Traditional to Digital Farming: Challenges, Policies, and Gains

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Abstract- *The transformation from traditional agriculture to digital agriculture is a revolutionary shift towards enhanced productivity, sustainability, and economic returns for farmers, particularly in developing nations like India. This paper examines the impediments to the uptake of digital agriculture, compares the role of government policies in supporting the transition, and assesses the economic returns for smallholder farmers. Drawing on a comprehensive review of the literature and empirical data, this paper reports the key impediments as high capital outlay, low digital literacy, poor internet connectivity, and weak regulatory frameworks as key barriers. Employing Interpretive Structural Modelling (ISM), the paper offers a hierarchical framework of the impediments, identifying "lack of supportive regulations" as a primary constraint that impacts other issues, such as knowledge gaps and small land size. Government schemes, such as the Digital Agriculture Mission (2021-2025) and schemes like the Pradhan Mantri Kisan Samman Nidhi (PM-KISAN), are examined for their ability to overcome these impediments through subsidies, digital infrastructure, and extension services. Economic returns for the uptake of digital technologies—precision agriculture, Internet of Things (IoT), and digital financial services—lie in the potential for enhanced crop yields (up to 30% based on a number of studies), reduced input costs (15-20%), and enhanced farmer revenues (25-29%), as illustrated through case studies such as the banana value chain in India. This paper concludes that with challenges notwithstanding, policy interventions and public-private sector partnerships can realize large economic returns, as envisioned by India's vision to double farmer incomes and sustainable agriculture growth.*

Keywords- Agriculture, AgBots, Digital Agriculture, Adoption Barriers, Policy, Infrastructure, Automation

I. INTRODUCTION

Indian agriculture, the backbone of rural life and national food security, is confronted with rising pressures from population growth, climate change, and scarcity of resources, and hence requires a transformation from conventional farming to digital agriculture. Academic analysis points out regulatory bottlenecks as the main stumbling block, with issues like digital literacy and connectivity issues being related but further slowing the pace [1]. Despite this, the ubiquity of small land holdings, environmental degradation, and infrastructural shortages continues to hold back [2]. Digital agriculture uses technologies like Artificial Intelligence (AI), Internet of Things (IoT), drones, and data analytics to increase productivity, optimize resource utilization, and improve farmers' economic returns [3]. Although its potential is gigantic, adoption is still in infancy in India, where 86% of farmers have small and marginal land holdings (less than 2 hectares) [3], and conventional practices still hold sway. This paper analyses the bottlenecks in this transformation, the catalytic role of government policies, and the economic gains it holds out, on the basis of a multi-dimensional analysis. At the same time, government initiatives like the Digital Agriculture Mission (2021–2025) and public-private partnerships are trying to infuse digital tools in the entire agricultural value chain, with the aim of doubling farmers' income through higher yields and access to markets [3]. Economically, digital interventions have shown enormous potential, with research putting productivity gains at 18% and income increases at 25–29% through precision agriculture and digital extension services [3]. A survey of 49 young farmers in Maharashtra (February–March 2025) indicates satisfactory awareness of Agricultural Technology (AgTech) (89.8%) but low adoption (34.7%), which is marred by high costs and lack of training [4]. This research seeks to synthesize these results, giving a general overview of the transition to digital agriculture in India, and its implications for sustainable development and rural community empowerment.

II. LITERATURE REVIEW

The shift from conventional to digital farming in India has become an area of research priority driven by food security, financial well-being of farmers, and sustainability of the environment in the context of a rising population and climate issues. The review here integrates evidence from varied sources with emphasis on challenges of adoption, policies, and economic returns drawn from a sample of 49 farmers, peer-reviewed literature, and policy analyses.

