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Digital Technology Adoption among Farm Households in Hiware Bazaar, Maharashtra: Preferences, Challenges, and Implications

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CERTIFICATE

This is to certify that Mr. **Mangesh Shivaji Jadhav**, a student of **Indian Institute of Technology (Indian School of Mines), Dhanbad**, has satisfactorily concluded the research report titled "**Digital Technology Adoption among Farm Households in Hiware Bazaar, Maharashtra: Preferences, Challenges, and Implications**" as part of the internship program at the National Centre for Good Governance (NCGG) under my mentorship.

I, **Dr. Seema Bathla**, hereby validate the successful completion of the internship report within the internship program at the National Centre for Good Governance (NCGG). The report submitted by Mr. **Mangesh Shivaji Jadhav** is an authentic work carried out by him under my supervision and guidance. I have reviewed and assessed his performance throughout the internship period.

Signature

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Undertaking

I, **Mangesh Shivaji Jadhav**, hereby declare that the research report titled "**Digital Technology Adoption among Farm Households in Hiware Bazaar, Maharashtra: Preferences, Challenges, and Implications**" is my original work. This study was conducted in accordance with the highest ethical standards, ensuring the integrity and objectivity of the research process.

I affirm that all sources of information and data used in this report are properly cited, and that no part of this report has been plagiarized. I have adhered to ethical guidelines in the collection, analysis, and presentation of data, ensuring respect for the privacy and confidentiality of all participants involved in the study.

Furthermore, I declare that there is no conflict of interest related to this report. I have no financial or personal relationships that could have influenced the outcomes of this study.

I am committed to maintaining the credibility of my research and upholding the principles of transparency and honesty in all my academic endeavors.

Abstract

The study explores the adoption of digital technology among farm households in Hiware Bazaar, a village in Maharashtra renowned for its successful transformation from a drought-stricken community to a prosperous one through collective efforts and innovative agricultural practices. The research utilizes a comprehensive case study methodology, including interviews, surveys, and focus group discussions with local farmers to gather detailed insights. The results indicate a high level of awareness and use of digital tools, such as mobile applications for market prices, weather forecasting, and crop management, which have led to significant improvements in crop yields and resource management. Despite these benefits, the study identifies challenges like limited training, infrastructural deficiencies, and socio-cultural resistance to technology adoption. The conclusion emphasizes the potential of digital technology to revolutionize agricultural practices in rural India, advocating for enhanced educational programs, infrastructure development, targeted incentives, and community engagement to overcome these barriers. Additionally, it suggests integrating traditional agricultural knowledge with modern digital tools to maximize benefits and ensure sustainable development.

(Keywords: digital technology, farm households,, agricultural practices, case study, market prices, weather forecasting, crop management, resource management, training, sustainable development.)

1. Introduction

Agriculture remains a high-priority sector in the Indian economy, accounting for the livelihood of around 58% of total population. An analysis of the supply-and-demand for food reflects that in spite of a 50% increase in crop production during the last ten years, the rate of growth in food production may not be sufficient to feed the increasing population (Birthal, 2024) The projections show that India may require 594 million tonnes by the year 2047-48 to feed the projected population around 160 billion. The situation is similar at the global level as the projected population will reach approximately ten billion by 2050 (Suzuki, 2019). Since land is limited, the only way out is to bring technological interventions that help in accelerating crop productivity. Besides meeting the growing food demand, the integration of technology into agriculture is essential to address reduce the incidence of rural poverty, and promote environmental sustainability. Advanced technologies can transform agricultural practices by enhancing land and labour productivity, optimizing resource use, and improving crop yields amidst increasing climatic variations. This is also crucial for meeting the nutritional needs of an increasing population. Additionally, technology can empower rural communities by providing access to better farming techniques, reducing labor-intensive processes, and increasing income opportunities. Moreover, sustainable technological solutions can minimize environmental impacts by promoting efficient water use, reducing chemical inputs, and fostering soil health, thereby ensuring that agricultural development is both productive and ecologically responsible.

Since the advent of High Yielding Varieties of wheat and paddy under the Green Revolution during the sixties, India has been witnessing a remarkable technological transformation. The yellow and white revolutions changed the agricultural land scape in many states. Since the last decade, initiation of flagship programmes like ‘Digital India’ and ‘Startup India’ in agriculture have revolutionized the way agriculture has been practiced historically. The smart farming practices aim to transform agriculture towards higher productivity growth path and help in mitigation of yield and price risks arising from pest attacks, extreme weather conditions (flood and famines) and volatility in market prices. It may lead to India becoming the third-largest startup ecosystem in the world, growing at a year-on-year (YoY) rate of 12–15%.

The entire system needs to adapt to a holistic approach which can be built upon indigenous and traditional farming knowledge integrated with transformative smart farming practices, including adoption of artificial intelligence (AI) tools and techniques. Adoption of AI technologies will pave the way for higher production with the optimum utilisation of available resources and facilitate predictive analysis, crop health management, enhance quality and traceability, etc (Goel, 2024). Smart and technology-driven resource management, modernisation of agricultural supply chains, climate risk mitigation strategy, digitising farm collectives as farmer producer organisations (FPOs), emergence of a start-up ecosystem and Government initiatives in digital farming are some of steps being taken to encourage smart farming practices.

From the global market point of view, smart agricultural systems and technologies, including AI and machine learning (ML), are showing remarkable growth with the investment and expenditure trends expected to triple by 2025 to USD 15.3 billion. Out of this, the AI technologies alone are projected to grow at a compound annual growth rate (CAGR) of 25.5%. (Sirsikar, 2022) Within the AI interventions, internet of things (IoT) enabled agricultural (IoTAg) monitoring is considered to be the fastest-growing technology segment, projected at USD 4.5 billion by 2025. The global market size for AI in agriculture stood at USD 1.7 billion in 2023 and is expected to reach USD 4.8 Billion by 2028, exhibiting a CAGR of 23.1% during the forecast period (2023–2028) (Market, 2023). This market growth is propelled by increasing penetration of IoT in the agriculture industry with implementation of data generation through sensors and aerial images for crops, leading to an increase in crop productivity through deep-learning technology. Further, technology advancements in recent years are reengineering both the upstream and downstream segments of the agri value chain. Cutting-edge technologies in AI such as IoT, ML, cloud computing, statistical computing, deep learning, virtual reality (VR) and augmented reality (AR) are enabling the sector to overcome the challenges of productivity, quality, traceability and carbon emission with enhanced profitability (Babu, 2024)

Drones or unmanned aerial vehicles (UAVs) are being predominantly used in the agriculture sector (Sylvester, 2018). Kisan drones are likely to bring change through accurate weather forecasts and secure, precise crop analytics which are AI enabled and accessible. Multi-spectral and imaging features of drones can aid crop stress monitoring, assess a plant’s growth stage, yield prediction and help in delivering fertilisers, herbicides and water. Drones can also help assess crop health, weed infliction, pests and infections status, and suggest judicious use of chemicals to address these issues. Hence, drone technology can help enhance the efficiency and consistency of crop management along with making it cost effective. There has been considerable development in the usage of drones in the agriculture sector. The Government of India (GoI) has also made a few important announcements towards the use of drones in the agriculture sector, and the notification of Drone Rules, 2021, launch of the drone Production Linked Incentive (PLI) scheme and introduction of a single-window Digital Sky Platform are some of the important steps taken by the GoI. As the agriculture sector of the country develops further, the usage of drones in farming methods is predicted to grow with many start-ups investing in low-cost drones which can support farmers, enhance their knowledge, and generate employment for the rural youth.

The GoI has been continually formulating and implementing policies and schemes to promote digital transformation in agriculture with increased impetus on supporting the ecosystem players, including agri-based start-ups. The Government is also enabling an institutional ecosystem for AgriTech start-ups through incubators/accelerators. It has adopted the theme of ‘AI for All’ and laid down broad recommendations for nurturing the AI ecosystem in India through the NITI Aayog. progress in creating and nurturing an AI-enabled ecosystem, the agriculture sector faces a number of issues and challenges that need to be addressed for facilitating a smooth transition. The major challenges with the innovation and technology aspects of AI in the agriculture sector are limited pool of AI and sectoral expertise, existing gaps in public AI research, poor data quality and lack of access to data, lack of coordination and cross-border collaboration. The adoption and application aspects of AI in agriculture have limitations in terms of achieving scale, IoT devices, data annotation, data security and privacy, and technical understanding. In the context of Indian agriculture, AI technologies need to sustain diverse and locally relevant practices that not only learn from local knowledge systems but also enable innovation along the entire value chain. (Saxena, 2023).

In this backdrop, the present research is undertaken to map the digital technologies and understand their adoption among the cultivator households (HHs) taking Hiware Bazaar, Ahmednagar as a case study. A primary survey of farm HHs is undertaken during May-June 2024. Hiware bazaar is purposively chosen as a study area. The listing of the farmers in the village is done as per the adopters and non-adopters. In all, 26 farmers are chosen randomly for the focussed group discussion (FGD). The analysis is based on the descriptive statistics. The following are the research questions and objectives taken up.

1.1. *Research Questions*

1. What are the primary preferences and utilisation patterns of digital technologies among agricultural households?
2. What specific challenges and barriers do adopters encounter when considering to incorporate digital technologies into their agricultural practices?
3. How does integration of digital technologies impact income generation and productivity levels of adopters as compared to the non-adopter farm households, and the factors that contribute to these effects?

1.2. *Research Objectives*

- To examine the digital technology choices and usage patterns among farmers: investigate the preferences and utilisation trends of ai technologies among agricultural households in India, delineating between adopters and non-adopters. This involves understanding the types of digital tools employed, the frequency of usage, and the reasons behind their adoption or non-adoption.
- To identify challenges faced by adopters and non-adopter farmers: explore the barriers hindering the adoption of digital technologies among agricultural households in India. This entails examining factors such as cost constraints, technological complexity, access to resources, and cultural or behavioural resistance, providing insights into the specific challenges faced by non-adopters.
- To assess the impact of tech adoption on farm income and productivity: evaluate the socioeconomic effects of digital technology adoption among agricultural households, focusing on changes in income levels and productivity outcomes. This includes analysing quantitative data to measure any discernible improvements or

setbacks resulting from the integration of digital tools, thereby assessing the overall efficacy and implications of digital technology adoption in the agricultural sector.

1.3. Structure of the Report

The report begins with an overview of the research topic and its importance in changing the agriculture land scape followed by the research questions and objectives taken. Section 2 provides a detailed review of literature to synthesize the existing research relevant to the topic. Section 3 explains the research methods and procedures used in the study, followed by results and discussion in section 4. Policy recommendations are delineated in the last section to offer practical suggestions based on the findings from the field.

