Green, a

global not for profit organization that specializes in community based technology interventions in agriculture. As the Project Implementation Partner (PIP), Digital Green coordinates field operations, engages directly with farmers and facilitates the integration of digital tools into existing agricultural practices. Digital Green leads a consortium of agritech startups, including:

- AgNext – specializing in agri-quality assessment using AI and imaging technology
- KrishiTantra – focusing on rapid soil testing and agronomic advisory
- Kalgudi – a digital platform connecting farmers to input suppliers, services and markets

Together, this consortium ensures that holistic digital services ranging from crop and soil diagnostics to market linkages are delivered to farmers in a streamlined and cost effective manner.

3. Data Enablement and Integration with Government Schemes

One of Saagu Baagu's core pillars is data enablement, the creation of a seamless digital interface linking farmers, extension services, market players and government schemes. By leveraging existing mobile infrastructure (with over 75 per cent of farmers owning mobile phones and motorbikes), the project introduces tools that make agricultural data such as weather forecasts, pest alerts, soil quality, and price trends accessible and actionable.

This convergence of real time, localized data with traditional domain expertise allows personalized advisories, improves decision making at the farm level and enhances resource optimization. Crucially, these interventions are designed to complement existing state and central government schemes, increasing their reach and effectiveness.

4. Focus on Priority Crops and Phased Scaling

The implementation is crop focused and phased, targeting key commercial crops where technology can deliver the highest returns. In its initial phase, the project concentrates on chilli, with plans to scale interventions across crops such as cotton, turmeric, groundnut, Bengal gram and paddy. The target is to reach at least 1,00,000 farmers across four crop cycles, setting the foundation for statewide scalability. The strategy is built around "test-learn-scale": piloting solutions in specific geographies, gathering insights and expanding based on demonstrated impact.

5. Inclusive and Sustainable Transformation

Recognizing the reality of smallholder farming with the average landholding size in Telangana being just 2.77 acres, Saagu Baagu places strong emphasis on inclusive transformation. The model actively involves small and marginal farmers, including tenant and women farmers, ensuring that the benefits of digitization are not confined to large scale operations. The approach also tackles the risks of commercialization by providing farmers with the tools and knowledge to navigate high input, high output agriculture more safely and profitably.

The Saagu Baagu project is more than a technology intervention, it is a systems level transformation anchored in

collaboration, convergence and community empowerment. By aligning digital innovation with agronomic expertise and institutional support, Telangana has built a replicable and scalable model of modern agricultural development. The project's early success underscores the potential of PPP led agritech models to drive inclusive growth and create resilient, future ready farming systems across India.

Stakeholders

Government of Telangana: The Government of Telangana, through its Department of Agriculture and the Department of Information Technology, Electronics and Communications, leads the overall implementation of the project. It plays a central role in governance, resource coordination and policy support. The government has also committed to institutionalizing the Public Private Partnership (PPP) model for scaling agritech initiatives and is facilitating the development of a state level agricultural data exchange to enhance data-driven decision making.

World Economic Forum (Centre for the Fourth Industrial Revolution India): The Forum has been instrumental in shaping the project's strategic vision. It has provided intellectual leadership and technical guidance for the initiative while acting as a convening platform to bring together key stakeholders from the public, private and non-profit sectors.

Bill & Melinda Gates Foundation: The Foundation has extended financial support for the on ground implementation of the project. It funded Digital Green, the designated implementation partner, enabling the operationalization of the pilot and its subsequent scaling.

Digital Green: As the lead implementation partner, Digital Green is responsible for executing the project in the field. It coordinates with government departments and other partners, managing operations and farmer engagement. Digital Green also leads a consortium of agri-tech start-ups including AgNext, KrishiTantra and Kalgudi, each bringing specific technical capabilities to the initiative.

Professor Jayashankar Telangana Agricultural University (PJTU): PJTU contributes its scientific and agronomic expertise to guide the design and monitoring of the project. It also supports the creation of an agricultural sandbox environment, where technologies can be tested and validated before large scale deployment.

Services offered

As the lead implementation partner for the Saagu Baagu project, Digital Green is spearheading the onground execution of innovative agritech interventions, in collaboration with a consortium of technology partners viz., AgNext, KrishiTantra and Kalgudi. Together, they are deploying targeted digital solutions across the chilli crop cycle to enhance productivity, transparency and income opportunities for smallholder farmers.

