

Rapporteur's Report on Innovations in Agri-Input and Services Market Towards Sustainable Agriculture

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I

INTRODUCTION

Improved agricultural inputs, mechanization and services have helped increase agriculture production and national income, enhancing food, nutritional and livelihood security globally and more so in developing countries (Hazrana and Mishra 2024; Li *et al.* 2023). Achieving sustained growth in agricultural production hinges on continual improvement through technological change and innovations in agri-inputs and services. If not adequately protected, damage and losses caused by weeds, insects, pests, diseases, and nematodes could range from one-fifth to one-third of total production. The quality seeds alone contribute 15-20 per cent to total production and even go up to 45 per cent with efficient management of other inputs. The role of farm mechanization in increasing productivity, reducing the cost of production, area expansion, and drudgery reduction has been well documented (Chaudhary *et al.* 2022; Hamilton *et al.* 2021; Pingali, 2007; van den Berg *et al.* 2007). Services like agricultural credit, insurance, context-specific climate information and technology dissemination play a pivotal role in facilitating the adoption of improved technologies and innovations in agriculture. The support services in the allied sector, such as livestock, fisheries and forestry, have a unique role in minimizing agricultural risks and improving the resilience of smallholders in developing countries (Ogola *et al.* 2023; Thomas *et al.* 2002). Access to financial services allows farmers to increase their purchases of agricultural inputs, promoting the adoption of improved technologies and, thus, increasing their productivity (Girma 2022; Feder *et al.* 1990).

Even though quality inputs and services play a great role, the access to and use of quality inputs and the adoption of improved technologies and innovations in the country remained low with high regional variability. The use of fertilizers and pesticides is often unbalanced and unscientific, adversely affecting the environment and farmers' income and export earnings. Access to agricultural credit from institutional sources remains low, particularly among resource-poor farmers. Therefore, it is imperative to understand the role of constraints in and enablers of innovations in agri-input and service systems, which help increase agricultural productivity, enhance sustainability, improve resource efficiency, and address challenges like climate change, population growth, and food security.

Equally important are the innovations in the country's agricultural extension system. While the grassroots-level public extension programs of the states face

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criticism for their perceived struggles in disseminating technology, there has been a notable increase in farmers' access to information. The percentage of farmers with access to technical support has risen from 41 per cent in 2012/13 to 49 per cent in 2018/19. To comprehend this apparent paradox, it is imperative not only to compressively assess the gross-root extension system but also to assess the role of alternative extension systems, including the frontline extension system, private extension services, agri-tech start-ups, civil society organizations, and farmers' associations, employing robust datasets and methodologies. Evidence from large-scale extension projects, whether public or private, is susceptible to methodological and identification challenges (Raabe 2008). The impact and effectiveness of various models and systems for technology dissemination and service delivery have received insufficient attention. The market-led extension has been increasingly recognized as necessary, with agri-tech start-ups playing a significant role. Evaluating the viability, challenges, and sustainability of agri-tech start-ups and Farmers' Producer Organizations (FPOs) is crucial for informing policy decisions and ensuring adequate support for the agricultural sector.

An overwhelming response was received from the contributors, and more than 75 full-length papers were obtained under the theme. The contributors to the theme covered a wide range of researchable problems related to agricultural inputs and services markets and technology delivery systems. The studies have also explored how innovations can address some associated challenges. The key highlights of the studies are summarized below under four sub-sections: (II) agricultural input marketing, (III) agricultural service marketing, (IV) bio-inputs and sustainability, and (V) others.

II

AGRICULTURE INPUT MARKETING

A number of studies analyzed the Indian seed market and its delivery systems using large-scale data like NSSO and independent field studies that assess the impact of improved seeds. These studies emphasize the critical role of formal seed sources, distribution schemes, and intellectual property rights (IPR) in boosting agricultural productivity. A pan-India level analysis using NSSO data by Nandi and Vatta reveals that access to formal seeds, particularly for crops such as paddy, wheat, and arhar, can increase yields by up to 50 per cent and significantly improve farmer incomes. Key factors influencing seed adoption include technical advice, farm size, and access to support systems, highlighting the need for improved seed distribution and extension services. In Maharashtra, the Seed Minikit (SMK) scheme for pulses led to higher yields and profits for beneficiary farmers, with recommendations for expanding outreach and training programs. Another study on IPR in the seed sector by Deepak Shah found that private companies dominate registrations for new varieties, particularly in crops like cotton, rice, and maize. However, potential conflicts between

Plant Variety Protection (PVP) and Geographical Indications (GI) need attention. Strengthening seed access and refining IPR mechanisms are essential to enhancing competition and supporting smallholder farmers in India's agricultural sector.