2. Literature Review

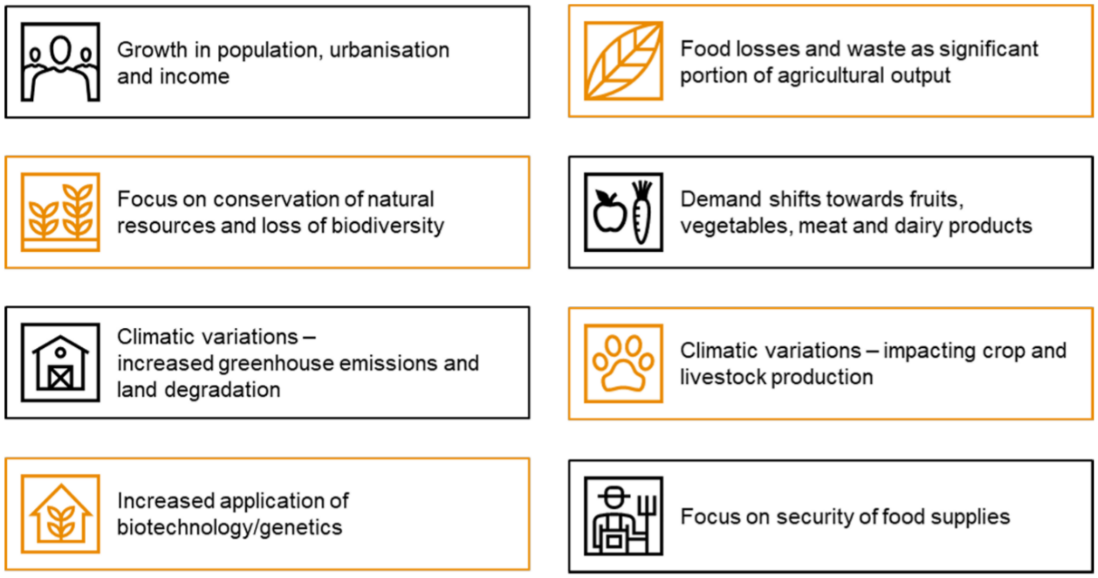
This section provides a detailed review of literature on the use and adoption of digital technologies among agricultural farm households, with a specific focus on the trends shaping the emergence of smart agriculture practices. The review synthesizes current scholarly insights into how farmers are increasingly integrating digital tools into their operations. It explores the drivers and barriers influencing the adoption rates, as well as the transformative effects of these technologies on agricultural productivity, sustainability, and resilience. The discussion highlights the evolving landscape where advancements in digital and smart technologies are revolutionizing traditional farming practices, paving the way for more efficient and technologically-enabled agricultural systems.

Need to Increase Agriculture Productivity through Digital Innovations

Agriculture is the basis of a sustainable economy and it is essential to the long-term growth of the economy as well as the structural change of society. Crop cultivation and food preparation were the bulk of agricultural activity historically (Fan, et al., 2012). On the other hand, over the last 20 years, the agricultural sector has grown more involved in the distribution, processing, marketing, and manufacturing of crop and livestock goods. These operations are part of the supply chain for agri-food. Currently, it serves as the main source of revenue and hence adds more and more to GDP. This indicates that it serves as a source of national commerce in addition to assisting with the decrease of unemployment, the supply of raw materials for other industrial operations, and the general expansion of the nation's economy. By 2050, when the world's population is predicted to reach 9 billion people, agricultural and food production would need to rise by 70% in order to meet the growing need for food (Krishna, 2016).

Major global trends necessitating the need to increase farm productivity

Figure 1: Global Trends in Agricultural productivity



Source: UN DESA, Fitch analysis and PwC analysis

A systematic shift from the current paradigm of higher output to sustainable methods in agricultural areas is urgently needed. By applying sustainable methods to practical solutions, this may help farmers and consumers make better decisions. This is especially true when employing digital technologies like the "Internet of Things (IoT)," "Machine Learning (ML)," Artificial Intelligence (AI), and so on (Sirsikar, 2022). An important aspect of agriculture is soil management. To maximize agricultural productivity and safeguard the planet's natural resources at the same time, a thorough understanding of the diverse types and conditions of soil is important. By managing the soil well, soil-borne pathogen impacts can be reduced (Abawi & Widmer, 2000). One of such AI-based method of managing soil is called "management-oriented modelling," and it includes a range of potential management choices that might help reduce nitrate-leaching. The ecosystem was safeguarded by doing this. To evaluate each alternative, it had a simulator, and to identify the user-weighted multiple-criteria alternative, it had an evaluator. For the purpose of characterizing and evaluating the soil-moisture dynamics, a remote sensing device integrated into a "higher-order neural-network" was also suitable. An "artificial neural network (ANN)" model assists in predicting soil textures based on their properties, while the current "coarse-resolution soil-maps" are merged with hydrographic parameters obtained from a "digital elevation model" (Zhao, et al., 2009).

AI in Agriculture

As per the Food and Agriculture Organization (FAO, 2009) a mere 5% additional land will come under cultivation worldwide by 2050. Crop production will continue to be under pressure and food production will have to increase by 60% to feed an additional two billion people

(FAO, 2009). However, traditional methods are not enough to handle this huge demand. This is driving farmers to find newer ways of increasing production and reducing waste. India's agriculture sector, which is worth USD 370 billion, continues to be the mainstay of the country's economy and supports the livelihood of more than 40% of the population, contributing 18.3% (FY 2023) to the national GVA. (Tomar, PIB, 2023) However, structural and operational deficiencies stall the sector's productivity growth. Thus, to strengthen the sector structure and increase productivity, the system is in dire need of integration of technology-aided practices and operations. It also requires reforms which are resilient enough to fasten easy adoption, scalability and sustainability of operations. Hence, the introduction and use of AI become critical to adopt these technological interventions. AI is steadily emerging as a part of the agriculture industry's technological evolution. AI-powered solutions envision to improve farming efficiencies and also enhance the marketability of produce in terms of quality as well as access. AI technologies are facilitating complex and routine tasks involving huge person hours. Such technologies operate to gather and process big data on digital platform, analyse it for getting the best course of action, and even initiating the required action when combined with other technology (Agrawal, 2021).

Existing agricultural scenario analysis – key trends and high-level transformations

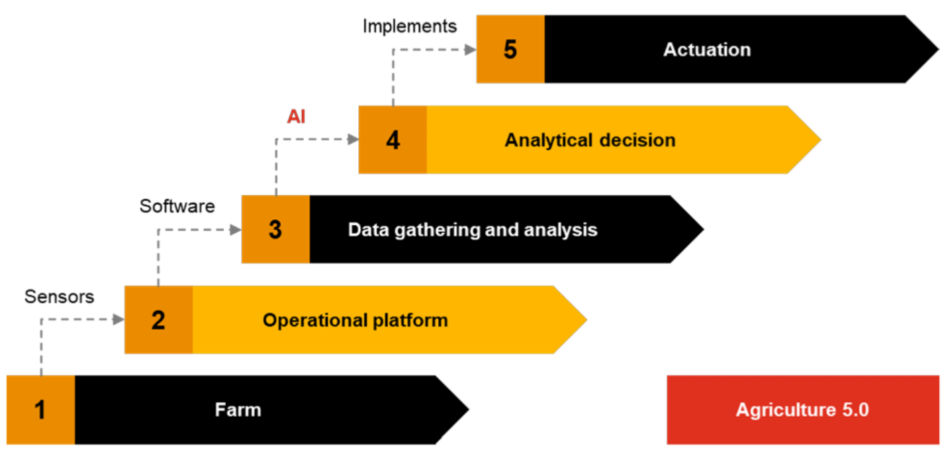
Agriculture presently is undergoing a significant shift facilitated by innovative technologies aimed at augmenting farming operations to boost yield. These technologies integrate data science and analytics throughout the agricultural value chain, ultimately optimising delivery efficiency. Despite a 50% increase in crop production over the past decade, projections indicate that this growth rate will not adequately meet the demands of the rapidly expanding global population, anticipated to reach approximately ten billion by 2050. (Suzuki, 2019) Concurrently, as per UN report highlighting that 60 million individuals globally are currently undernourished, a figure unchanged since 2014, underscoring the urgency to enhance agricultural productivity. Various global trends are shaping the sustainability of food and agricultural systems, necessitating transformative measures within the agricultural ecosystem. (Guterres, 2023)

Trends of AI in National and International Agriculture

Geographical spread of AI in agriculture AI was first attempted to be used in agriculture in 1985 and since then, the usage of such technology has come a long way. AI in agriculture is expected to be worth USD 4.7 billion worldwide by 2028. (Market, 2023) The market for AI in agriculture is globally divided into six major regions – North America, Europe, Asia Pacific, the Middle East and Africa, and South America. Of these, North America has emerged as the largest market for AI in agriculture owing to early adoption of advanced technologies for different agricultural practices. Further, the largest civil funding programme on robotics was introduced by the European Union (EU) that prioritises agri-food as one of the four application areas for the robotics programme in Horizon 2020 (EU's research and innovation funding program with a budget of nearly EUR 80 billion). The EU has strongly focused on digitising the agriculture sector by implementing Internet of Food and Farm 2020 (IoF2020), DEMETER, Agricultural Interoperability and Analysis System (ATLAS) and SmartAgriHubs with an investment of EUR 80 million (EC, 2023). In recent years, Latin America and the Caribbean have witnessed an increase in technological innovation in the AgriTech domain across the food and agriculture sector. Countries like China and India are also increasingly adopting AI and ML in agriculture at a massive rate. In 2019, the Asia Pacific region stood next to North America in the AgriTech market with a revenue share of 29.68% which is expected to grow continuously owing to the ongoing technological revolution in the agri-food industry. (Market, 2023)

Transformative smart farming practices: Introducing AI in Indian Agriculture (PMKSY, 2023)

Figure 2: PM Krishi Sinchayee Yojana



Source: Pradhan Mantri Krishi Sinchayee Yojana

The above-mentioned national trends further reiterate the urgent need of increasing farm productivity and AI tools and technologies have an important role to play. Adoption of AI technologies will pave the way for higher production with the optimum utilisation of available resources. Integrating AI with other applications provides an AI-leveraged model for the farming ecosystem. AI can be combined with remote sensing and weather station data, and used for predictive analysis and suggesting the time of sowing, scheduling irrigation, crop health management through AI-powered pest control, and combining AI and blockchain at market linkage platforms to enhance quality and traceability. (Tomar, 2022) There are some major trends in the Indian agriculture system which are leading to the adoption of innovative and transformative smart farming practices in the country.

