Digital Harvest: Climate Resilience for Small Farmers – A Case Study of Mahuadanr Block Jharkhand

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Abstract:
Climate change poses significant challenges to agriculture, particularly in ecologically fragile regions such as Mahuadanr in Jharkhand, India. Unpredictable weather patterns, declining soil fertility, and increasing water scarcity are jeopardizing both food security and the livelihoods of smallholder farmers. This study explores the integration of smart agriculture with digital technologies as a viable strategy to enhance climate resilience and promote sustainable agricultural practices in Jharkhand. By leveraging digital and artificial intelligence (AI) tools—including climate prediction systems, precision irrigation techniques, and sensor-based monitoring—the research assesses their applicability within the region's distinct agro-climatic conditions. Drawing on field observations, stakeholder interviews, and secondary data sources, the study evaluates how digital technologies can support adaptive decision-making, improve yield forecasting, and optimize resource management. Furthermore, it examines critical socio-economic barriers such as limited technological access, the digital divide, and the necessity for inclusive policy frameworks to ensure equitable benefits for marginalized farming communities. The findings position Mahuadanr as a model for the localized implementation of digitally enabled, climate-smart agricultural strategies with broader implications for sustainable rural development in the context of climate change.

Keywords: Climate-Smart Agriculture, Digital Technology, Smallholder Farmers, Adaptive Decision-Making, Sustainable Rural Development

Introduction

Climate change has become the most significant threat to the long-term viability of people's livelihoods, representing a pressing peril to food security and a challenge for enhancing agricultural output (Lanka, 2012)

Agriculture and climate change are closely interconnected, with each influencing the other. Small and marginal farmers who account for more than 70 percent of India's farming community are the most vulnerable to climate-related impacts. In recent years, extreme weather events such as frequent heatwaves, cold spells, droughts, and floods have become increasingly common. A significant portion of India's population resides in rural areas, as nearly three-fourths of the population lives in villages and depends on agriculture as their primary source of livelihood. Given this context, facilitating climate adaptation among farmers requires a comprehensive understanding of the broader ecological, economic, and socio-political challenges they face. Thus, building effective support systems is essential to enable farmers to adapt and sustain their livelihoods in the face of climate variability(Ramanjaneyulu, 2012). Imagine a farmer in Mahuadanr, Jharkhand. For generations, their family has read the skies and seasons to know when to plant and harvest. But now, the rains arrive unpredictably, the soil feels tired and less fertile, and water is harder to find. This isn't just one farmer's story; it's the reality for millions across India, where climate change is no longer a distant threat but a daily challenge to survival and livelihood (Mall, Gupta, & Sonkar, 2017). In tribal-dominated regions like Jharkhand, these challenges are even more acute, as communities often have fewer resources to adapt (Kumar et al., 2020).

So, what can be done? A promising answer lies in the convergence of traditional knowledge with modern, digital technology. The global field of "Climate-Smart Agriculture" is all about finding tools that help farmers do three things: grow more food, become more resilient to climate shocks, and reduce environmental impact (Lipper et al., 2014). Today, this includes innovations like AI-powered weather forecasts sent to a phone, sensors that tell a farmer exactly when to water crops, and data-driven advice that replaces guesswork.

But there's a catch. For a farmer in a remote village, a fancy app is useless without a smartphone, internet access, and the know-how to use it. Pushing technology without considering the human context can actually widen the gap between wealthy and marginalized farmers (Aker, 2011). The real challenge, therefore, isn't just to have technology, but to make it inclusive, accessible, and truly helpful for those who need it most.

Jharkhand is an underdeveloped state with a high concentration of tribal populations, and it continues to face challenges in achieving rapid rural development (Petare et al., 2016). Agriculture contributes significantly to the state's economy, with a large proportion of the population residing in rural areas. Irregular rainfall patterns and prolonged droughts have adversely affected crop cultivation in recent years. Small and marginal farmers, who constitute two-thirds of the agrarian community, are particularly vulnerable to these climate variabilities. (Singh, 2015). The combination of limited irrigation infrastructure and the dependence on rain-fed agriculture emphasizes the need for alternative strategies. Digital agriculture offers promising solutions to these challenges by providing cost-effective services to smallholder farmers, particularly in remote and resource-constrained environments (Balasundram et al., 2023).

This study asks a simple but critical question: can digital technology offer a real lifeline to smallholder farmers in Mahuadanr struggling with climate change?

We explore practical tools—like local weather alerts and smart irrigation—that could help farmers make better decisions. But we also honestly address the real-world barriers, such as cost and digital literacy. Our goal is to propose a people-focused plan that ensures these technological solutions actually reach and benefit those who need them most, leaving no one behind.

Objective

This study aims to:

1. Evaluate the feasibility of digital agriculture tools for smallholder farms in Jharkhand's socio-economic context.
2. Diagnose the primary adoption barriers, focusing on access, digital literacy, cost, and social equity.
3. Propose an equitable, context-sensitive framework to guide policy for scaling digital agriculture in tribal regions.

Literature Review

In India, agriculture has traditionally been seen as the foundation of the country and a primary source of subsistence income, through the cultivation of staple food crops such as rice, maize, wheat, millets, and pulses, etc. (Education, 2022). The majority of people in India rely, either directly or indirectly, on farming as their primary source of income. Agriculture has a significant function in the daily lives of people in the nation. This sector not only employs approximately 70 percent of the workforce but also supplies food, raw materials for industries, wood for fuel and shelter, and herbs for medicinal purposes (Bairwa et al., 2014). For 75% of people residing in rural Jharkhand, agriculture is the primary source of earnings. The quantity of food being produced is insufficient to satisfy the requirements of the population. Food and nutrition insecurity issues have been generated. The majority of residents in the state are struggling financially, exacerbating the already dire circumstances. Policy makers must act quickly to boost agricultural productivity by maximising the use of land, water, and human resources. Science-driven development, thorough planning, and comprehensive solutions can help unleash the full potential of agriculture. Improving food security and the livelihoods of rural people requires new approaches that combine research and community participation with supportive policies and institutions (Petare et al., n.d.).