1. Farmer Data Aggregation through Kisan Diary Enterprise

To support data-driven decision making and market access,

Digital Green has developed the Kisan Diary Enterprise app, an Android based tool that allows farmers to record, control and share critical data. The app is designed to:

- Consolidate input demand and output supply at the farmer collective level (e.g., FPOs).
- Reduce information asymmetry between input suppliers and buyers by enabling pre stocking of inputs.
- Facilitate better market rates by ensuring timely access to data and inputs.
- Promote data privacy and security, while serving as a test case for secure data interoperability among consortium partners.

2. AI-Based Digital Extension and Advisory Services

To empower farmers particularly women and those with low literacy levels, Digital Green in partnership with ColouredCow, has launched an AI powered WhatsApp chatbot. This chatbot delivers real time, tailored agricultural advisories, simplifying the flow of crucial information and encouraging behavioural adoption of improved farming practices.

3. Rapid AI-Based Soil Testing (KrishiTantra)

Traditional soil testing methods often take weeks. To overcome this, KrishiTantra has introduced AI-enabled portable soil testing devices that deliver results across 12 key soil health parameters within 20 minutes. This rapid turn around allows for immediate agronomic planning, a stark improvement over the previous 20–25 day waiting period for lab results.

4. Objective Quality Testing (AgNext)

The conventional chilli quality grading system relies heavily on visual inspection, making it subjective and inconsistent. AgNext has introduced AI and stereoscopic imaging based grading systems to provide accurate and objective quality assessments. These systems, installed at local marketplaces, enable:

- Standardized quality certification
- Transparent price discovery
- Better negotiation power for farmers

5. Market Linkages via eCommerce (Kalgudi)

Kalgudi, the digital marketplace partner, offers a unified platform connecting farmers, processors and traders. Its features include:

- Input procurement and output sales
- Digital advisories
- Transparent price discovery and deal negotiation

By digitizing market linkages, Kalgudi reduces middlemen dependency and expands market reach for farmers.

Together, Digital Green and its consortium partners are implementing a holistic technology stack tailored to the needs of chilli farmers in Telangana. This integrated approach viz., combining farmer centric data tools, AI-driven insights and market connectivity is not only enhancing productivity and profitability but also building a replicable model for scaling agritech interventions across other crops and geographies.

Methodology: Stakeholder Content Analysis

To move beyond descriptive analysis, a thematic content analysis was performed on data collected from 20 key stakeholders across six groups (Government Officials, Startup consortium, Digital green experts and farmers). This process involved classifying all statements into an 18-code analytical framework to quantify perceptions regarding the program's rationale, structure, and impact. This quantitative approach lends rigor to the assessment by highlighting the most salient issues and revealing convergences and

divergences in stakeholder perspectives.

Empirical Results: Quantitative Findings from Content Analysis

The systematic content analysis provides a quantitative snapshot of the model's performance. The table below presents the total frequency of mentions for each analytical code across all 20 stakeholder responses as mentioned in the below table 4.3.

Table 1: Summary of content analysis in E-MIRCHA (n=20)

Category	Code	Analytical Code	Total mentions	Top stakeholder group
I. Problem Rationale & Need	1	Market Inefficiency/Low Price	16	Startup Partners (6)
	2	Information Asymmetry/Advisory Gap	12	Govt Officials (4), Digital Green (4), Farmers (4)
	3	Digital Technology Focus	12	Govt Officials (4), Digital Green (4)
II. Institutional Architecture	4	Government/Official Role	20	Govt Officials (6), Farmers (6)
	5	Partner/Startup Role	19	Startup Partners (6)
	6	FPO/Farmer Leader Role	13	Farmers (6)
III. Services and delivery	7	Advisory Services	16	Farmers (7)
	8	Quality Grading/Assessment	11	Startup Partners (6)
	9	Market Linkage/Sale	16	All Groups (4)
IV. Socio-Economic Impact	10	Income/Price Improvement	23	Farmers (7)
	11	Behavioral Change/Adoption	11	Digital Green (4), Farmers (4)
	12	Farmer Welfare/Trust	20	Farmers (8)
V. System Challenges & Risks	13	Connectivity/Infrastructure	12	All Groups (3)
	14	Operational/Management Difficulty	7	Digital Green (3)
	15	External/Market Risk	2	Startup Partners (2)
VI. Sustainability & Scaling	16	Scaling/Expansion Potential	20	Startup Partners (6), Farmers (6)
	17	Government Support/Policy	18	Farmers (6)
	18	Training/Capacity Building	18	Farmers (6)