Major Challenges in Indian Agriculture

The agricultural sector in India retains a central position within the national economy, supporting approximately 58% of the population. It also holds significance on a global scale, contributing 11.9% to the global agricultural Gross Value Added (GVA) of USD 3,320.4 billion, second only to China. This sector encompasses farming, forestry, livestock, and fisheries activities. Despite undergoing a phase of transformation marked by the integration of technological advancements to enhance operational efficiency, Indian agriculture confronts numerous challenges throughout its value chain. These challenges, coupled with the imperative to meet escalating food demands, threaten the sector's sustainability, necessitating its operation at the expense of heightened environmental burdens and substantial produce wastage. (Jasti, 2023)

Figure 3: Major Challenges in Digital Technology Adoption

1	Small and marginal farmers (86% of farmers own <2 ha of land, causing unsustainable farm incomes and poverty
2	Unsustainable farming practices, resulting in soil degradation and water stress
3	Unorganised and fragmented systems with existence of multiple levels of intermediaries and middlemen across the agricultural value chain
4	Limited access to technology, inputs, credit, capital and market, etc.
5	High-input, resource-intensive farming systems causing massive deforestation, water scarcities, soil depletion and high levels of greenhouse gas emissions
6	Lack of datasets at farm, farmer and sector levels, leading to higher cost of services
7	Gaps in market linkages, challenges in price discovery for farmers and price volatility in the market
8	Challenges in financial and digital inclusivity
9	Lack of food processing, logistics and warehousing infrastructure close to farm gates, increasing wastage
10	Poor farm mechanisation due to affordability challenges

The challenges faced make it evident that disruptive interferences are required in order to provide technical solutions for interventions. The agricultural must change to a more holistic approach, which can be based on traditional and indigenous farming knowledge combined with innovative smart farming techniques. The National Informatics Centre (NIC) developed the Agriculture Information Management System (AIMS), which has undergone several stages of transformation to yield the most advantageous smart farming solutions.

Trends that are paving the way for agricultural transformation

Smart and technology-driven resource management: Water management is one of the most important initiatives in terms of optimum utilisation of resources. Such initiatives range from watershed management to drip irrigation. The GoI has focused on this extensively and started the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) with a total allocation of INR 50,000 crore (from 2015–16 to 2019–20) for a period of five years. As a part of the allocation, INR 4,043.38 crore has been earmarked under the Per Drop More Crop programme of the PMKSY for improving irrigation efficiency during (FY 22-23) (PMKSY, 2023). Geotagging of assets under the scheme can be monitored through the Bhuvan app for better implementation across the country. Similarly, the Fertiliser Monitoring System (FMS) software is introduced to monitor the movement of fertilisers at different stages across the value chain. Relevant information such as rate of concession on fertilisers, maximum retail prices (MRPs), dispatch details, fertiliser receipts and company details are provided on the website.

Modernisation of the agricultural supply chain: Integration in the agriculture sector is enhancing with better connects in the value chain, access to the global market and along with environmental concerns, food safety and quality, animal welfare regulations are also increasingly impacting the sector. To minimise the supply chain losses, efforts are being put to enhance the efficacy of operations by focusing on critical factors such as quality, traceability, logistics and distribution. Smart/responsible sourcing technologies are used through predictive market demand forecasting using AI and prescriptive intelligence for route optimisation is obtained using AI/ML (Patel, Rai, Das, & Singh, 2021). Also, data-driven simulation modelling of food systems and quality with traceability are maintained by using AI-integrated systems.

Climate risk mitigation strategy: Several initiatives are being taken to create a climate risk mitigation strategy as India suffers from huge crop losses owning to the erratic weather conditions in the country. Solutions for early warning systems are playing a vital role in estimating and minimising risks incurred due to sudden climate-change scenarios (Mohd Javaid, 2023). Automatic weather stations (AWS) are examples of one such initiative. They consist of weather and lightning sensors, rain gauge and data loggers to measure the atmospheric conditions and provide prior weather-related information for production planning.

Preponderance and digitising farm collectives as FPOs: Farmer producer organisations (FPOs) are formed when individual small and marginal farmers come together and engage in farming operations and businesses as members of an aggregated body. FPOs help in creating opportunities for better credit facilities, insurance terms, post-harvest management (PHM) infrastructure for quality management, precision agriculture solutions for better crop management, etc. (Tomar, Press Information Bureau, 2022)

Emergence of a start-up ecosystem: A number of start-ups working on different aspects of digital/smart agriculture have been founded. There is scope for more incubation and funding support for these start-ups. The global AgriTech market grew by 35.4% between 2019–2020 and is further projected to grow between 2020–27 at a CAGR of 12.1%. India is also growing in this segment along with China and the US. The GoI is supportive of technology adoption and has invested in more than 300 AgriTech start-ups during 2019–20, totalling to INR 3,150 crore.

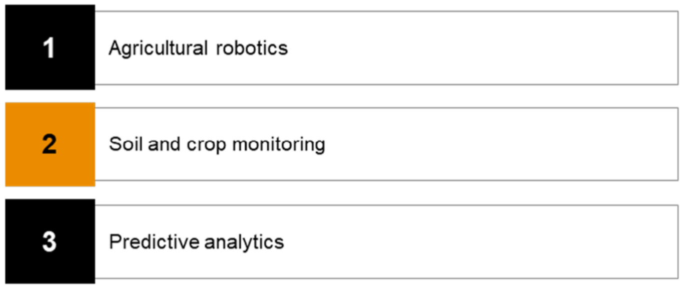
Government initiatives in digital farming: Adoption of innovative technologies is becoming one of the major driving forces for increasing productivity and promoting agricultural development. In addition to growing focus on technological adoption for increasing production, productivity and farm incomes, policies for agricultural development are also being emphasised. The Government has initiated multiple projects based on new technologies like AI, blockchain, remote sensing and geographic information system (GIS), drones and robots through a digital mission for 2021–2025((Munda, 2023)). The Ministry of Agriculture has signed a memorandum of understanding (MoU) for pilot projects with many of the major industry players in the digital market. The GoI is also focusing on digitising farmers' data with the India Digital Ecosystem for Agriculture (IDEA) initiative. This National Farmers Database is an 'AgriStack' with a collection of technologies and digital databases of farmers and other stakeholders in the agriculture sector. It includes digitised land records and other relevant information for farmers. Such digitised farmer endowment data facilitates in providing benefits under various schemes such as the Pradhan Mantri Kisan Samman Nidhai (PMKSNY) and Pradhan Mantri Fasal Bima Yojana (PMFBY). A lot of data collected through these systems has information of different aspects of agriculture and enhances the possibility of implementing AI technologies in farming systems.

Thus, it is observed that the Indian agriculture is in the process of infusing technologies aiming at enhancing the productivity growth and incomes of farmers. These innovations are driven by the Fourth Industrial Revolution and comprises technologies such as AI, ML, IoT, big data, drones and blockchain, and aimed at bringing rapid and large-scale changes to increase the efficiency and farmer's welfare.

Emerging AI Components in Agriculture

With the emergence of AI as a leading technology solution towards improving productivity, agriculture is slowly getting digitalised with focus on the following three areas.

Figure 4: AI Components in Agriculture

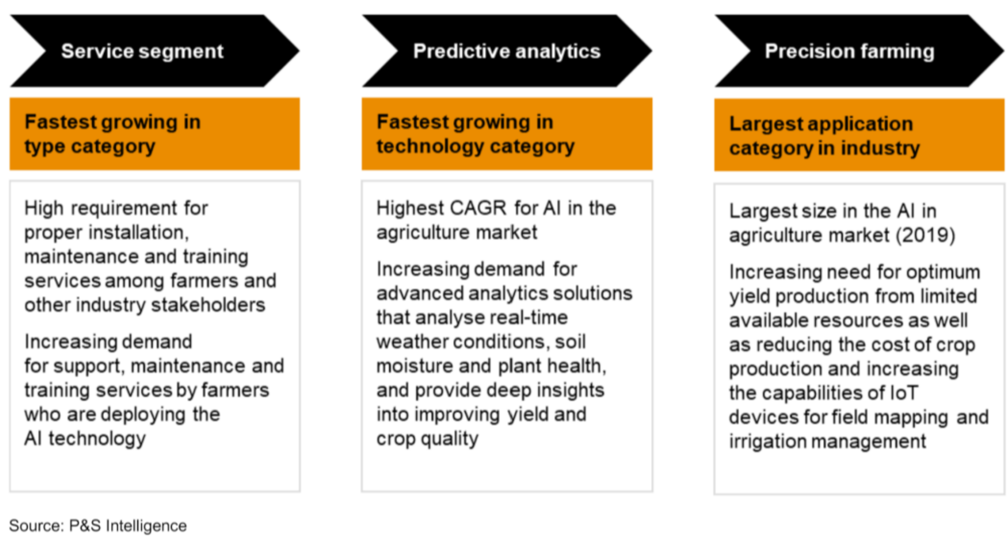


An increasing number of farmers are collecting data through soil sampling, robotics, and sensors. This data is then stored on farm management systems, enabling improved processing and analysis. AI in agriculture is becoming more and more feasible due to the availability of such agricultural data (Neeraj Mittal, 2024).

AI application types

Various AI technologies have been classified into distinct groups based on their type, industry, and technology. The service segment in the type category, predictive analysis in the service category, and precision farming in the industry category are the three categories with the fastest-growing segments (Mohd Javaid, 2023; Saxena, 2023). The three fastest-growing segments are further examined in the image below.

Figure 5: Application of AI in Agriculture



Major Digital Technologies coupled with AI

The Internet of Things (IoT) is used in intelligent farming using various sensors for light, humidity, soil moisture, temperature, crop health monitoring, and so on. (Khaled Obaideena, 2022)

- Data gathering by sensors on farms, such as wearables, button cameras, robots, and control systems;
- Drones operating from the air and the ground for field analysis, monitoring, spraying, irrigation, and crop health assessment;
- Monitoring the health of cattle by geo-fencing with livestock tracking and wireless IoT sensors;
- Predictive analytics for humidity, soil, temperature, and rainfall, among other variables;
- Using Internet of Things devices and monitors, an inventive greenhouse that eliminates the need for human interaction.

GIS used to analyse complex spatial data, such as rainfall, topography, soil elevation, slope aspect, wind direction, flooding, and erosion, etc (Krishna, 2016)

- Mapping of irrigated terrain;
- Evaluation of crop health;
- Irrigation amendment analysis;
- Assessment studies of land deterioration;
- Repairing erosion;
- Efficient drainage elevation model.