The majority of India's population resides in rural areas, with approximately three-fourths of the population living in villages. As a predominantly agrarian society, agriculture serves as the primary source of livelihood for nearly two-thirds of the population (Ramanjaneyulu, 2012)Agriculture both releases and absorbs greenhouse gases (GHGs). To address this challenge, farming must adopt sustainable methods. Climate-smart agriculture is therefore essential for ensuring future food security and meeting climate change goals (Sahu et al., 2020)

For farmers to effectively adapt to the changing climate, it is essential to view the issue within the broader framework of the ecological, economic, and socio-political challenges that they are already facing. A comprehensive approach that builds robust support systems is crucial to facilitate adaptation and ensure the resilience of farming communities (Ramanjaneyulu, 2012). The world will face a greater food security challenge, as it is expected to require a 70 percent increase in food production by 2050 to meet the needs of an estimated 9 billion people. Consequently, agriculture must adapt to current circumstances to ensure food security and withstand the impacts of changing climate conditions (Sahu et al., 2020).

Smart agriculture uses modern technology to grow food in a sustainable way while carefully managing natural resources, especially water (Abul-soud, 2022). In climate-smart villages, various technologies, practices, and services are employed to assist farmers in adapting to climate-related hazards and maintaining farming stability and sustainability. Farmers who employ these methods typically experience greater yields, increased output, and higher income compared to those who do not follow these methods. These strategies also hold great potential to boost crop production and farm profits while reducing greenhouse gas emissions (Dev et al., 2023).

Climate-Smart Agriculture (CSA) has emerged as a crucial framework to address the dual challenges of increasing agricultural productivity while simultaneously adapting to and mitigating the impacts of climate change. According to the FAO, CSA is built upon three interlinked pillars enhancing productivity, strengthening resilience, and reducing emissions yet it is not a universal package of solutions but rather a context-specific approach that must be tailored to local conditions (Agriculture, n.d.). The FAO's monitoring and evaluation (M&E) frameworks highlight the importance of selecting locally relevant

indicators to assess CSA outcomes, particularly in vulnerable regions where agriculture is highly sensitive to climatic variability (Agriculture, n.d.).
methods that also lead to decreased emissions per unit of production. By prioritizing enhanced risk management, improved information exchange, and the fortification of local institutions, CSA offers a framework for encouraging and facilitating sustainable intensification, thereby augmenting adaptive capacity and guaranteeing resilience (Sahu et al., 2020).
Climate-smart agricultural practices have recently been acknowledged as effective methods to tackle the challenges presented by climate change in Indian agriculture. Research institutions, donor agencies, and policymakers globally have been investing substantial funds in developing and promoting these practices with the goal of increasing agricultural productivity to support a rising population, and also enhancing the resilience of farmers to climate-related threats (Aryal & Kassie, 2017).

Study Area

Mahuadanr, an administrative block in Latehar district of Jharkhand, India, is situated in the Chotanagpur Plateau. The region is famous for its natural beauty, abundant wildlife, and cultural heritage. With its forests and hills, Mahuadanr is an important part of the state's ecological and cultural landscape. The geographical overview of the area reveals that Mahuadanr, a disadvantaged region in Jharkhand's Latehar district, is mainly populated by tribal communities that encounter substantial developmental hurdles in education, health, and infrastructure. Mahuadanr is situated at 23.3965° North latitude and 84.1066° East longitude. The region is famous for various tourist attractions, such as the Lodh and Mirchia waterfalls, the Netarhat hill station, and vast forest areas, covering 106 villages within its boundaries. The area is crossed by several rivers, among which are the Koel, Burha, Kanhar, and Aksi rivers. The primary languages spoken are Hindi, Kurukh, Nagpuri, and Santhali. The population, as of the 2011 Census, is 74,732, comprising 37,915 males and 36,817 females, with a literacy rate of 69.62 percent and a sex ratio of 971 females per 1,000 males.