A few papers on fertilizers and agrochemicals revealing challenges and opportunities for sustainable practices were also received. A study by Renjini et al. analyzed India's agricultural exports to the EU, focusing on pesticide rejections, underscored the need for adopting good agricultural practices to meet stringent EU standards and boost exports. Another study in Tamil Nadu by Priya *et al.* examined the impact of the fall armyworm (FAW) on maize production and assessed the effectiveness of integrated pest management (IPM) technology. The study found that users of the IPM technology capsule had a lower environmental impact, highlighting its ecological and economic benefits. A micro-level study in Kerala by Mathew and Devi explored the use of chemical fertilizers in paddy cultivation, revealing a tendency among farmers to over-apply major nutrients while neglecting secondary nutrients and micronutrients. Socioeconomic factors, such as education and household income, significantly shaped fertilizer investment decisions. The study advocates for incorporating modern technologies like sensors, AI, and remote sensing to enhance real-time soil quality monitoring, with targeted training programs for farmers and educated family members to improve decision-making in soil health management.

Studies received on farm mechanization have primarily focused on the intensively cultivated northwestern plains, where mechanization is more advanced. The analysis of the second-hand tractor market in Punjab by Singh highlighted the dynamic role of these markets in promoting farm mechanization in the state's agrarian economy. These markets help farmers, especially smallholders, reduce production costs by providing access to affordable machinery, such as tractors, often bought for changes in horsepower or model. However, many farmers rely on high-interest loans from private lenders for such purchases, underscoring the need for government support. The credit constraint was also highlighted by Kumar et al. in their study of Custom Hiring Centres in Uttar Pradesh. Institutions like NABARD could offer lower-cost or joint liability group loans to make second-hand tractors more affordable. The draft National Policy on Farmer Producer Organizations (FPOs) and the new National Cooperative Policy can play a pivotal role in promoting the involvement of FPOs and Primary Agricultural Credit Societies in running Custom Hiring Centers (CHCs) and acquiring second-hand machinery. These policies encourage farmer collectives to facilitate access to affordable equipment, reducing the need for individual ownership. With second-hand tractor markets expanding to states like Haryana, Rajasthan, and Gujarat, the study highlighted the need for formal infrastructure and support from state governments, with larger FPOs potentially managing these markets.

Another study from the state using data from the All-India Debt and Investment Survey (AIDIS) by Rohith *et al.* identify household and socio-economic factors like age, education, and land ownership as key determinants of machinery ownership, with recommendations for policy interventions such as custom hiring centers and

infrastructure improvements. Research conducted across Punjab's agro-climatic zones by Ranguwal and Sachdeva shows that farm size influences the use of owned versus hired machinery, with custom hiring playing a crucial role for marginal and small farmers. In a paper on straw management machinery, Awasthi *et al.* demonstrated that community outreach through events like kisan melas is most effective, though high costs remain a barrier to adoption.

A study by Pouchepparadjou *et al.* in the Cauvery Delta region, outside the traditional Green Revolution areas, evaluated the economic viability and cost-effectiveness of mechanization in rice farming. The findings revealed that mechanization significantly boosts farmers' incomes, with factors such as education, access to machinery, and extension services playing a key role in adoption. It was also observed that mechanization helps reduce labour dependency. Similarly, a survey in eastern Uttar Pradesh by Kumar *et al.* found that using services from Custom Hiring Centers (CHCs) lowers cultivation costs by 3.50- 4.50% and enhances farmers' net income in paddy farming by 10-14.5%, compared to private services. However, no significant improvement in paddy yield was noted. This suggests the need for more advanced machinery to optimize resource use, reinforcing the role of CHCs in making farm mechanization more cost-effective and improving farm earnings.