AI/ML and data science technologies help and benefit farmers by providing reliable data analysis and forecasts. Critical agricultural data acquired by IoT devices and ML algorithms is analysed and channelled using data science (Agrawal, 2021)

Real-time applications of AI/ML and data science in agriculture include:

- Predicting production and assessing quality;
- Utilizing predictive analytics to ensure crop sustainability;
- Use machine learning to remove weeds by identifying plant and crop species;
- Detecting crop illnesses and diseases;
- Intelligent harvesting and pricing decisions;
- Preventing waste and fulfilling demand;
- Autonomous robots for livestock management.

Blockchain helps farmers in safeguarding their harvests, stopping fraud and theft, effectively running the supply chain, and maintaining the equilibrium of the food chain

(Patel, Rai, Das, & Singh, 2021). Examples of how blockchain technology is being used in agriculture right now are:

- food supply chain transparency;
- food traceability;
- E-commerce for the agribusiness;
- Farmer insurance;
- Agricultural subsidies.

Automation: Smart farming and farm automation are acknowledged by machines that carry out agricultural tasks, which reduces the strain on human labor. Among the contemporary technologies utilized for agricultural automation are harvesters, drones, bespoke tractors, and watering motors (Jasti, 2023)

AI-/ML-led technologies are being used in agriculture for various innovations, some of which are mentioned below. (Babu, 2024)

Crop monitoring

Drone-based crop monitoring is being used worldwide to address drought and other harmful environmental phenomenon affecting agriculture. The 3D imaging from drones is being utilised to predict soil quality, farm patterns and parameters, diseases and pest infestations, etc. Drone-based chemical spraying on crops is also prevalent as it has been analysed that the pace of spraying increases by five times compared to other machineries (Sylvester, 2018). However, care must be taken to avoid groundwater penetration of chemicals. Improving nutrient quality of the grains, for example, through XRF Analysers to assess mineral content in grains, grain analyser to digitise grain seed quality and establish traceability and hyperspectral Imaging to predict nutrient concentration in leaves over developmental stages (Tavares, 2023).

Robotics in agriculture

The usage of robotics has improved productivity and resulted in higher yields in agricultural systems. Around 90% agrochemical usage can be achieved by using weeding and spraying robots. Using camera for guidance and laser, robots can remove weeds without any human involvement as they are capable of navigating crop rows by themselves. Utilising robots in plant transplanting is bringing in more efficient methods compared to traditional ones. Robots are also being used for fruit picking and nut harvesting (Krishna, 2016)

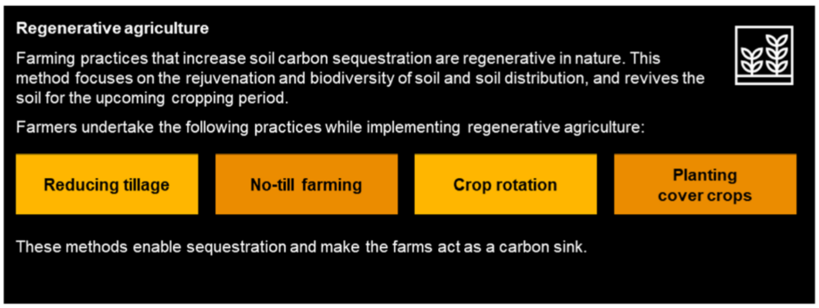
RFID sensors and tracking

Radio frequency identification (RFID) sensors are used to track food from source for consumers. Such sensors create an end-to-end traceability trail for a product, thereby enhancing trustworthiness and product conformance for fresh and quality produce (Tavares, 2023)

Adoption of AI technologies has also led to the emergence of two unique and innovative farming practices.

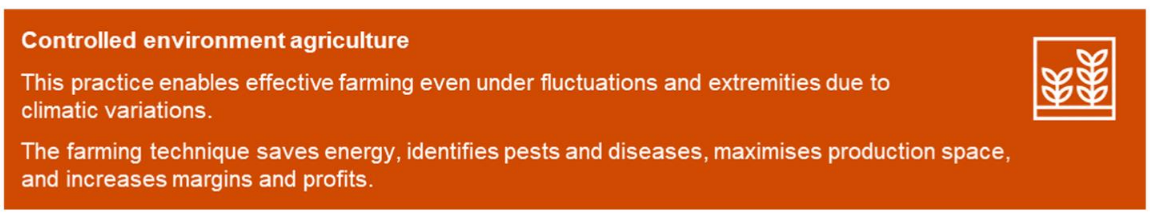
Regenerative Agriculture

Figure 6: Regenerative Agriculture



Controlled Environment Agriculture

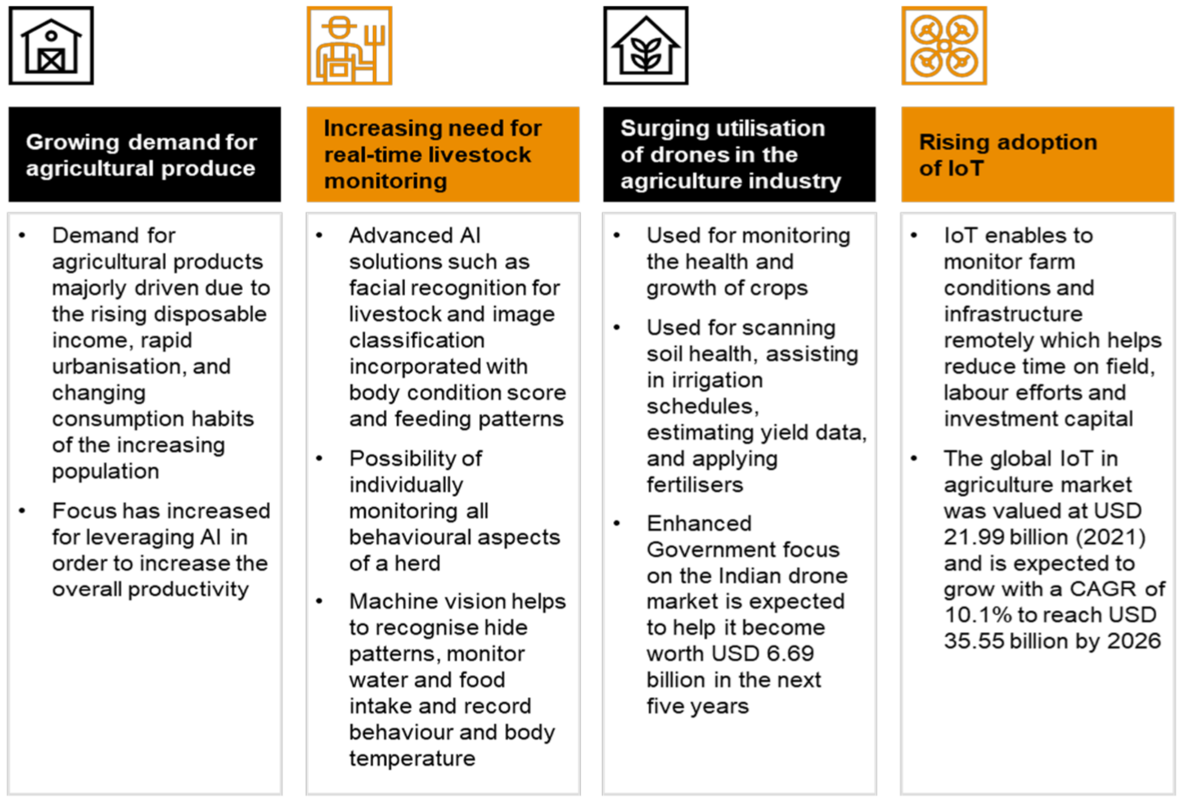
Figure 7: Controlled Environment Agriculture



Considering the potential of digital farming techniques, it can be assumed that digital transformation will drive the future of agriculture and empower farmers. They will have access to crops with better yields, improved and efficient farming methods and be free from worrying about environmental concerns. With our ever increasing population and the additional pressure of ensuring food availability for all, technology must be taken advantage of, which, in turn, will lessen the burden on our farmers as well.

Driving factors of AI in Agriculture

Figure 8: Driving factors of AI in Agriculture



Source: P&S Intelligence

Key objectives of emerging technology interventions in agriculture include the following: (Zhang, 2016; Saxena, 2023; Sirsikar, 2022)

Table 1: Pre-Intermediate and Post Production Technology usage

Pre-Production	**Production**	**Post-Production**
Improving productivity and efficiency through farm mechanisation and optimum utilisation of resources Financial and Digital Inclusivity	Facilitating input market linkages digitising records through farm management Precision agriculture enhancing yield by up to 30%	Better connected farm-to market supply chains Safety and trust in food systems Managing food wastage through digital enablement Introducing quality management and traceability of storage and logistics infrastructure Facilitating output market linkages
Real Time Monitoring of Environment		

AI-integrated practices in agriculture

AI-integrated practices are revolutionizing agriculture across decision support, market access, logistics, finance, livestock management, irrigation, and automation. AI-driven decision support enhances precision farming, AI-powered marketplaces offer insights into market trends, logistic and infrastructure management benefit from AI-driven optimisation, financial services provide tailored solutions, livestock management tools enable health monitoring and genetic optimisation, AI-driven irrigation enhances water management, and robotics and automation increase productivity (Mohd Javaid, 2023; Fan, et al., 2012; Sirsikar, 2022; Sylvester, 2018). These innovations signify a shift towards data-driven, sustainable farming systems with significant implications for global food security and rural livelihoods.