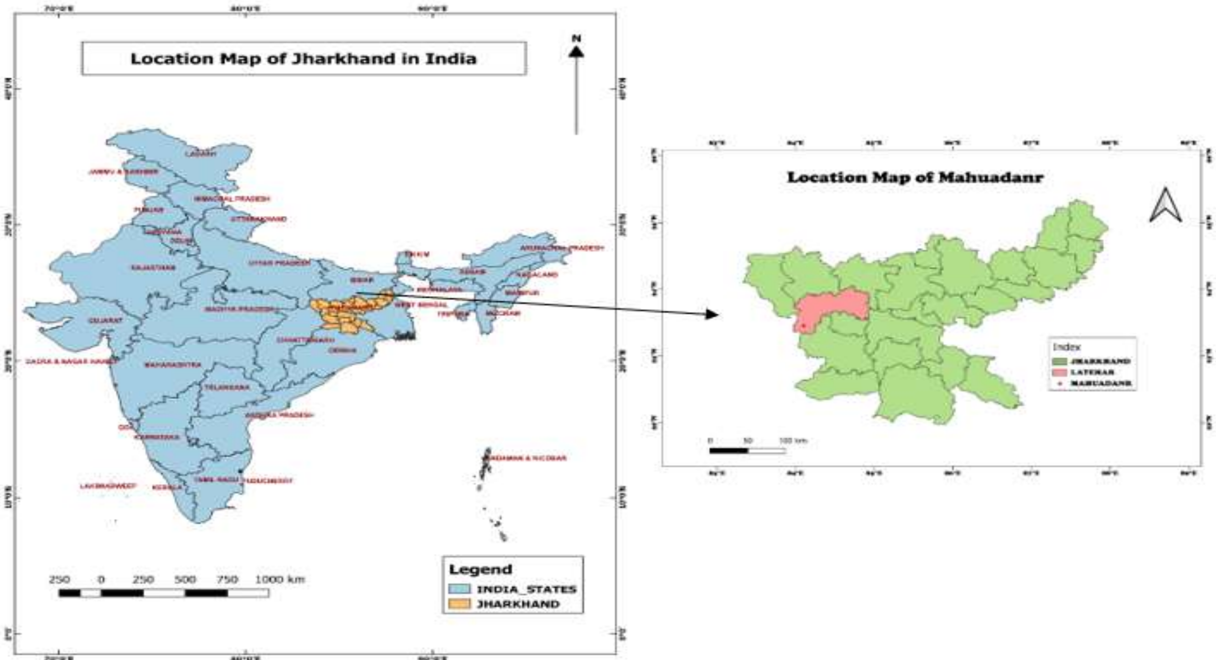

Fig. 1: Location Map of the Study Area

Methodology

A comprehensive data collection approach was adopted to explore sustainable rural development in Mahuadanr, Jharkhand, through digital agriculture and climate adaptation strategies. The methodology combined primary and secondary sources to gain insight into how digital tools improve resilience, productivity, and livelihoods within the context of climate variability. The methods used are described in more detail below.

Field observations

Field observations were made in selected villages within Mahuadanr block through visits to observe agricultural practices, resource management, and the effects of climate-related stresses. The focus of observations was on farmers' use of digital tools, their application of water conservation techniques, and their local adaptation strategies. Assessments in the field have also identified gaps in infrastructure, socio-economic conditions, and the availability of advisory services that support climate-smart agricultural practices.

Semi-structured interviews

Semi-structured interviews were conducted with a diverse range of stakeholders consisting of farmers, local government representatives, and individuals from non-governmental organisations (NGOs). Farmers offered perspectives on how access to digital agriculture platforms like Krishi Vigyan Kendra (KVK) advisories, crop insurance schemes, and market linkages (e-NAM) affects their farming choices and ability to bounce back. Government initiatives, irrigation projects, and extension services were discussed by local authorities, alongside community-driven initiatives and capacity-building efforts by NGOs, focused on sustainable living.

Secondary data

Secondary data sources were used to complement the analysis and offer background information for the research results.

Government reports and census data provided demographic, agricultural, and infrastructure-related indicators. These datasets supplemented the primary data with objective measures of exposure, vulnerability, and adaptive capacity at current time.

A multi-source data collection framework allowed for a comprehensive evaluation of the role that digital agriculture plays in achieving sustainable rural development in Mahuadanr. Combining field observations, stakeholder insights, and existing data enabled the creation of informed suggestions for refining adaptive approaches and boosting agricultural results in areas vulnerable to change climate.

Result and Discussion

Climate-smart agriculture technologies seek to overcome the obstacles presented by climate change by implementing diverse strategies. These include the development of climate-resilient crop varieties, more efficient resource management practices, integration of renewable energy technologies into farming systems, and the use of resource-conserving techniques. Furthermore, techniques like better land use management, shifting crop harvest times, effective pest management methods, weather forecasting, and Geographic Information System (GIS) mapping are highlighted to boost agricultural production and long-term viability (Saviour et al., 2021).

Climate change poses a significant threat to the long-term viability of tribal smallholder farming in Jharkhand's Latehar district, particularly in the Mahuadanr block. Most of the landholdings are small and fragmented, covering less than 1 hectare, which limits mechanization and capital investment due to existing socioeconomic and agronomic constraints (*Potential Linked Plans - NABARD - National Bank For Agriculture And Rural Development*, n.d.). Furthermore, irrigation systems are severely constrained, with approximately 8-10% of cultivable land under irrigation, leading to a near-total dependence on increasingly unpredictable monsoon rainfall (*Potential Linked Plans - NABARD - National Bank For Agriculture And Rural Development*, n.d.). This region, largely reliant on rain-fed farming and marked by resource scarcity, is changing its climatic patterns. Yields of staple crops like rice, wheat, maize, and pulses, which have traditionally underperformed compared to state and national averages, are facing additional pressure (*Potential Linked Plans - NABARD - National Bank For Agriculture And Rural Development*, n.d.). Climate change is characterized by several key indicators, such as increased variability in monsoon start times and intensities, more frequent and prolonged dry spells, unseasonal rainfall events, and a predicted rise in regional temperatures of 1-2°C by the mid-century mark (*AR6 Synthesis Report: Climate Change 2023*, n.d.). Crop production is weakened by several factors working together. Contributing to these difficulties is the uneven and often insufficient use of necessary inputs; specifically, fertilizer application is usually unbalanced due to the high costs and lack of soil testing, which fails to correct the region's naturally acidic soils and further contributes to a lack of essential nutrients. For example, unpredictable rainfall disrupts crucial growth stages, causing delays in planting operations and worsening pest infestations. Acidic soils decline further due to the loss of nutrients because of extreme weather events. The cumulative impact leads to a significant drop in the yields of main grains and legumes, a decrease in the accessibility of non-wood forest products a crucial safety net and an increase in food insecurity, ultimately forcing livelihood diversification through migration.