III

AGRICULTURE SERVICE MARKETING

Several studies analyzed the agricultural credit market in India, focusing on improving access to affordable credit for adopting new technologies, increasing farmer incomes and promoting agricultural sustainability. One simulation study by Sanyal *et al.* explored three transition scenarios—quicker, gradual, and stagnated transitions to sustainable solutions—showing that farmers' productivity and cash flows improve as they adopt sustainable practices. However, income losses limit credit access during the transition, necessitating government subsidies. Wealthier farmers benefit from faster transitions because they can make significant upfront investments, while marginal farmers rely on gradual transitions and greater government support. Another study by Srinivasamurthy *et al.* using NSS data highlighted that only 35 per cent of agricultural households accessed institutional credit, with biofertilizer adoption among paddy farmers remaining low at 12.62 per cent. Factors like Kisan Credit Cards (KCC), social group affiliation, and access to groundwater positively influenced biofertilizer expenditure, while larger land areas and crop insurance reduced adoption. The paper by Thureja and Thakur explored institutional credit use and its influence on adopting sustainable practices in Punjab and Bihar. While Punjab's farmers have better access to credit, they resist crop diversification due to income uncertainties without a Minimum Support Price (MSP). In contrast, Bihar's farmers face greater livelihood challenges, needing immediate focus on financial stability before considering

environmental sustainability. In all, these studies underscore the importance of policy-driven credit accessibility and incentives for balancing sustainability with farmer livelihoods.

Papers were also received on the marketing of other agri-service. Based on the primary data from Southern Semi-arid Tropics, Saranya Devi evaluated impact of drone technology's on paddy farming and found that use of drones helps reducing the cost of cultivation, managing the operations timely, realising higher returns, and reducing environmental externalities. The study underscores the need for thoughtful policy considerations to maximize the benefits and ensure sustainable implementation of drone technology in agriculture.

IV

BIO-INPUTS AND SUSTAINABILITY

The studies concerning bio-inputs emphasized the impact, constraints, enablers and potential of bio-pesticides, bio-fertilizers, and organic manures in Indian agriculture. The study by Praveen *et al.* highlights the slow growth of bio-pesticide usage in India despite its environmental benefits. It stresses the need for government intervention, streamlined regulations, and farmer organizations to promote their use. It points out lessons India can learn regarding safety and efficacy standards from other countries. Another paper by Das using NSSO data analyzed bio-inputs' impact on farm productivity and showed that while bio-inputs have the potential to improve agricultural output, their returns are generally lower than those of chemical fertilizers. The study argues for better policy and institutional support to enhance bio-input adoption, especially in backward regions, and the need for knowledge dissemination and tailored interventions. Another study by Srinivasamurthy *et al.* also uses NSSO data and finds that integrating bio-inputs with chemical inputs can improve productivity and profits, especially for rice and wheat farmers. The study underscores the importance of creating awareness and encouraging farmers to adopt sustainable practices through evidence-based approaches, highlighting the necessity of institutional support and training to drive the transition towards sustainable agriculture.

Papers on irrigation have highlighted significant shifts in energy sources, yet these transitions are not universally sustainable across regions, particularly regarding groundwater extraction. In Bihar, the move from diesel to electric pumps for groundwater irrigation, driven by rural electrification, has provided smallholder farmers with more affordable options (Beniwal and Kishore). The study further highlighted that the uneven distribution of electric pumps and reliance on heavily subsidized electricity raises fiscal and environmental sustainability concerns. While electric pump users enjoy lower irrigation fees, most do not engage in water sales, limiting broader market benefits. This subsidy-driven model risks over-extraction of groundwater and exacerbates inequalities, especially in areas experiencing declining water tables. Study recommend redirecting public investments toward expanding the electricity grid to underserved regions instead of maintaining heavy subsidies.

A paper by Nandhini *et al.* from Tamil Nadu highlights the benefits of solar-powered irrigation (SPI) over electric-powered irrigation (EPI). SPI not only reduces costs associated with fuel and electricity but also aligns with sustainable development goals by decreasing greenhouse gas emissions. Solar irrigation is economically viable compared to both diesel and electric systems. Another study from the state on sprinkler irrigation systems (SIS) demonstrates significant cost reductions and enhanced resource efficiency in groundnut cultivation (Harini and Anjugam). Together, these findings underscore the importance of promoting awareness and providing technical guidance to farmers regarding these innovative irrigation technologies, ultimately improving sustainability and profitability in agricultural practices.

V

OTHERS

Number of papers received on issues indirectly related to input markets like climate change, input use pattern, efficacy, effectiveness and sustainability of different extension delivery models. A paper on Climate-Smart Agriculture (CSA) in Odisha and Punjab highlights the significant positive impacts of CSA adoption on productivity and income, with practices like crop rotation and laser land levelling showing notable benefits. These findings underscore the need for targeted interventions, enhanced agricultural extension services, and policies supporting CSA to build resilience against climate change. Apart from these, studies emphasize the growing negative impact of climate change on crop yields and labour productivity, highlighting the urgency for climate-resilient strategies.