Figure 9: AI integrated practices

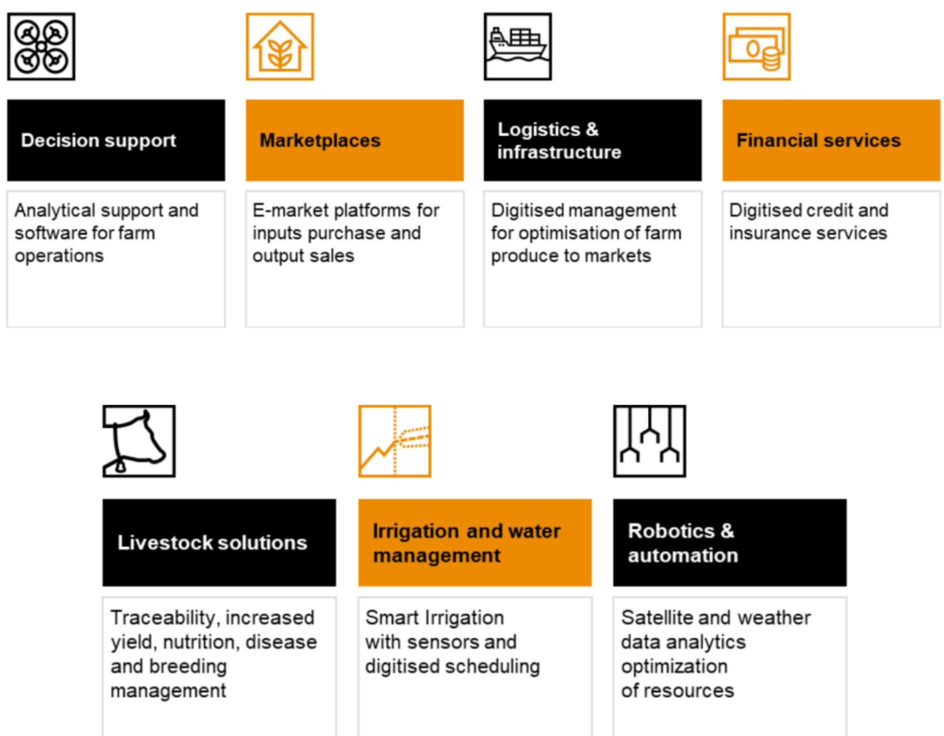
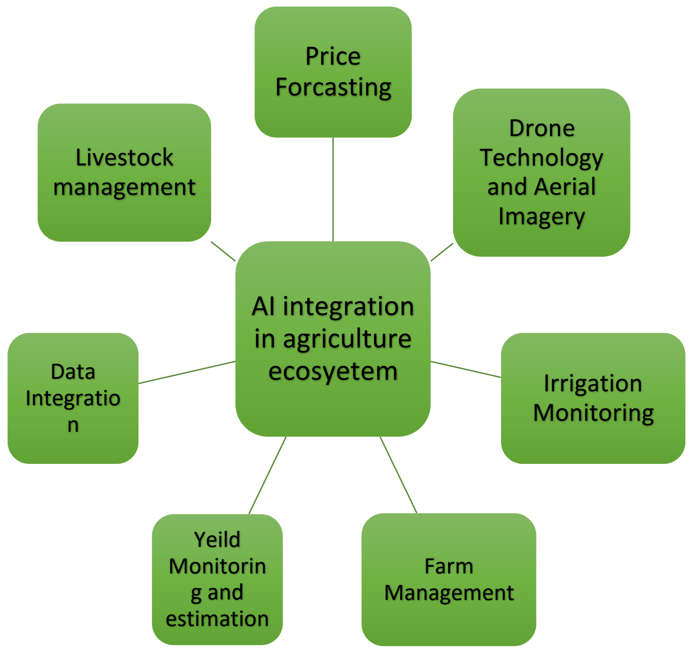


Figure 10: Major areas of AI benefiting agricultural ecosystem



3. Research Methodology:

Rationale for selecting Hiware Bazaar

Hiware Bazaar, situated in the Ahmednagar district of Maharashtra is considered to be India's model village. This village has transformed from water-scarcity, poor and deserted villages and schools to economically energetic, environmentally stable and socially cohesive communities. The concerted efforts of the villagers show that with united efforts and some key initiatives specially in agriculture, all Panchayats across the country just by involving and working together with their communities can also establish such transformations in their own villages in a few years.

In 1972 village Hiware Bazaar was largely hit by drought and after that the condition of the village getting downwards day by day as the wells were dried and water scarcity took place. Situated in the rain shadow area of the Western Ghats, the village receives erratic and uneven rainfall of less than 400 mm. This resulted in the formation of uncultivated lands and there is hardly any source of income. The consequences of this was depression, alcohol addiction that results in low efficiency of workers, domestic violence, and migration. During 1989-90, less than 12% of the cultivable land was under cultivation. The wells of the village used to have water only during the rainy season. As there was huge unemployment the village habituated in making, drinking and selling country liquor. Every family of the village were suffering from these issues. One leader, working together with all others in the village, changed it back to a vibrant, lush, and green with well- supported community, and with all facilities and amenities.

In the last 15 years, the average monthly income of the village has risen up to 20 times from Rs 832 to Rs 24000. Each village residents earns almost double the average income of the top ten percent of the rural population of India. The villages have now the place of 91 millionaires. The number of wells has increased to 217 from 97 as well as the irrigation land which has increased from 120 ha to 300 ha. Farmers grow at least three crops in a year sometimes four with a past experience of one unreliable crop a year following the rules of crop rotation and abandoned the use of water-intensive crops, and instead vegetables, pulses, flowers and fruit that use less water were grown. Grass production has increased drastically from 100 metric tonnes to 1000 metric tonnes in just 4 years (2000-2004) due to the ban on open grazing. The villagers started focusing on cattle farming, results in an increase in milk production which further produces large revenue. Back in the mid-90s, about 150 litres of milk were produced per day, and today milk production has increased to 4000 litres per day. In 1992 there were 180 families in the village standing below poverty line and surprisingly now there are no such families under the B.P.L category according to the sarpanch of the village Popatrao Pawar. The village has potential to tackle any kind of challenge launched in their way by Nature or man-made. Slowly and steadily the village has experienced growth and prosperity which has resulted in reverse migration.

A true leader masters in this transformation process to be the long standing sarpanch Mr Popatrao Pawar whose level of education and leadership abilities matches with some social leaders like Mahatma Gandhi, Jayprakash Narayan, Anna Hazare and others. He not only gained all youths and friends support initially but his early career, success and participatory skills resulted in a position of respect and leadership in the society. Even the elders of the village acknowledged him for his capabilities. Mr Pawar represented India in the international conferences which include SAARC and gave his speech at several university and colleges. He became member of some committees involving developmental activities in India. He has been the government advisor for the replication of water shed programme in the state of Rajasthan and Andhra Pradesh. Moreover number of visitors from foreign countries spend time in this village to examine the model of self-reliance and self-sustainenace.

Study Design

The methodology outlines the process for conducting Focus Group Discussions (FGDs) with two distinct groups of farmers: those who have adopted digital technology in farming (adopters) and those who have not (non-adopters). The primary aim is to understand the factors influencing the adoption of digital technology in farming, the benefits perceived by the adopters, and the barriers faced by non-adopters. The farmers are usually small landholders, having less than 2 hectares of land.

FGDs were chosen for this study due to their proven effectiveness in gathering in-depth qualitative data through interactive discussions, a method well-suited for exploring complex behaviors, motivations, and social dynamics. By allowing participants to express their views in their own words, respond to others, and build upon shared ideas, FGDs facilitate a rich, nuanced understanding of the topic at hand. This approach is particularly useful for generating insights into the decision-making processes regarding technology adoption, as it helps uncover the underlying reasons behind different choices and behaviors. Additionally, FGDs enable the identification of collective opinions and diverse perspectives both within and between groups, providing a comprehensive view of the factors influencing digital technology adoption in farming. The interactive nature of FGDs also creates a non-threatening environment where participants feel comfortable discussing sensitive topics openly, leading to more honest and detailed responses. These benefits of FGDs are well-documented in academic literature (Krueger, 2002) supporting their selection as the primary method for this study.

Research Methodology

The study included a total of 26 farmers, divided into two groups: 13 adopters of digital technology and 13 non-adopters. Participants for the focus group discussions were carefully selected to ensure a balanced representation of both adopters and non-adopters of digital technology in farming. Adopters were defined as farmers who had integrated at least one form of digital technology into their farming practices for a minimum of one year. This criterion ensured that the adopters had sufficient experience with the technology to provide meaningful insights. Non-adopters, on the other hand, were those farmers who had not incorporated any digital technology into their farming practices. The selection process aimed to include a diverse group of participants, taking into account variations in age, gender, farm size, and type of farming (e.g., crop farming, livestock farming, mixed farming). All participants were drawn from the same geographical location to maintain consistency in environmental and socio-economic conditions, thereby allowing for a more focused comparison between adopters and non-adopters. This diversity was crucial to capture a wide range of perspectives and experiences, enriching the discussion and the study’s overall findings.

4. Results and Discussions

The FGD design included two separate sessions to ensure focused discussions: one for adopters of digital technology in farming and another for non-adopters. This separation allowed for more tailored and relevant conversations within each group. Each session was planned to last approximately 90-120 minutes, providing ample time for participants to share their experiences and perspectives in depth. The sessions were held at the gram panchayat office of Hiware Bazaar, a neutral and comfortable location that was easily accessible to all participants. This venue was chosen to ensure a convenient and familiar setting, promoting open and honest dialogue among the farmers.

The FGD session began with a warm welcome and introduction of the facilitator and the participants, followed by an explanation of the study's purpose. Participants were assured of confidentiality and asked for their consent to participate and be recorded. Ground rules for the discussion were established to create a respectful and open environment. The discussion commenced with warm-up questions aimed at understanding the participants' general farming practices and experiences. This set a comfortable tone and provided context for the ensuing conversation. For adopters of digital technology, the core questions explored the specific types of digital technologies they had integrated into their farming practices, the motivations behind their adoption, and the benefits they had observed. They also discussed any challenges they had faced in using these technologies and described how digital technology had transformed their farming operations. For non-adopters, the core questions focused on their current farming practices and their views on digital technology. They were asked whether they had considered adopting digital technology, the reasons for their decisions, and the barriers preventing adoption. Additionally, they were queried on what information or support would be necessary for them to consider integrating digital technology into their practices. The session concluded with a summary of key points discussed, final thoughts from the participants, and expressions of gratitude for their contributions. This structured approach ensured comprehensive data collection on the factors influencing digital technology adoption in farming.

Using FGDs in this study has facilitated a rich, detailed understanding of the dynamics around digital technology adoption in farming. This methodology ensures that diverse farmer experiences are captured, providing valuable insights that can inform efforts to promote the adoption of digital technologies in agriculture. (Onwuegbuzie, 2009). Following is a tabular analysis of the observations and findings from the FGDs of the technology adopter farmers and technology non-adopter farmers.