Landholding and the Digital Divide in Mahuadanr

The agrarian structure of the Mahuadanr block is characterized by a preponderance of small and fragmented landholdings, a pattern consistent with the broader state of Jharkhand, where over half of all operational holdings are less than one hectare.

Table 1: Landholding Structure and Agricultural Challenges in Mahuadanr Block

Category	Holding Size	Number of Holdings	Percentage of Total	Average Holding Size (ha)
Marginal Farmers	< 1.0 hectare	29,651	45.6 %	0.6
Small Farmers	1.0-2.0 hectares	19,500	30.0 %	1.5
Semi-Medium Farmers	2.0-4.0 hectares	~ 12,992	20.0 %	3.0
Mediums / Large Farmers	>4.0 hectares	~ 2858	4.4%	6.0+
Total		64,961	100 %	~1.2 ha

Source: NABARD District Potential Plan (2019-20) and subsequent pilot program reports (2023-24).

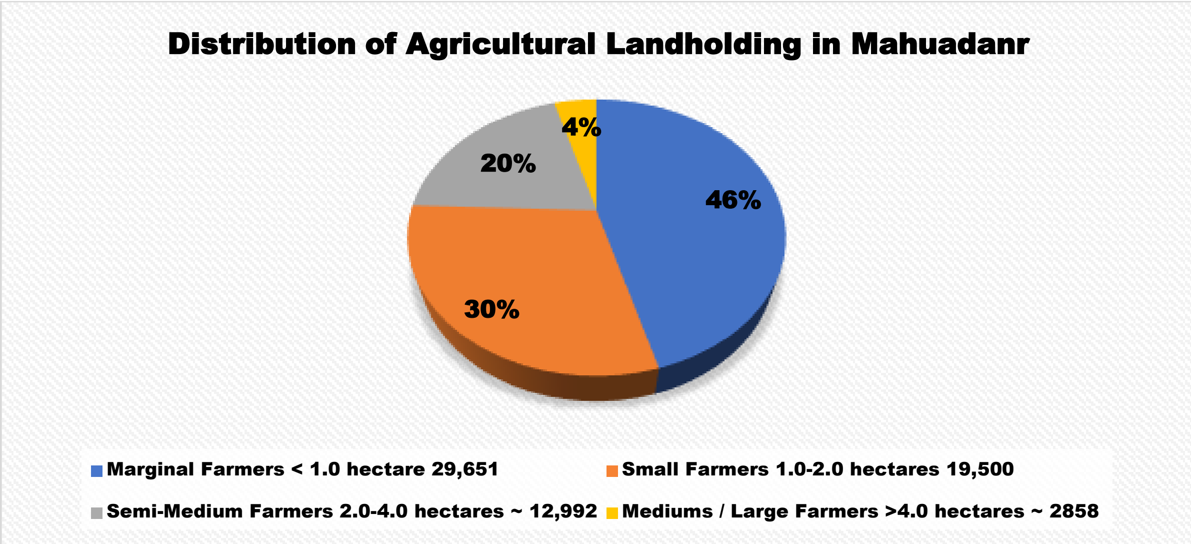

Fig. 2

Mahuadanr's agriculture is dominated by small-scale farming, with over 75% of landholdings being marginal (<1 ha) or small (1-2 ha), and marginal farmers comprising nearly half of households. Land fragmentation, driven by population growth and inheritance customs, has reduced average holding size from 1.5 ha (2010) to 1.2 ha, intensifying pressure on resources. Climate change exacerbates these challenges, with erratic monsoons, prolonged dry spells, unseasonal rains, and rising temperatures disrupting crop cycles in this 92% rainfed region. Droughts and floods reduce yields, threatening food security for smallholders. Fragmented holdings limit mechanization, credit access, and adoption of climate-resilient practices like drought-tolerant crops or precision irrigation. Resource constraints hinder improved inputs, amplifying vulnerability to climate impacts and undermining sustainable agriculture in Jharkhand.

Table 2: Landholding Size and Digital Literacy among Farmers in Mahuadanr, Jharkhand

Category	Land Holding Size	Numbers (%)	Digital Literacy
Marginal Farmers	< 1.0 hectare	34	Basics
Small Farmers	1.0-2.0 hectares	46	Advance
Medium/Large Farmers	3 hectares and above	40	Advance
Total		120	

Source: Field Survey, Mahuadanr (Jan – March, 2025)