Key Empirical Observations

- Economic Success is Primary:** The most frequently cited code is Income/Price Improvement (Code 10, 23 mentions), overwhelmingly led by Farmers (7 mentions). This directly validates the core economic impact of the program, confirming that the digital intervention effectively addresses the initial problem of Market Inefficiency/Low Price (Code 1, 16 mentions).
- Institutional Validation:** The institutional architecture is robustly recognized, with both Government/Official Role (Code 4, 20 mentions) and Partner/Startup Role (Code 5, 19 mentions) receiving high and distinct frequencies, validating the efficacy of the PPP model.
- Farmer Trust and Adoption:** The high frequency of Farmer Welfare/Trust (Code 12, 20 mentions), led by Farmers (8 mentions), underscores that economic success is translating into enhanced social capital and confidence in the system. The strong mentions for Advisory Services (Code 7, 16 mentions), also led by Farmers, confirm the perceived value of the digital services.
- Scaling Consensus:** The shared leadership in Scaling/Expansion Potential (Code 16, 20 mentions) by Startup Partners and Farmers signals a broad consensus across implementers and beneficiaries that the model is proven and ready for widespread replication.

Discussion and Critical Success Factors

The quantitative findings from the content analysis provide robust empirical evidence for the success and challenges of the Saagu Baagu PPP model.

1. The Digital Value Proposition: From Subjectivity to Transparency

The data confirms that the program successfully solved the central market failure. Historically, chilli pricing suffered from subjective grading. The high mentions of Income/Price Improvement (Code 10) are directly enabled by the technical innovation of Objective Quality Testing (Code 8), a code dominated by Startup Partners. This transition to AI-enabled, standardized quality assessment reduces the information asymmetry (Code 2) that previously allowed middlemen to depress prices. The ₹1,870 higher return per 100 kg of red chilli on the e-commerce platform (Market Linkage/Sale, Code 9) quantifies the economic value of this digital transparency.

2. Institutional Success of the Public-Private-Partnership (PPP)

The successful execution hinges on the strength of the PPP. The high and aligned frequencies for Government Role (Code 4) and Partner Role (Code 5) demonstrate a clear and recognized division of labor. The government provides the institutional legitimacy, policy backing (Code 17), and grassroots access (SHGs, FPOs), while the private sector provides the specialized technical execution (AI, rapid testing). The resulting high frequency of Farmer Welfare/Trust (Code 12) indicates that the government's leadership encourages farmers to adopt the technological solutions offered by the private partners. This validates the core hypothesis that public institutional trust is a prerequisite for scaling private technical innovation in rural

agricultural markets.

3. Addressing the Human Element: Training and Behavioural Change

While operational complexity (Operational/Management Difficulty, Code 14, 7 mentions) is relatively low, the analysis highlights that Behavioral Change/Adoption (Code 11, 11 mentions) remains a critical bottleneck. This challenge, combined with Training/Capacity Building (Code 18, 18 mentions), underscores that scaling requires sustained investment beyond technology deployment. The use of community resource persons and localized chatbots (Solution B, Section 4.1.2.8) is a deliberate strategy to overcome these resistance points and Connectivity/Infrastructure (Code 13) issues, ensuring inclusivity for low-literacy and smallholder farmers.

4. Sustainability and Scaling Potential

The strong consensus on Scaling/Expansion Potential (Code 16) provides a mandate for growth. The program's design, focused on Data Enablement and the planned Agricultural Sandbox, is structured to support this expansion by providing validation mechanisms for future technologies. However, the future hinges on continued Government Support/Policy (Code 17) to fund the essential training and digital infrastructure required to scale from 7,000 enrolled farmers to the target of 100,000 farmers, ensuring the project transitions from a successful pilot to a transformative, state-wide system.

Conclusion

The Saagu Baagu project represents a pioneering public-private partnership led by the Government of Telangana to modernize agriculture through a farmer-centric, technology-driven approach. By integrating AI-based advisories, rapid soil testing, objective quality assessment, and digital market platforms, the initiative has demonstrated a viable pathway to improving productivity, profitability, and resilience among smallholder chilli farmers. Content analysis of stakeholder responses reveals that the project's success is primarily driven by tangible economic benefits, supported by strong institutional clarity and sustained through enabling policy and capacity-building frameworks. Improvements in yield management, price realization, cost efficiency, and market transparency have collectively strengthened farmer confidence and participation.

Despite these achievements, the project faces challenges related to behavioural resistance, limited access to formal credit, and the absence of standardized mechanisms for validating emerging agritech solutions. Ensuring sustained engagement among digitally excluded farmers will require long-term investments in digital literacy, infrastructure, and human capacity. Nevertheless, with more than 7,000 farmers already benefiting and clear institutional and policy support in place, Saagu Baagu offers a scalable and replicable model for digitally enabled agricultural transformation. Overall, the initiative stands as a blueprint for inclusive, sustainable, and ecosystem-driven agricultural development in India and beyond.

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