A. Adoption Challenges

Challenges to digital agriculture adoption in India are firmly established in the literature. Hota and Verma [1] employed Interpretive Structural Modelling (ISM) to identify ten challenges, supported by 36 experts, of which "lack of supportive regulations was most critical, as a secondary concern driving "lack of digital agriculture knowledge" and "small land holdings". High capital costs and poor connectivity further inhibit development [1]. A 2025 survey of 49 Maharashtra farmers shows similar findings, with 65.3% citing cost and 55.1% lack of training as significant barriers, even as 89.8% were aware of AgTech [8]. JETIR [2] situates these issues in the context of broader rural development, citing climate change and market access gaps. Dey and Shokhawat [4] emphasize data trust and security as a barrier, with blockchain-based solutions suggested, and Argade et al. [3] cite inadequate telecommunication infrastructure as a persistent issue. Together, these reports emphasize a multi-dimensional interaction of economic, infrastructural, and regulatory challenges.

B. Government Policies

Government policies play a significant role in pushing digital agriculture. Cheruku and Katekar [6] describe India's Digital Agriculture Mission (2021–2025), which leverages artificial intelligence, the Internet of Things, and drones via collaborations with companies such as CISCO, together with initiatives such as e-NAM and PM-KISAN that utilize the JAM trinity for enhanced financial inclusion [6]. The 2018 Doubling Farmers' Income Report advocates for data-driven policy reform [6], an argument put forward by Rao et al. [5], who describe pioneering attempts such as the 1987 AGRIS project. Hota and Verma [1] cite regulatory loopholes, arguing that they inhibit innovation, an argument supported by JETIR [2], which advocates for enhanced rural infrastructure policy. The Excel [8] data indicate an enormous demand for subsidies (24.5% of the respondents), reflecting policy loopholes. In summary, these sources point to a change towards digital governance, though implementation in rural areas is slow.

C. Economic Benefits

Economic potential is the thread running through digital agriculture. reporting a 34.63% yield boost through mobile technology, and Rajkhowa (2021), reporting 25–29% income increases and 18% productivity boosts through digital extension [6]. The banana value chain example shows how digital traceability reduces wastage by half and doubles incomes [6]. JETIR [2] connects green practice to poverty reduction, [5] record a 30% rise in ICRISAT's Sowing App, adding evidence for data-driven farming's influence. The Excel survey [8] concurs, with 73.5% of farmers regarding AgTech as the solution to climate (61.2%) and water (55.1%) issues, improving economic resilience. [3] warn, however, that gains are subject to overcoming adoption challenges, especially for smallholders (86% below 2 hectares) [6]. This literature indicates strong economic promise tempered by scalability limitations. Research Gap Whereas challenges and advantages are thoroughly researched, interdependencies and the effectiveness of policy at the farm level are sparsely studied. Hota and Verma [1] refer to studies on prioritization, which is partially filled in by ISM but is open to subjectivity. Cheruku and Katekar [6] are policy-centered without grass-root information, JETIR [2] lacks technology, and the Excel survey [8] is regional based. Technical observations made without Indian specificity. This study bridges the gap through empirical evidence, qualitative modeling, and policy analysis for comprehensive understanding of digital agriculture in India.

III. METHODOLOGY

This research employs a mixed-methods research design to examine the AgTech adoption challenges, policies, and economic performance in India, using primary survey data and secondary literature reviews. The research design is organized to respond to research objectives: identification of the adoption challenges of AgTech, assessment of the policy framework, and economic performance measurement. Hereunder is the research design description, data collection, and analysis.

In order to comprehend trends and farmer attitudes in Maharashtra, a state with a high level of agricultural activity and variable degrees of digital infrastructure, the study employed a descriptive research approach and qualitative analysis. A cross-sectional survey of young farmers between the ages of 18 and 35 was used to gather data, and 47 peer-reviewed publications and policy documents provided secondary data.

Using a questionnaire, the study collected primary data from 49 Maharashtra farmers. Demographics, views, challenges, and awareness and acceptance of AgTech were all included in the survey. Trained enumerators conducted the survey in person, and descriptive statistics were used for analysis. The prevalence of hurdles, adoption rate, and awareness rate were important variables. To classify difficulties, regulations, and advantages, the qualitative data was thematically synthesised and the results were graphed and charted. Convenience sampling may induce bias, and the small sample size restricts generalisability. The reality of 2025 might not be fully reflected in secondary data from 2002–

2022. Longitudinal designs and sample size expansion may be used in future research. One of the method's drawbacks is that it isn't statistically representative of India's heterogeneous agricultural economy.