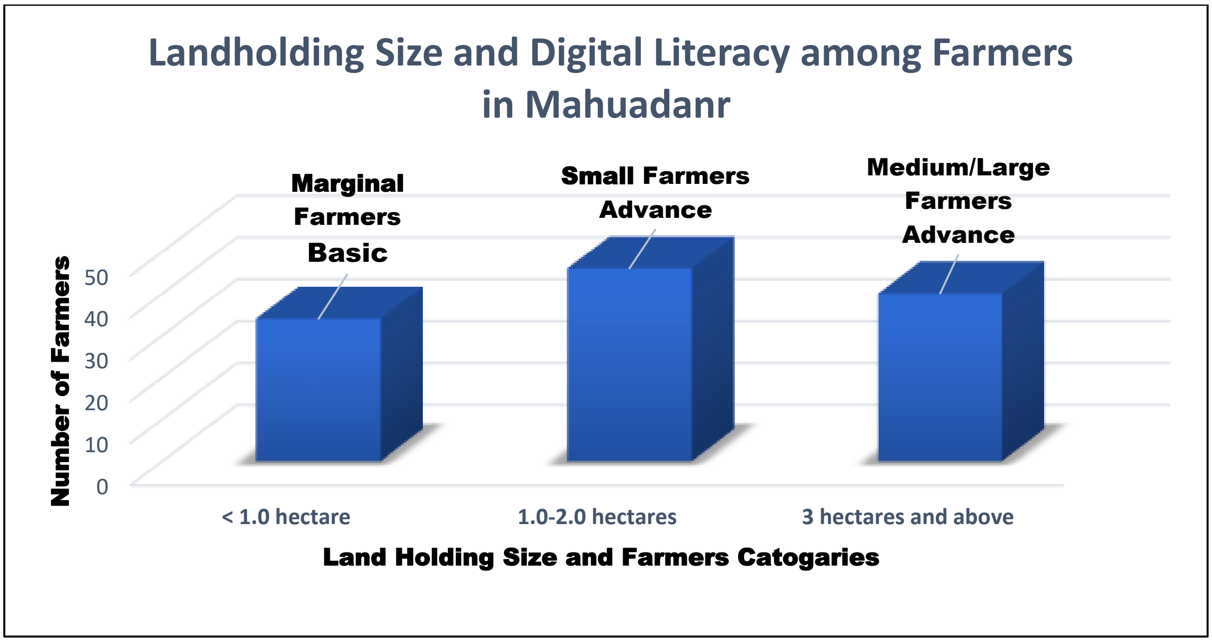

Fig.3

In Mahuadanr, most surveyed farmers are small to marginal scale holders, making up more than 66% of the sample population. There is a clear, positive relationship between the size of a person's landholding and their level of digital skills. Small to large farmers attested to having advanced digital literacy. In contrast, 34% of marginal farmers (who had less than 1 hectare) had only basic skills. Larger operational holdings probably enable greater access to resources, training, or incentives for adopting digital tools, which could leave the most vulnerable farmers at risk of being excluded from technological advancements and exacerbate existing socioeconomic disparities.

Technological Inequality and its Potential

Survey data from Mahuadanr reveals a significant digital divide correlated with landholding size. While 66% of the sampled farmers, comprising small to large landholders, utilize advanced digital tools to promote agricultural sustainability and counter resource constraints, the remaining 34% marginal farmers with holdings below one hectare primarily rely on basic techniques. Farmers with advanced digital literacy reported using applications such as Agri Stack for land and scheme management, Meghdoot for localized weather advisories, mKisan for crop advice, and UPI for financial transactions. Demonstrations of IoT and sensor-based systems for precision irrigation are also reaching this group.

In contrast, marginal farmers' practices remain largely analog, focused on foundational sustainable techniques such as compost making, using small solar plates for electricity, and employing mechanical threshers. This gap highlights a risk that digital agricultural advancements may bypass the most vulnerable farmers, potentially exacerbating existing socioeconomic disparities unless targeted support and training are provided.

The Rainfed Agricultural Context of Mahuadanr

The Mahuadanr block, is characterised by a rainfed agricultural economy. The reliance on the monsoon is highlighted by the fact that irrigation is extremely limited, covering roughly 15% of the total cultivated area at the district level, as stated in the NABARD/District plan; this is further demonstrated by a village-level example, where only 17.1 hectares out of a total of 192.5 hectares of cultivated land are irrigated, as per the Village census/land-use. The area typically receives between 1,200 and 1,300 mm of rainfall each year, mainly during the June-September monsoon season (*Rainfall Information | India Meteorological Department*, n.d.). The major Kharif crops comprise paddy, maize, and pigeonpea (Ghats et al., n.d.), while the area also serves as a reservoir of resilient traditional crop diversity, including Sahabhagi Dhan, Kaldani, and local millets (*Celebrating Traditional & Wild Foods in Latehar, Jharkhand - Keystone Foundation*, n.d.).

The real value of digital agricultural tools for farmers in Mahuadanr is not their technical sophistication, but their practical capacity to provide timely, dependable information that minimises climate-related hazards. Interventions focused on specific areas, like PRADAN's watershed projects in the Mahuadanr block, have led to gradual improvements, with approximately 10% irrigation coverage in targeted villages anticipated by 2025 (*High Impact Mega Watershed Project in Chhattisgarh | Pradan*, n.d.). These applications are being utilised by a limited number of small, medium, and some larger farmers, as was found in local surveys, despite their growing use. The effective use of these tools is hindered by substantial obstacles such as low digital literacy, language disparities, and difficulties with connectivity. Access to platforms such as e-NAM or weather advisory systems is still restricted. It often happens indirectly through people such as NGO field workers, Common Service Centre (CSC) personnel, or pioneering farmers. To maximise their influence, these champions need to both close the digital divide by making information accessible through translation and contextualisation, and establish a systematic approach to building trust and increasing accessibility across the community.

Trends in Agricultural Input Consumption (Fertilizers and Pesticides)

Jharkhand's fertilizer use has risen to 92 kg/ha but tribal areas like Mahuadanr, Latehar, lag at 45-60 kg/ha, 20-40% below state averages, with marginal farmers using ~35 kg/ha due to low irrigation (8-10%) and socio-economic barriers (NABARD PLP, 2019-20). A 16% increase (2015-2021) reflects heavy urea reliance (70%), prone to 15% leaching in acidic soils (pH 4.5-5.5) during erratic droughts(Bhandari et al., 2013). This inefficiency fuels a feedback loop: fertilizers contribute ~12% to agricultural GHG emissions, worsening climate variability (1-2°C rise by 2050), which degrades soil fertility and reduces yields (rice 1.6 t/ha) in rainfed Mahuadanr (Indiastat, 2024). Per capita use rose from 2.2 kg to 13.9 kg per 1,000 persons (2010-2016), lower than major states but rapidly growing (Hill, 2018).