Education Levels

Figure 11: Education level among adopters

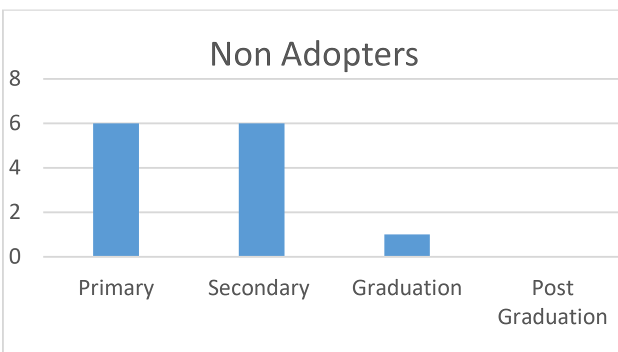
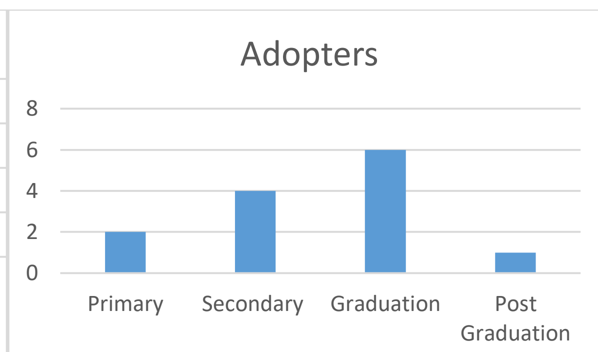


Figure 12: Education level among non-adopters



The information and data obtained indicates a clear correlation between education level and the adoption of digital technologies in agriculture. Farmers with primary education are predominantly non-adopters, while those with secondary education show a more balanced adoption rate. Notably, graduates and post-graduates are significantly more likely to adopt digital technologies. To bridge this gap, it is essential to implement educational programs to boost digital literacy, conduct training sessions, and promote peer learning. Providing easy access to resources, creating incentive programs, and developing localized content can further enhance technology adoption among less-educated farmers, leading to increased productivity and efficiency in agriculture

Table 2: Age Group Variation

Age Groups	Adopter Respondent	Non-Adopter Respondent
20-35 yr	4	0
35-50 yr	8	4
50-65 yr	1	7
65 & above	0	2

Figure 13: Age group among adopters

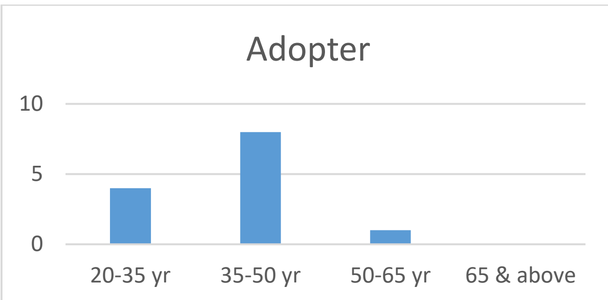
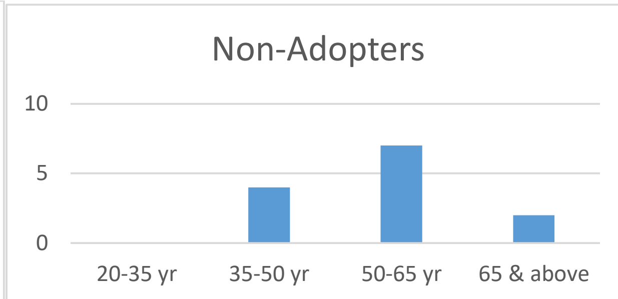


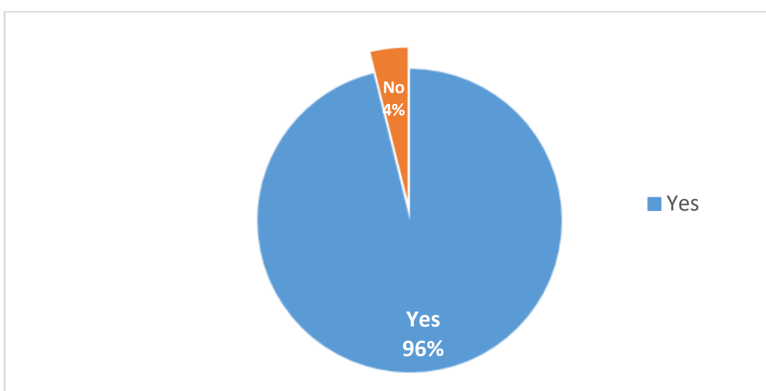
Figure 14: Age group among non-adopters



The adoption of digital technologies in agriculture shows a clear age-related trend. Younger farmers, particularly those in the 20-35 and 35-50 age groups, are more likely to adopt digital technologies, with 12 adopters versus 4 non-adopters. In contrast, older farmers, especially those in the 50-65 and 65+ age groups, are less inclined to use such technologies, with only 1 adopter compared to 9 non-adopters. This suggests that younger farmers are more open to integrating digital tools into their practices, potentially due to greater familiarity and comfort with technology, while older farmers may be more resistant or find it challenging to adopt new methods.

Influence of information technology in farms make its maintenance easier

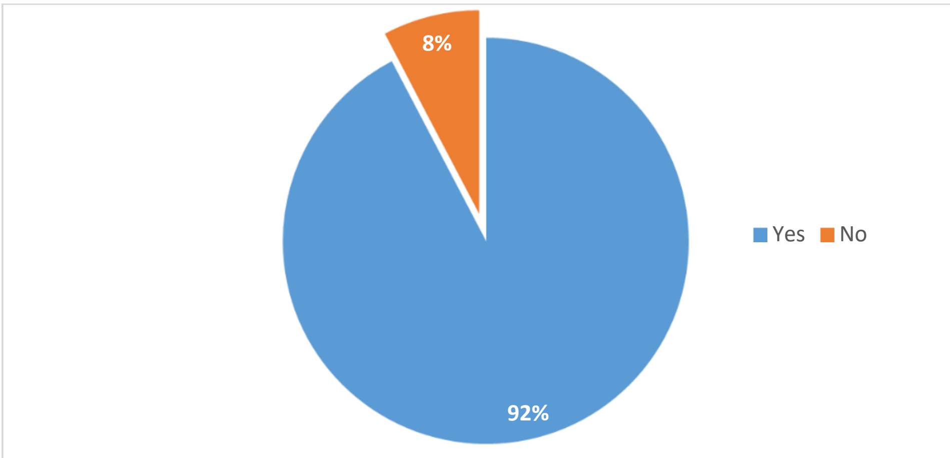
Figure 15: Farmers' Attitude Towards Using Information Technology



The integration of information technology into agricultural practices is widely perceived as beneficial for farm maintenance, as evidenced by 96% of respondents affirming its positive impact. This substantial majority underscores the general consensus that digital tools and technologies significantly enhance the efficiency and effectiveness of farm operations. These advancements facilitate better crop management, optimize resource use, and streamline various farming processes, thereby reducing the overall labor and time required. The remaining 4% of respondents, who do not share this view, represent a minority perspective, potentially due to a lack of familiarity or comfort with technology. Nevertheless, the predominant positive response highlights the transformative potential of information technology in revolutionizing agricultural maintenance and operations, aligning with broader trends towards digitalization in various sectors.

Responses of the farmers as to whether or not IT provides easier farm management.

Figure 16: Ease of Farm Management



The majority of farmers exhibit a positive attitude towards the role of information technology (IT) in agriculture, with 92% of respondents affirming that IT facilitates easier farm management. This substantial consensus underscores the perceived benefits of digital tools in enhancing operational efficiency, optimizing resource allocation, and improving decision-making processes. The high percentage of affirmative responses indicates that farmers recognize the potential of IT to streamline various aspects of farming, from crop monitoring and pest control to inventory management and market access. Conversely, 8% of respondents who do not share this view may highlight potential barriers such as technological literacy, initial costs, or the suitability of IT solutions to specific agricultural contexts. This dichotomy suggests that while the integration of IT in agriculture is largely viewed favorably, efforts to address the concerns of the minority could further enhance the adoption and effectiveness of digital technologies in the sector.

Table 3: Comparison of Adopters and Non-Adopters of Digital technology in Agriculture

Parameter	**Farmer A (Adopter)**	**Farmer B (Non-Adopter)**
Technology Use	Smart Phones, AI, ML, Drones	Traditional methods
Yield per Acre	41% higher yield	Average yield

Resource Utilization	Optimized through precise data analysis	Higher resource wastage
Operational Costs	20% reduction due to efficiency	Higher due to manual processes
Pest and Disease Management	Proactive with predictive analytics	Reactive with conventional methods
Market Access	Limited growth due to lack of awareness of communication channels	Limited to local markets
Sustainability	Better soil health and water use	Conventional practices impacting sustainability
Revenue	35% higher due to better yield and market prices	Lower due to lower productivity
Decision Making	Data-driven and timely	Experience-based and slower
Labor Requirements	Reduced due to automation	Higher due to manual labor
Investment	Higher initial investment in technology	Lower initial investment
Training and Skill Requirements	Requires continuous learning and training	Minimal additional training
Crop Quality	Higher quality produce with fewer defects	Varied quality due to inconsistent methods
Weather Resilience	Better adaptation to weather changes	Vulnerable to extreme weather conditions
Farm Management	Integrated farm management systems	Fragmented and less organized
Customer Trust	Higher trust due to transparent practices	Lower due to lack of transparency
Supply Chain Efficiency	Streamlined supply chain with less waste	Inefficient supply chain

A comparative analysis of Adopters, who adopts digital technologies, and non-adopters, who relies on traditional methods, highlights stark contrasts across various agricultural metrics. Adopters leverages advanced technologies such as smart phones, artificial intelligence (AI), machine learning (ML), the Internet of Things (IoT), and drones. These tools facilitate precise data analysis, optimizing resource use and reducing operational costs by 20%. Additionally, Adopters employs predictive analytics for proactive pest and disease management, resulting in a 41% higher yield per acre compared to non-adopters, whose traditional methods lead to greater resource waste and higher costs due to manual processes.

Market access, sustainability practices, and revenue generation further differentiate the two farmers. While adopters’ growth is somewhat restricted by limited awareness of modern communication channels, the advanced market prices and higher crop quality translate to a 35% increase in revenue. The use of technology also promotes better soil health and efficient water use, enhancing sustainability. In contrast, non-adopters remain confined to local markets and practices conventional methods that negatively affect sustainability and result in lower productivity and varied crop quality, leading to reduced revenue. Adopters’s data-driven, timely decision-making and integrated farm management systems contribute to a more organized operation, whereas non-adopters’ experience-based decisions are slower, and their management remains fragmented.

Investment and labor needs reveal additional disparities. Adopters incurs higher initial technology investment and ongoing training costs but benefits from reduced labor due to automation and higher customer trust through transparent practices. Conversely, non-adopter faces lower initial costs and minimal additional training needs but deals with higher labor costs and less customer trust due to limited transparency. Furthermore, Adopters' farm is better adapted to weather changes and enjoys a more efficient supply chain, while non-adopters’ farm is more vulnerable to extreme weather and has an inefficient supply chain. This comparison underscores the significant benefits of digital technology adoption in improving agricultural productivity, sustainability, and profitability.