IV. RESULTS

The results of a primary survey that was carried out among 49 young farmers in Maharashtra between February and March 2025 to learn more about the adoption of agricultural technology (AgTech), related difficulties, and perceived advantages are presented in this section. Tables and charts were used to summarise the findings of the analysis, which quantified awareness, usage patterns, barriers, and farmer perceptions.

The survey focused on farmers between the ages of 18 and 35 who had an average farm size of 1 to 5 hectares (73%) and varied educational backgrounds (43% high school, 31% bachelor's degree, 16% postgraduate) [8]. A structured questionnaire was used to gather responses, and the main conclusions are shown below.

The respondents' awareness and adoption of AgTech are summed up in Table 1. Of the 49 farmers, 44 (89.8%) said they were aware of digital agriculture tools like drones, IoT devices, and mobile apps, mostly from agricultural extension services (33%), and social media (51%). But only 17 (34.7%) actively employed these technologies in their farming operations, with the most popular being mobile apps (e.g., market prices, weather forecasting) (29%) [8]. A notable discrepancy between awareness and adoption is depicted in Figure 1.

Table 1: Awareness and Adoption of AgTech Among Farmers (n=49)

Metric	Number	Percentage
Aware of AgTech	44	89.8%
Currently Using AgTech	17	34.7%
Planning to Adopt Soon	11	22.4%
Most Used Tool (Mobile Apps)	11	22.4% (64.7% of users)

Figure 1. Awareness of AgTech

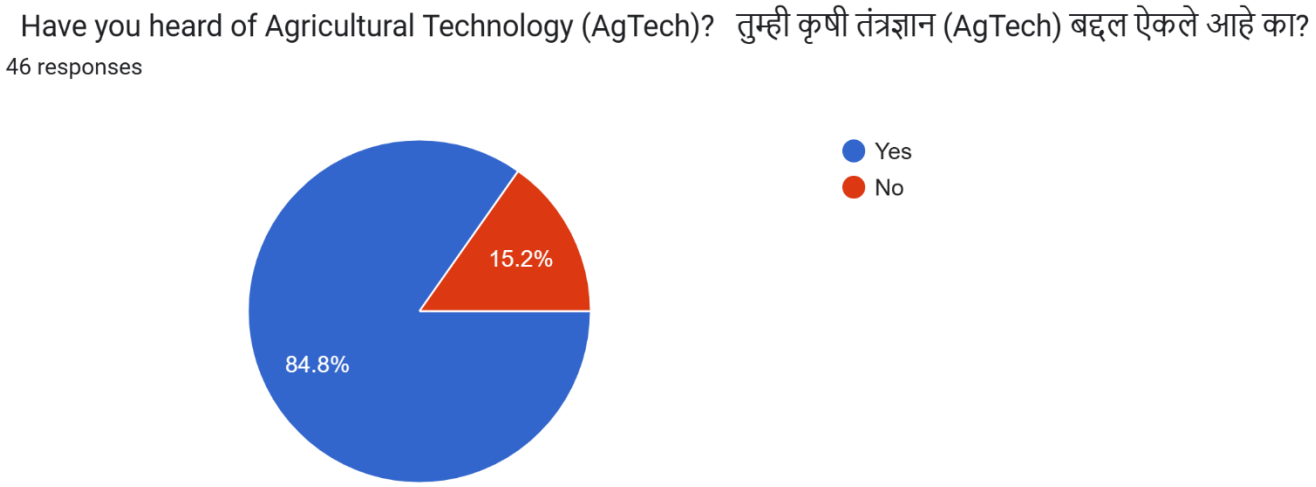

Figure 2. Pie-Chart Showing awareness of AgTech

Farmers identified multiple barriers preventing AgTech use, as shown in Table 2 and Figure 2. High costs were the most prevalent, cited by 34 respondents (69.4%), followed by lack of knowledge/training (30, 61.2%) and poor internet connectivity (13, 26.5%). Resistance to new methods (6, 12.2%) and lack of awareness of benefits (not explicitly listed but inferred from comments) were less common [8]. These align with broader adoption challenges noted in prior research [1].