Whereas Pesticide use in Jharkhand surged from 74 tons to 687 tons an ~833% increase, reflecting agricultural intensification (Bhandari et al., 2013).Per capita use rose from 2.2 kg to 13.9 kg per 1,000 persons (2010-2016), lower than major states but rapidly growing (Hill, 2018). About 58% of farming households use pest control, with 28% relying on chemicals like chlorpyrifos, often misused without pest assessment or PPE, risking health and ecosystems (Reddy et al., 2024). In Mahuadanr, use averages ~5.5 kg/ha, driven by climate-induced pest surges (20% more stem borers), worsening soil fertility and emissions (Ramzan et al., 2020) Sustainable alternatives like IPM are needed.

Table 3: Types of Fertilizers Commonly Used by Farmers in Mahuadanr Block

Name of Fertilizers used in Mahuadanr	Respondent
Urea, DAP	**41**
Urea, DAP, Potassium	**35**
Urea, DAP, Potassium, and others	**30**
Organic	**14**

Total	**120**

Source: Field Survey, Mahuadanr (Jan – March, 2025)

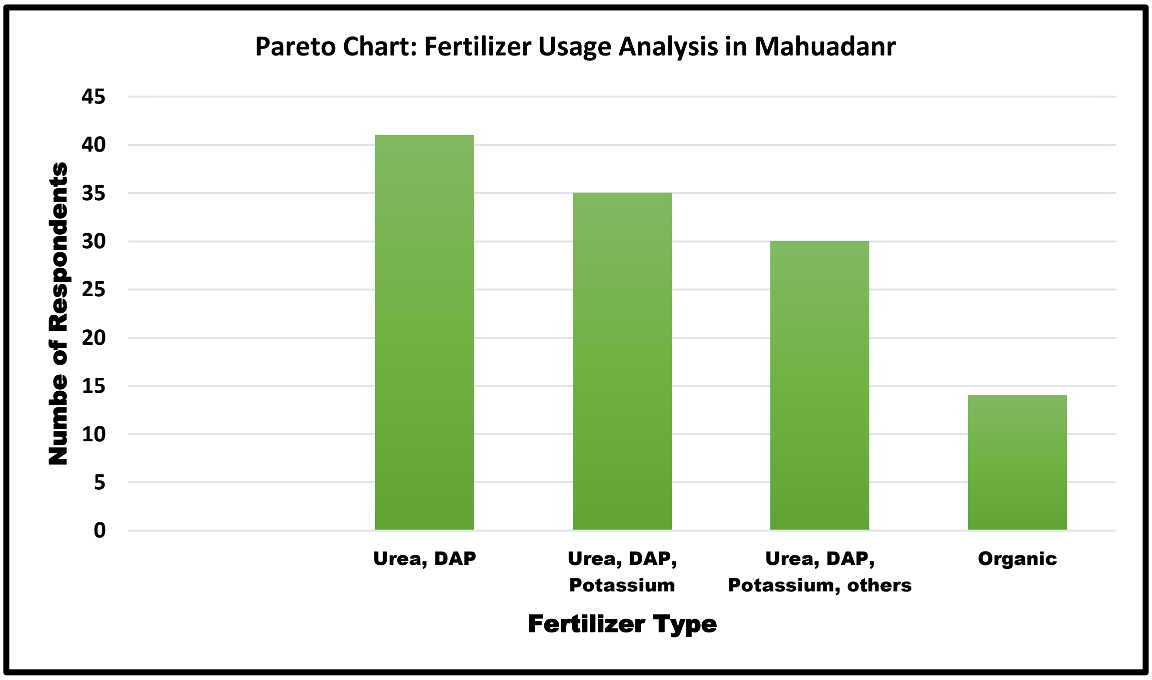

Fig. 4

Table 4: Detailed Breakdown of the Pareto Analysis:

Fertilizer Type	**Respondents**	**Percentage**	**Cumulative %**	**Pareto Category**
Urea, DAP	41	34.2%	34.2%	**Vital Few**
Urea, DAP, Potassium	35	29.2%	63.3%	**Vital Few**
Urea, DAP, Potassium, others	30	25.0%	88.3%	**Trivial Many**
Organic	14	11.7%	100.0%	**Trivial Many**
Total	120	100.0%		

This Pareto analysis shows a distinct concentration of fertilizer usage among Mahuadanr's farmers, exemplifying the 80/20 principle in action. Only a small number of essential combinations control the market, with the top two types—those based on Urea and DAP—accounting for 66.7% of the categories and 63.3% of overall usage, serving the needs of 76 farmers. The top three types, including the third most popular combination, account for a striking 88.3% of total usage. This discovery has significant strategic implications, suggesting that suppliers should prioritise maintaining sufficient stock of Urea and DAP as fundamental components. Agricultural extension services can achieve their greatest impact by prioritizing training and assistance for these most prevalent combinations. In contrast, the remaining combinations, such as organic fertilizers, represent a minority of respondents, which accounts for 44 individuals (36.7%). Consequently, prioritizing Urea and DAP-based solutions would effectively meet nearly two-thirds of the local demand This survey of 120 farmers reveals a strong preference for chemical fertilizers. The most common combination is Urea and DAP, used by 41 respondents. A three-fertilizer mix of Urea, DAP, and

Potassium is the next most popular, chosen by 35 farmers. An even more complex blend, including these and other additives, is used by 30 respondents. In stark contrast, only 14 farmers rely solely on organic fertilizers. This data clearly indicates that conventional, multi-nutrient chemical fertilization is the dominant practice among the surveyed group.