Participants' Awareness and Sources of Information on Digital Tools

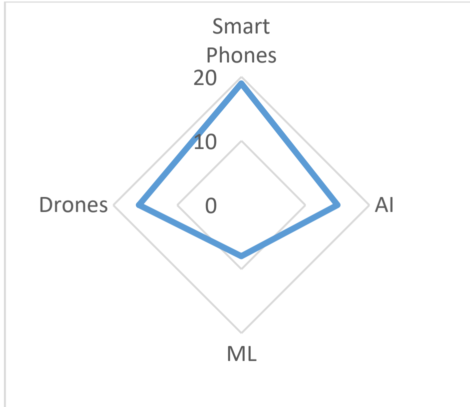
Awareness of Digital Tools

Table 4: Awareness response

Digital Tools	Number of Participants Aware
Smart Phones	19
AI	15
ML	8
Drones	16

The awareness of digital tools among agricultural participants varies significantly, as indicated by the data on their familiarity with different technologies. Among the participants, smart phones are the most widely recognized digital tool, with 19 individuals acknowledging their awareness. This widespread recognition underscores the ubiquitous presence and perceived importance of smart phones in modern agricultural practices. Drones also demonstrate a high level of awareness, with 16 participants familiar with their application, reflecting the growing interest in and adoption of aerial technology for tasks such as crop monitoring and land surveying. Artificial intelligence (AI) follows closely, with 15 participants aware of its potential in optimizing agricultural processes through data-driven insights and automation.

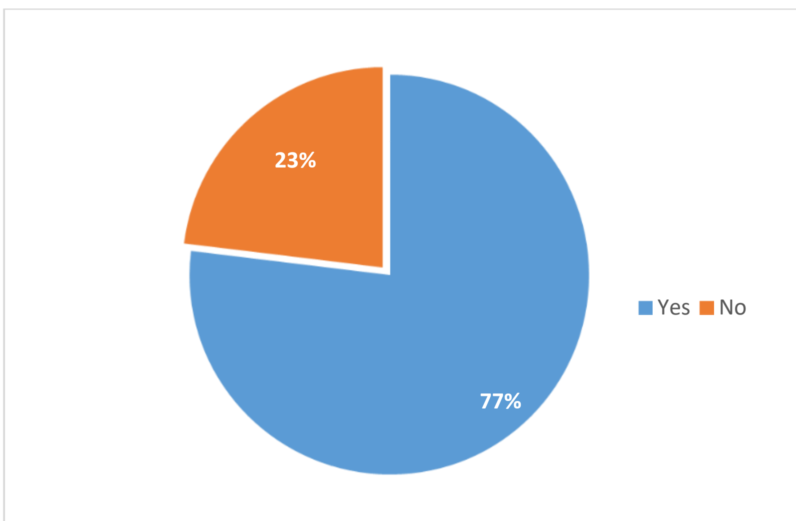
Figure 17: Awareness of Digital Tools



However, awareness of machine learning (ML) is comparatively lower, with only 8 participants indicating familiarity, suggesting that while ML is integral to advanced agricultural analytics, it may require further dissemination and education to enhance its recognition and adoption among farmers. These findings highlight the varying degrees of awareness and the need for targeted informational campaigns to promote comprehensive understanding and utilization of diverse digital tools in agriculture.

Cost Savings

Figure 18: Cost Savings due to Digital Technology Intervention

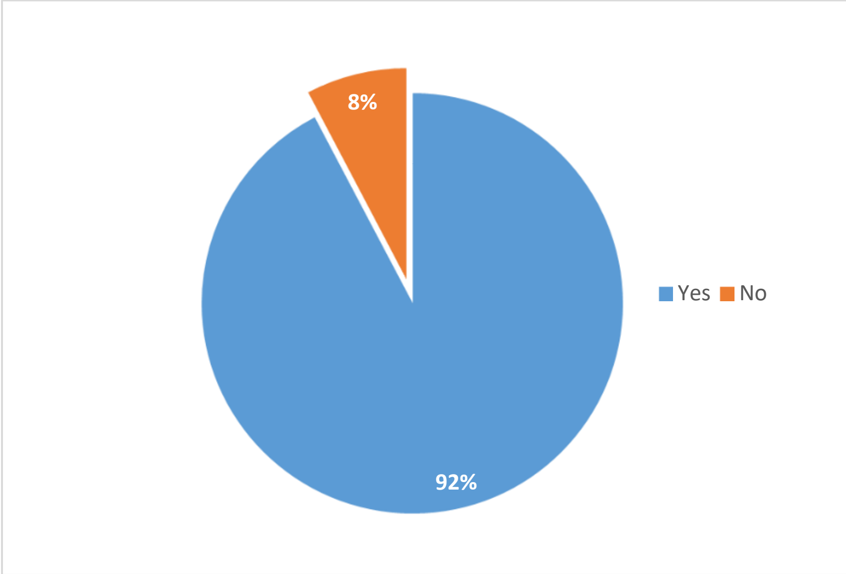


The application of digital tools in agriculture has yielded notable cost savings among adopters, as evidenced by the reported experiences of participants in this study. Out of the total respondents, 10 individuals affirmed experiencing cost savings due to the implementation of digital technologies, highlighting the tangible financial benefits associated with their adoption. These savings are indicative of efficiencies achieved through enhanced precision in resource management, streamlined operational processes, and reduced dependency on labor-intensive tasks.

Such outcomes are consistent with the broader literature on digital agriculture, which underscores the potential for technology to optimize input utilization, mitigate operational expenditures, and ultimately improve farm profitability. Conversely, 3 participants reported no observed cost savings, underscoring potential variability in outcomes based on factors such as technology selection, implementation strategies, and the specific contextual realities of individual farming operations. This dichotomy underscores the importance of tailored approaches to technology adoption and ongoing evaluation of its economic impacts to maximize benefits and address potential challenges in integrating digital tools within agricultural practices.

Impact on Decision Making

Figure 19: Improved Decision Making

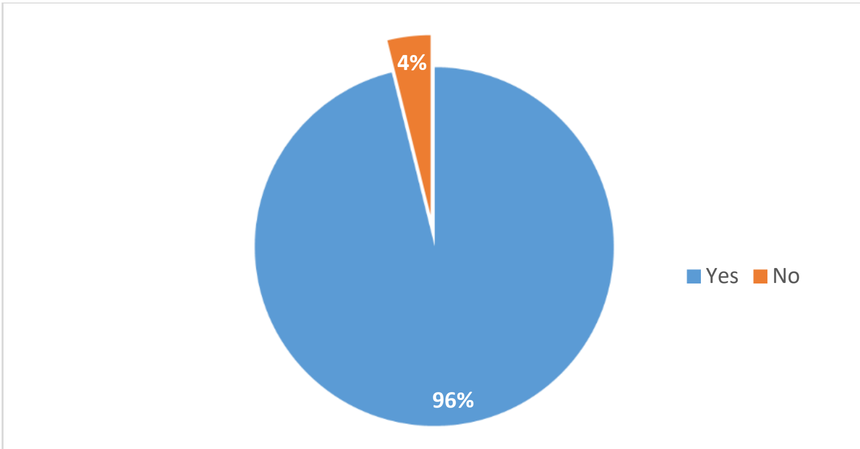


Adopters of digital tools in agriculture reported notable enhancements in decision-making processes, as indicated by the majority of participants. Among those surveyed, 12 individuals affirmed experiencing improved decision making following the application of digital tools. This positive response underscores the perceived benefits derived from technologies such as artificial intelligence, machine learning, and data analytics, which facilitate informed and timely decisions based on comprehensive data analysis. Such advancements are pivotal in optimizing resource allocation, mitigating risks associated with weather variability, and enhancing operational efficiencies throughout agricultural production cycles. Conversely, only one participant reported no discernible improvement in decision making, suggesting a marginal minority that may require further exploration regarding the specific challenges or limitations encountered in effectively integrating digital technologies into decision-making frameworks. Overall, these findings underscore the transformative potential of digital tools in fostering informed decision making among adopters in agricultural contexts, thereby contributing to overall productivity and sustainability within the sector.

Barriers to Adoption of Digital Tools

Investment Issues

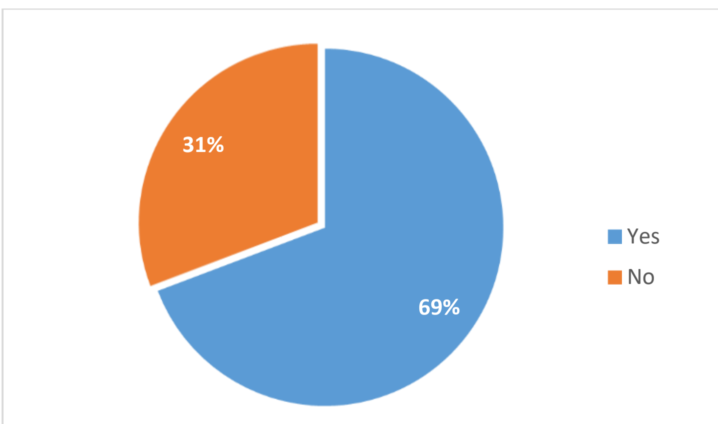
Figure 20: Financial Constraints



The study on barriers to adoption of digital tools in agriculture reveals significant financial constraints among participants, with 25 individuals acknowledging this obstacle compared to only one reporting no financial hindrance. This disparity underscores a critical challenge where the upfront cost of acquiring and implementing digital technologies pose a substantial barrier to adoption. For instance, farmers often face high initial investments in hardware such as sensors or drones, along with ongoing costs related to software updates and maintenance. These financial burdens can deter adoption despite potential long-term benefits, such as improved crop monitoring and yield optimization, as seen in cases where small-scale farmers struggle to afford precision farming technologies that could enhance their productivity and profitability. Addressing these financial constraints through subsidies, financing options, or collaborative efforts with technology providers is crucial to fostering wider adoption of digital tools in agriculture.