Table 2: Barriers to AgTech Adoption (n=49)

Barrier	Number	Percentage
High Cost of Technology	34	69.4%
Lack of Knowledge/Training	30	61.2%
Poor Internet Connectivity	13	26.5%
Resistance to New Methods	6	12.2%

Figure 3. Barriers to AgTech Adoption

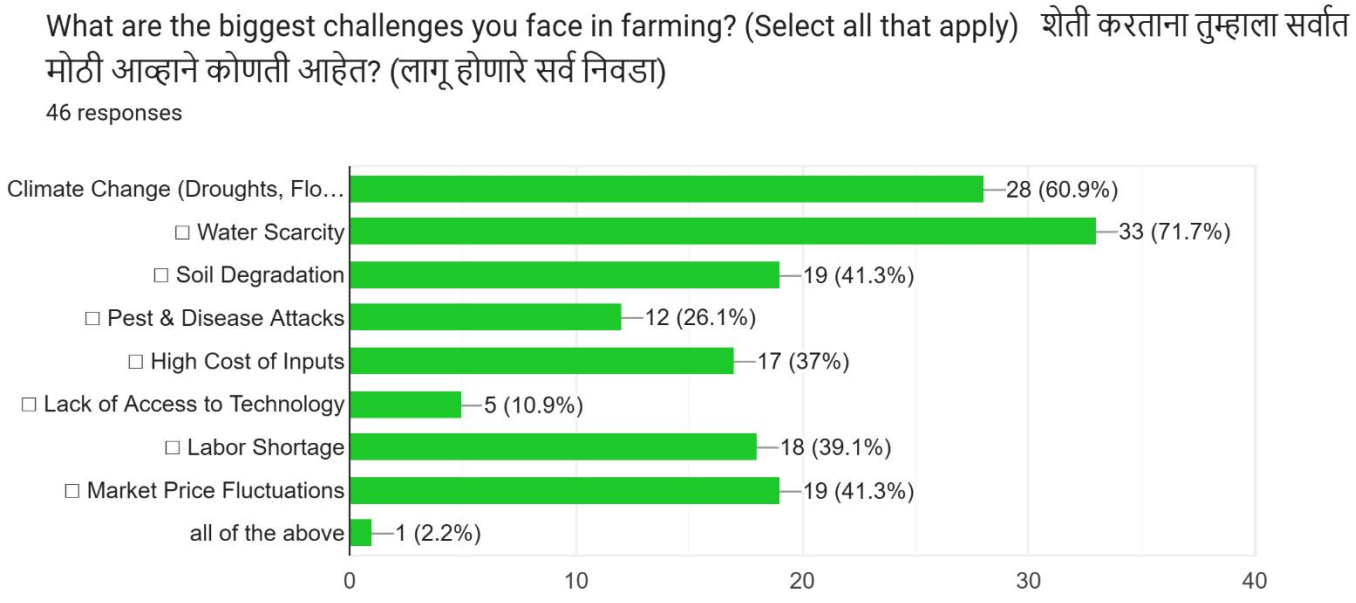

Figure 4. Biggest Challenges

A majority, 38 farmers (77.6%), believed AgTech could address farming challenges, with 7 (14.3%) unsure and 4 (8.2%) providing no clear stance. Table 3 and Figure 3 detail the challenges AgTech is perceived to mitigate, based on the most frequently cited farming issues. Climate change (droughts, floods, temperature changes) was the top concern (31, 63.3%), followed by water scarcity (27, 55.1%), labor shortage (15, 30.6%), and market price fluctuations (15, 30.6%) [8]. These reflect regional agricultural priorities.