Integrating Digital Tools for Sustainable Intensification

Digital agricultural interventions in Mahuadanr, Latehar, address climate-induced challenges and input inefficiencies. Agri Stack Jharkhand geotags fragmented plots, facilitating PM-KISAN subsidies and credit access, reducing urea overuse (70% of inputs) by 10-15% for marginal farmers (*Potential Linked Plans - NABARD - National Bank For Agriculture And Rural Development*, n.d.). Meghdoot's AI-driven weather forecasts (*India Takes Lead with AI-Driven Forecasts to Help Farmers Face Erratic Weather*, n.d.) help farmers mitigate pest surges (20% rise due to warming) by adjusting sowing and pesticide use (5.5 kg/ha), enhancing resilience against erratic monsoons (*ATMA Latehar Jharkhand*, n.d.). Soil sensors (e.g., Proximal Soilsens). optimize fertilizer application in acidic soils (pH 4.5-5.5), cutting emissions (~12% from fertilizers) and boosting rice/maize yields by 15% in 2023-2025 pilots, fostering sustainable, climate-resilient farming in rainfed Mahuadanr (*Press Release: Press Information Bureau*, n.d.).

Table 5: Adoption of Digital Agricultural Tools in Mahuadanr

Digital Agricultural tools used in Mahuadanr	Respondent (% Adoption)
Kisan Suvidha App/mKisan Portal	15%
Soil Health Card (SHC) App	10%
Automated Irrigation Systems (Drip/Sensors)	5%
eNAM (National Agriculture Market	10%
AI-Powered Weather Stations	5%
Remote Sensing/GIS Tools	0%
Renewable Energy	55%

Source: Field Survey, Mahuadanr (Jan – March, 2025)