A few papers analyzed the pattern in input use in agriculture, revealing that farmers' socio-economic status significantly influences input expenditures, suggesting that policies must account for these disparities. Critical findings include the rising capital intensity in irrigated lands and the role of education, credit access, and Minimum Support Price (MSP) awareness in shaping input use patterns. Research on paddy cultivation costs in eastern India also shows a sharp rise in operational costs post-2009, influenced by government schemes. Another study assessed the sustainability of Farmer Producer Companies (FPCs) in Himachal Pradesh, forecasting significant growth and highlighting their potential in promoting Sustainable Development Goals. The role of digital agricultural extension services in improving productivity and sustainability was reviewed, signalling a broader shift toward tech-enabled solutions in agriculture.

VI

POLICY IMPLICATIONS

Numerous policies and schemes have been introduced to strengthen agricultural input markets. Research studies have highlighted vital challenges, offering valuable

insights for policymakers to address implementation gaps and improve policy coherence between central and state governments. For instance, the seed sector has undergone significant reforms over the years, including the Seed Act of 1966, the phased implementation of the National Seed Project, the National Seed Development Policy of 1988, the Protection of Plant Varieties and Farmers' Rights Act of 2001, the National Seed Policy of 2002, the Biological Diversity Act of 2002 (amended in 2023), and the Plant Quarantine (Regulation of Import into India) Order of 2003. However, despite these efforts, the sector has yet to realize its full potential.

One major challenge is the gap between the number of seed varieties released and those available in the supply chain. This gap highlights the need for greater awareness, demand-driven varietal development, and improved affordability for farmers. States must also prioritize participatory breeding programs, focusing on developing climate-resilient varieties. Moreover, the transformation of State Seed Corporations includes enhancing management practices, expanding storage capacity, and upgrading quality testing infrastructure to meet industry standards and build trust with farmers.

Regarding technology transfer, research underscores the necessity of a paradigm shift in agricultural input delivery systems to address emerging challenges and support sustainable farming practices. A targeted approach must be followed to meet the diverse needs of smallholders who require access to affordable and adaptable inputs. For example, the Sub-mission on Agricultural Mechanization (SMAM) plays a critical role by aiming to enhance smallholder access to mechanization by promoting custom hiring services, establishing hubs for high-tech and high-value farm equipment, and creating farm machinery banks that allow small farmers to access modern equipment on a rental basis. The success of SMAM, however, hinges on the sustainable operation and management of custom hiring centers. These centers provide access to costly machinery without requiring farmers to purchase the equipment outright, which is often financially prohibitive for smallholders. Identifying and scaling successful institutional frameworks for operating these centers is essential. In addition to mechanization, states must focus on developing and promoting small-scale machinery tailored to challenging topographies, such as hilly or uneven terrains, where conventional large machinery is impractical. This includes investing in research and development to create efficient, affordable, and easy-to-use tools that meet the unique needs of small farmers in such regions.

Another critical aspect is building the infrastructure for producing, distributing, and storing bio-inputs, including biofertilizers and biopesticides. Demand for eco-friendly inputs rises as farmers move towards more sustainable agricultural practices. However, many regions lack the necessary production facilities and cold storage systems to maintain the quality and effectiveness of bio-inputs. By improving infrastructure, states can support a more sustainable input market that reduces reliance on chemical fertilizers and pesticides, benefiting farmers and the environment. The success of these efforts depends on how states align policies with those of the central

government. Policy coherence is essential for smooth implementation and avoids contradictory regulations that could stifle innovation and access.

VII

RESEARCH AND POLICY ISSUES FOR DISCUSSION

Researchers have covered a wide range of topics, but several important areas related to input markets remain underexplored. Young agricultural economists, in particular, are encouraged to address the following issues in their research:

- What are the quality issues in pesticides and best practices in pesticide application? How can sustainable pesticide application practices be promoted?
- What is the impact of various agricultural extension models? What cost-effective and efficient agricultural extension delivery models could be in multiple contexts and regions?
- What role are agri-startups playing in promoting quality inputs, and what strategies could further enhance their effectiveness?
- How can service marketing be made more efficient, especially by customizing the hiring of precision machinery for input applications? What is the potential of custom hiring in improving agricultural productivity, input use efficiency, reducing drudgery, and attracting youth in agriculture?
- What is the current status of water markets in India, and how these can be developed further? Do water markets help improve water-use efficiency and equitable distribution?
- Are the agricultural inputs being used sustainably? What could be policy options for integrated and sustainable use of different input types?

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