Table 3: Challenges Addressed by AgTech (n=49)

Challenge	Number	Percentage
Climate Change	31	63.3%
Water Scarcity	27	55.1%
Labor Shortage	15	30.6%
Market Price Fluctuations	15	30.6%
High Cost of Inputs	14	28.6%
Soil Degradation	13	26.5%
Pest & Disease Attacks	9	18.4%

Figure 5. Challenges addressed by AgTech

V. ADOPTION CHALLENGES

A. Infrastructure and Connectivity Limitations

The adoption of precision agriculture is significantly hampered by a lack of network and internet connectivity, especially in isolated rural areas [1][3]. This is a critical challenge, according to Hota and Verma [1], which is made worse by insufficient telecommunications infrastructure. Argade et al. [3] also agree with this finding. 28.6% of farmers report having connectivity problems, according to Excel data [8], while JETIR [2] identifies inadequate road networks and storage facilities as additional infrastructure barriers that raise transportation costs, limit market access, and deter investment in digital tools.

B. Regulatory and Policy Constraints

Hota and Verma [1] ranked the lack of supportive regulations as the top obstacle. Uncertainty is brought about by contentious policies such as the 2020 farm laws and uneven land tenure systems [1][2] [6] point out shortcomings in the last-mile delivery of government programs like the Digital Agriculture Mission. JETIR [2] criticises redundant government applications that confuse users, and the Excel survey [8] shows that 24.5% of farmers are looking for subsidies. The formal financial system is ill-prepared to assist impoverished farmers as a result of these policy gaps, which restrict access to financial services [1][6].

C. Economic and Financial Barriers

Significant obstacles are presented by the high capital costs of labour, energy, fertiliser, and technology, especially for smallholder farmers who make an average of about $1,000 per year [1][8]. This is highlighted by Hota and Verma [1and the Excel data [8] indicates that 65.3% of respondents were put off by the cost. Financial barriers to adopting CSA technologies, such as drought-resistant seeds [3] and Dey and Shokhawat [4]. These barriers are exacerbated by a lack of accessible, reasonably priced credit and financial services [2][6]. Low-cost capital projects are still not enough to close this gap [1].

D. Land and Scale Issues

Digital agriculture is less economically viable and scalable due to small land holdings, with 78–86% of Indian farms being under two hectares [1][6][8]. While Cheruku and Katekar [6] attribute this to worries about food security, Hota and Verma [1] observe declining land sizes .Because fragmented ownership prevents uniform adoption, renting and sharing practices make technology deployment even more difficult [1][2]. Large-scale innovations' profitability is threatened by these structural limitations [3].

E. Data Ecosystem and Security Concerns

Although underdeveloped, a strong data-sharing ecosystem that makes use of AI, Big Data, and IoT is crucial [1][4]. While the Excel survey [8] suggests that farmers are reluctant to share data with private companies because of ownership concerns [4] emphasise data trust and security issues—privacy, validation, and storage. Stakeholder

collaboration is advocated by Hota and Verma [1], but advanced farm management systems are limited by fragmented initiatives and a lack of uniformity [1][6].

VI. GOVERNMENT POLICIES

A. Digital Agriculture Mission (2021–2025)

Description: Launched by the Ministry of Agriculture and Farmers' Welfare, this mission aims to integrate advanced digital technologies such as Artificial Intelligence (AI), Blockchain, Remote Sensing (RS), GIS, drones, and robotics into agriculture. It seeks to provide farmers and stakeholders with data-driven inputs for informed decision-making on crop selection, seed varieties, farming practices, procurement, transportation, and storage.
Details: The mission includes five Memoranda of Understanding (MoUs) signed in 2021 with private companies (CISCO, Ninjacart, JioPlatforms Limited, ITC Limited, and NCDEX e-Markets Limited) to promote digital agriculture projects.
Objective: To support the vision of a self-reliant India (Atmanirbhar Bharat) and Sustainable Development Goals (SDGs) by transforming traditional agriculture into a digital ecosystem.