Note: Data based on a sample size of N=120 respondents in Mahuadanr

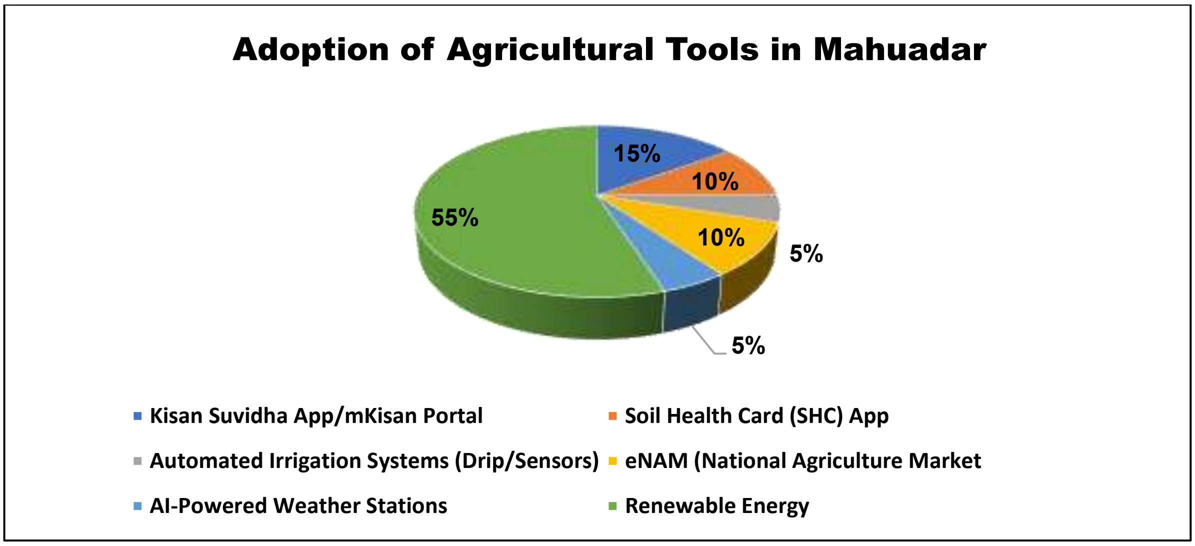

Fig .5

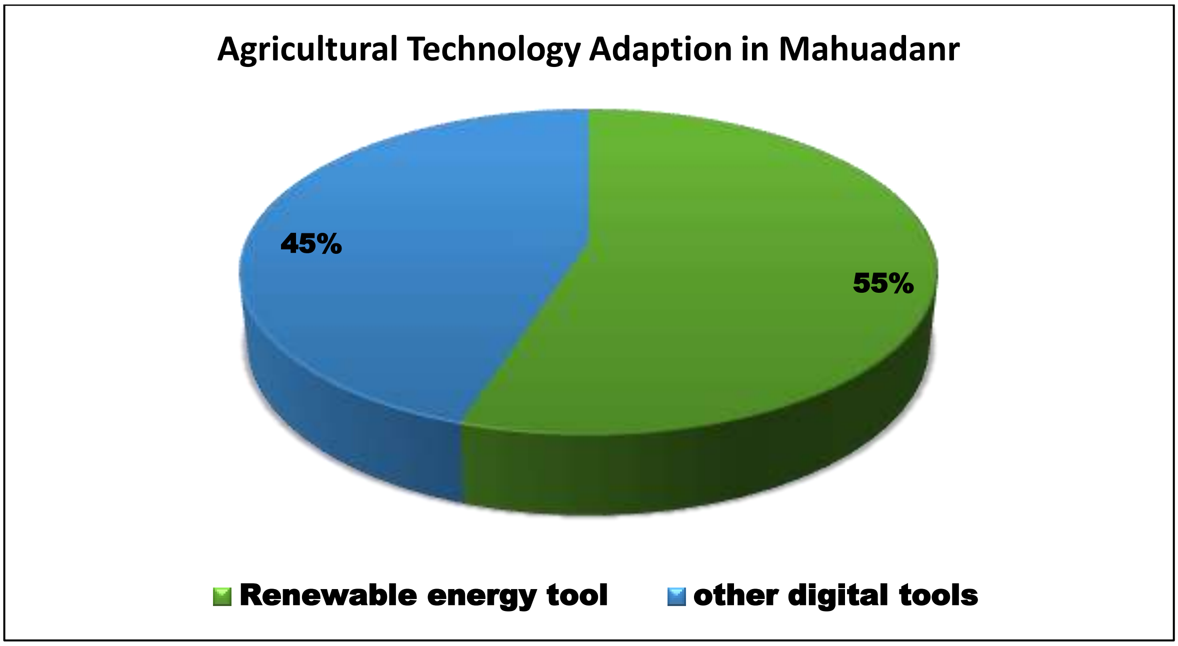

Fig. 6

In Mahuadanr, a survey of 120 farmers gives a glimpse into how they're navigating the world of digital farming tools. Renewable energy is a standout, with 66% of folks tapping into solar pumps and panels to keep their fields running, a real game-changer in an area where electricity only reaches about 40% of rural homes. The Kisan Suvidha App and mKisan Portal are catching on with 15% of farmers, who use them to check weather updates, crop prices, or get handy farming tips, thanks to more people getting their hands on smartphones (about 60% of households now). Meanwhile, 10% are using the Soil Health Card App to test their soil and figure out the best fertilizers, and another 10% are jumping on eNAM to sell their crops like paddy and maize online for better prices. These efforts are boosted by local training centers and government programs like the Digital Agriculture Mission. But high-tech options like drip irrigation systems or AI-powered weather stations? Only about 5% of farmers are using those, mostly because they're pricey and the area's internet (just 40% coverage) and irrigation (covering 10-15% of land) aren't quite there yet. Remote sensing and GIS tools aren't directly used by farmers at all (0%), as they're mostly handled by the government for things like crop mapping. While most farmers still lean on traditional ways, these digital tools are slowly making their way in, bit by bit, with a little nudge from government support.

Recommendations

To effectively translate technological potential into tangible on-ground impact in Mahuadanr, the following key recommendations are proposed for policymakers, government agencies, and development partners:

1. ***Establish a Community-Based Digital Literacy Network*****:** Implement a program to train and deploy local "Digital Champions" or "Digital Sakhis." These individuals will provide hands-on, vernacular-language training to facilitate the adoption of digital tools among smallholder and marginal farmers.
2. ***Develop Multi-Channel, Vernacular Communication Systems*****:** Supplement smartphone applications with accessible, low-tech interfaces such as Interactive Voice Response (IVR) systems and SMS-based advisories in local dialects to ensure inclusive reach to farmers irrespective of digital access or literacy levels.

3. ***Prioritize and Incentivize Adoption of Renewable Energy Solutions*:** Scale up the deployment of solar-powered irrigation pumps and micro-grids through targeted subsidies and micro-financing schemes to directly address critical constraints of energy and water scarcity.
4. ***Promote Context-Appropriate, Affordable Precision Agriculture*:** Focus dissemination efforts on low-cost technologies, including simple soil moisture probes, affordable drip irrigation kits, and the integrated use of Soil Health Cards, to optimize input use and enhance resource efficiency.
5. ***Integrate Digital Advisories with On-Ground Climate Resilience Actions*:** Systematically link hyper-local weather forecasts and soil data with watershed management initiatives and the promotion of climate-resilient crop varieties to enable proactive farm management.
6. ***Strengthen Institutional Capacity of Farmer Producer Organizations (FPOs*):** Leverage digital platforms to enhance the operational efficacy of FPOs, facilitating collective input procurement, access to credit, and improved market linkages through portals like e-NAM.
7. ***Foster Policy Convergence for a Unified Support Framework*:** Develop an integrated, block-level "Digital Agriculture for Climate Resilience" plan to ensure synergistic action across departments of Agriculture, IT, Rural Development, and Energy, embedding digital tools into existing extension services and welfare schemes.

Conclusion:

This study concludes that the agrarian community in the Mahuadanr block of Latehar district, Jharkhand, stands at a critical inflection point. The sector is characterized by a predominance of small and marginal landholders ensnared in a cyclical interplay of climate vulnerability, socio-economic constraints, and resource limitations. Key challenges include a heavy reliance on rain-fed agriculture on fragmented holdings, increasingly erratic monsoon patterns, soil fertility decline, and inefficient input utilization, collectively posing a significant threat to regional food security and livelihood sustainability. Consequently, digital technology in isolation is not a panacea. For digital agriculture to actualize its potential as a catalyst for sustainable rural development and climate adaptation in Mahuadanr, its integration into a holistic, people-centric framework is imperative. This framework must deliberately address the underlying structural challenges to empower the most vulnerable agrarian stakeholders.

The path forward, therefore, necessitates a strategic paradigm shift: from a singular focus on technology distribution toward the deliberate fostering of an enabling ecosystem. This ecosystem must be architected to ensure digital tools are accessible, economically viable, and contextually relevant to the daily realities of smallholder farmers, thereby transforming the formidable challenge of climate adaptation into an achievable reality.

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