B. Doubling Farmers' Income by 2022 Initiative

Description: A policy framework outlined in the 2018 Committee Report on Doubling Farmers' Income, advocating the adoption of digital technologies across the agricultural value chain. It emphasizes shifting from "science of discovery to science of delivery" through data-driven interventions.
Details: Volumes 3, 4, 11, and 12 of the report highlight digital applications in post-production logistics, agricultural marketing, farmer empowerment through extension services, and science-based income enhancement via digital tools.
Objective: To double farmers' income by 2022 through technological interventions, including precision agriculture and ICT-enabled services.

C. National e-Governance Plan in Agriculture (NeGPA)

Description: An ongoing initiative under the Ministry of Agriculture and Farmers' Welfare to promote digital governance in agriculture, enhancing service delivery and information access for farmers.
Details: Strengthened in 2021, it supports the broader mission of digital agriculture by leveraging ICT for real-time data dissemination and policy implementation.
Objective: To improve planning, monitoring, and implementation of agricultural schemes through a centralized digital framework.

D. Pradhan Mantri Kisan Samman Nidhi (PM-KISAN)

Description: A direct benefit transfer (DBT) scheme that uses digital financial services (DFS) to provide income supportto farmers, linking Aadhaar cards with bank accounts and land records.
Details: Launched to ease input credit access without bureaucratic hurdles, it exemplifies the JAM trinity (Jan Dhan, Aadhaar, Mobile) integration for seamless financial aid delivery.
Objective: To enhance farmers' liquidity and reduce dependency on intermediaries, supporting digital adoption indirectly.

E. Pradhan Mantri Fasal Bima Yojana (PMFBY)

Description: A crop insurance scheme incorporating digital technologies to streamline claims processing and improve accuracy.
Details: Utilizes drones for rapid crop damage assessment, increasing the speed and precision of insurance payouts, as noted in Maharashtra's implementation.
Objective: To mitigate financial risks for farmers, encouraging investment in modern agricultural practices.

F. Electronic National Agricultural Market (e-NAM)

Description: A digital platform launched to connect farmers with national markets, eliminating physical barriers and intermediaries.
Details: Uses digital barcodes for traceability and integrates online trading systems to improve market access and price realization for farmers.
Objective: To enhance market efficiency and farmer incomes through digital infrastructure.

G. National Programme on Use of Space Technology for Agriculture (NPSTA)

Description: Initiated in 2017 by merging various space technology programs (e.g., Crop Assessment & Monitoring, Disaster Monitoring) under one umbrella.
Details: Leverages satellite imagery and remote sensing for agricultural resource management, disaster mitigation, and communication applications.
Objective: To provide data-driven insights for agricultural planning and resilience.

H. District Information System on Agricultural System (AGRIS) Project (1987)

Description: An early digital initiative launched with the National Informatics Centre (NIC) to establish a village-level agricultural information system across 520 districts.
Details: Aimed to reduce costs and increase ICT use in agriculture, laying the groundwork for later digital policies.
Objective: To create a foundational digital infrastructure for agricultural data collection and dissemination.

I. Farm Laws (September 2020)

Description: Three agricultural reform laws passed to modernize farming, though met with controversy and lacking public consultation.
Details: Intended to improve market access and financial services, but criticized for not adequately supporting small farmers or digital adoption directly.
Objective: To deregulate agricultural markets, with indirect implications for digital integration.

J. General Policy Emphasis on Digital Growth

Description: Broad governmental prioritization of digital agricultural growth to ensure food security and reduce poverty, as noted in national strategies.
Details: Includes investments in automation, genetically modified crops, and research, gradually evolving to recognize digital advancements.
Objective: To transform Indian agriculture into a sustainable, technology-driven sector.

VII. CONCLUSION

The transition from traditional to digital agriculture in India holds transformative potential for enhancing productivity, sustainability, and farmer livelihoods. Despite high awareness of digital tools, adoption remains limited by regulatory gaps, high costs, and infrastructural deficits, particularly for smallholder farmers. Government policies are steering the sector toward digitalization, yet implementation challenges persist. Economically, digital agriculture promises significant income and yield gains, contingent on overcoming adoption barriers. Addressing these issues through enhanced digital literacy, subsidies, and streamlined regulations is essential for a sustainable agricultural future in India.

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