Infrastructure Issues

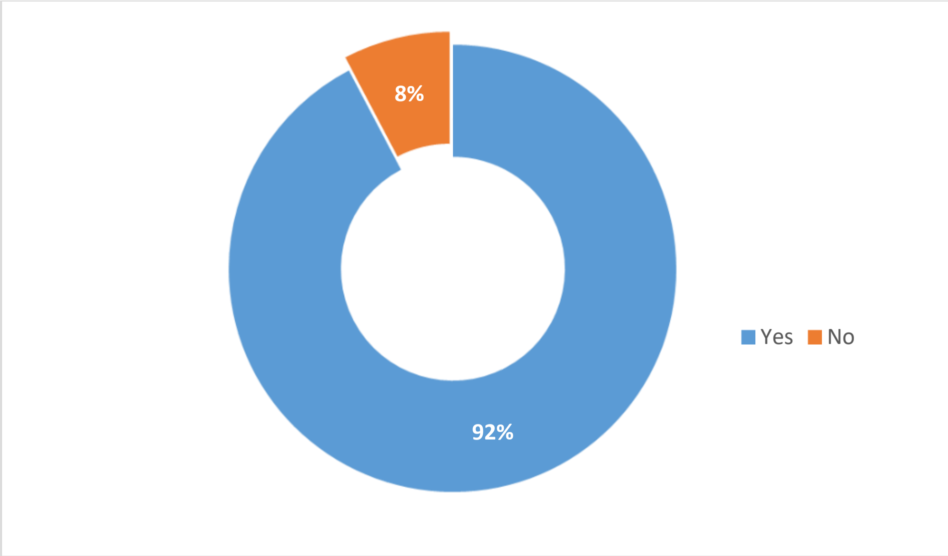
Figure 21: Common Infrastructure Issues



The study on common infrastructure issues affecting the use of digital tools in agriculture reveals a significant disparity, with 18 participants indicating challenges such as poor connectivity and lack of electricity, while 8 reported no such issues. Poor connectivity poses a substantial hindrance in rural areas where reliable internet access is limited, impacting the effectiveness of digital tools for real-time data transmission and remote monitoring. For instance, farmers relying on IoT devices for soil moisture monitoring may face delays in receiving critical data updates, potentially affecting irrigation scheduling and crop yield. Similarly, the lack of electricity infrastructure limits the deployment of digital technologies that require continuous power supply, such as automated irrigation systems or climate control sensors in greenhouses. These challenges underscore the critical need for infrastructural improvements to support broader adoption and effective utilization of digital tools in agricultural practices.

Digital Literacy and Technical Skills Gap

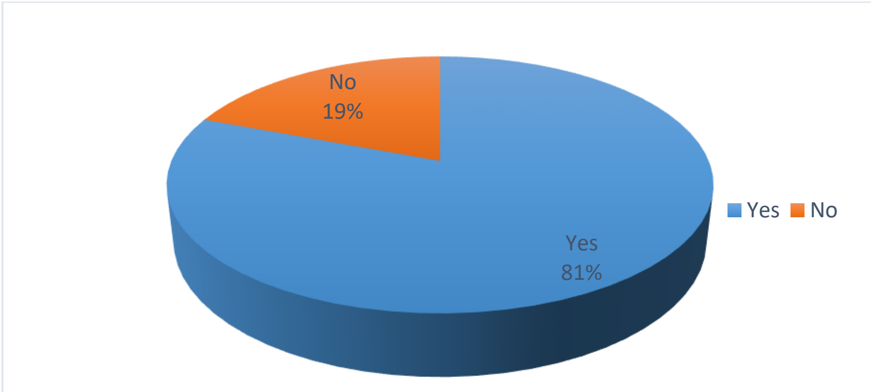
Figure 22: Digital Literacy and Technical Skills Gap



The study on digital literacy and technical skills in the use of agricultural digital tools reveals a notable gap among participants, with 24 respondents acknowledging a lack of digital literacy and technical skills ("Yes" category) necessary for effectively utilizing these tools. In contrast, only 2 respondents reported possessing adequate skills ("No" category). This disparity underscores a prevalent challenge in agricultural sectors where the adoption of digital technologies requires specific competencies for maximizing benefits such as operational efficiency, data-driven decision-making, and sustainable practices. Addressing this gap through targeted training and educational initiatives is crucial to empower farmers with the necessary skills to harness the full potential of digital tools in modern agriculture.

Socio-Cultural Resistance

Figure 23: Cultural and Social Resistance



The findings regarding cultural or social resistance to the adoption of technology among the 26 participants reflect a predominant trend towards resistance, with 21 participants (80.8%) indicating some form of reluctance or barriers associated with cultural or social factors. This resistance manifests in various forms such as traditional farming practices deeply rooted in familial customs or community norms that emphasize manual labor and interpersonal communication over technological integration.

The prevalence of cultural or social resistance suggests that these participants may face challenges in reconciling the perceived benefits of technology with existing socio-cultural values and practices within their farming communities. Factors contributing to resistance could include concerns over the displacement of traditional knowledge and skills, skepticism towards unfamiliar technologies, and a preference for maintaining established social structures within agricultural practices.

Conversely, 5 participants (19.2%) reported no significant cultural or social resistance to technology adoption. These individuals may represent a minority who are more receptive to technological advancements or operate within socio-cultural contexts that are more open to change and innovation in agricultural practices. Their experiences may highlight instances where cultural adaptation or alignment with technological advancements has been successfully achieved, potentially through community education, support networks, or gradual integration processes that mitigate resistance.

In conclusion, the prevalence of cultural or social resistance underscores the importance of understanding and addressing socio-cultural factors in the adoption of agricultural technology. Strategies aimed at promoting technology adoption should consider cultural sensitivities, community dynamics, and the preservation of traditional knowledge while emphasizing the potential benefits and relevance of technology in enhancing agricultural productivity and sustainability.

5. *Policy Recommendations*

This report aims to study the usage of digital tools in agriculture which is influenced by a myriad of factors. Awareness and exposure play crucial roles in fostering adoption, with benefits including increased efficiency and productivity. However, barriers such as limited awareness, inadequate training, and infrastructural gaps hinder widespread adoption. Government and policymakers can drive change through targeted policies, regulations, and incentives that promote awareness, provide training, and develop robust infrastructure. Effective implementation of these measures can accelerate the integration of digital technologies, benefiting farmers and enhancing agricultural productivity sustainably.

Additional Factors influencing usage of Digital Tools in Agriculture

Awareness and Exposure

The analysis of awareness and exposure among farmers reveals that there is a high level of awareness regarding digital tools, particularly those such as mobile applications designed for market prices, weather forecasting, and crop management. The primary sources of this information include local agricultural extension services, interactions with fellow farmers, digital platforms, and local non-governmental organizations (NGOs). Furthermore, farmers frequently encounter information about these digital tools through participation in farmer groups, attending training sessions, and exposure via various media channels. This consistent and multifaceted exposure contributes significantly to their understanding and potential adoption of digital technologies in agriculture.

Adoption of Digital Technology

The adoption of digital technology in agriculture involves utilization of a variety of digital tools, prominently including mobile applications for weather updates, market pricing, pest management, and access to online marketplaces. These tools serve multiple purposes, such as facilitating market access, providing real-time weather forecasts, enabling precision farming, managing pest and disease threats, and conducting financial transactions. The frequency and duration of usage indicate that many farmers integrate these tools into their daily or weekly routines, thereby actively incorporating them into their farm management practices. This consistent use underscores the integral role of digital technology in modern agricultural operations, enhancing efficiency and decision-making.

Benefits of Adoption

The perceived benefits of adopting digital technologies in agriculture are multifaceted, significantly impacting various aspects of farm operations. Farmers have reported substantial improvements in productivity, noting considerable increases in crop yields and enhanced efficiency in managing their farms. Additionally, there has been a marked reduction in input costs, coupled with more effective resource management, leading to overall cost savings.

Market access has also seen notable improvements, as farmers are now able to reach broader markets and obtain better prices for their produce. Furthermore, the decision-making process has been greatly enhanced, with timely and accurate information allowing for more informed and effective decisions in farm management. These benefits collectively illustrate the profound positive impact of technology adoption on agricultural practices.

Barriers to Adoption

The barriers to the adoption of digital technologies in agriculture are multifaceted and significant. One primary concern is financial constraints, as the initial investment required for digital tools and services poses a challenge for many farmers, even though these technologies can lead to cost savings in the long run. Infrastructure issues also hinder adoption, with farmers facing problems such as unreliable internet connectivity and occasional electricity shortages, which are critical for the consistent operation of digital tools. Additionally, there is a notable skill gap; while farmers may possess basic digital literacy, the effective use of advanced tools like artificial intelligence requires more specialized knowledge and training. Cultural and social barriers further complicate the adoption process, as traditional farming practices and scepticism about the effectiveness of new technologies lead to resistance among some farmers. Lastly, trust issues arise from concerns about data privacy and the reliability of digital tools, making farmers hesitant to fully embrace these innovations. These barriers collectively highlight the complexity of integrating digital technologies into agricultural practices and the need for targeted interventions to address these challenges.

Reasons for non-adoption

The reasons for non-adoption of advanced agricultural technologies among some farmers are multifaceted. A significant factor is the lack of awareness, as many farmers possess limited knowledge about the existence and benefits of advanced digital tools and AI applications. Additionally, the perceived complexity of these technologies discourages their use, as they seem too intricate and daunting for practical implementation. Some farmers express contentment with their traditional methods, believing these established practices to be sufficient for their needs. Economic constraints also play a crucial role, with the high costs associated with adopting new technologies acting as a significant barrier. Furthermore, inadequate infrastructure, particularly issues related to unreliable internet and electricity supply in certain regions, hampers the ability to integrate these technological advancements into their agricultural practices.

Policy Recommendations

Awareness and Training through Extension Officers or Public Private Partnership Models

Effective training methods in agricultural technology should encompass a variety of approaches to ensure comprehensive understanding and practical application. Government through extension officers or private training centres can provide or facilitate the farmers hands-on workshops with direct experience and the opportunity to engage with new tools in a controlled environment. Field demonstrations offer real-world scenarios where farmers can observe the benefits and functionality of digital technologies in practice, facilitating better comprehension and retention of information. Additionally, mobile-based training modules cater to the need for flexible learning, allowing farmers to access instructional content at their convenience and pace.

The training content should be meticulously designed to address several critical areas. Firstly, it must cover the basics of digital literacy to ensure that participants are comfortable with the foundational aspects of technology. Secondly, specific training on the use of various digital tools should be included, providing detailed guidance on their operation and maintenance. Lastly, advanced applications of artificial intelligence (AI) in farming should be highlighted, illustrating how these technologies can optimize agricultural practices through predictive analytics, automated processes, and enhanced decision-making capabilities. By focusing on these key areas, training programs can significantly enhance the technological proficiency of farmers, leading to improved productivity and sustainability in agriculture.

Infrastructure Development

Enhancing connectivity in rural regions is crucial for fostering technological adoption and improving agricultural productivity. This can be achieved through targeted infrastructure projects aimed at upgrading internet and mobile network services. Collaborations with telecommunications providers are essential to extend coverage and ensure robust, high-speed connectivity that supports modern agricultural practices and access to digital tools.

Equally important is addressing energy reliability in these areas. Ensuring a consistent and dependable electricity supply is fundamental for operating advanced agricultural technologies. Emphasizing renewable energy sources, particularly solar power, can provide sustainable and reliable energy solutions, especially in regions where the electricity supply is inconsistent. Implementing solar power systems not only supports continuous technological use but also promotes environmental sustainability, aligning with broader goals of reducing carbon footprints and enhancing resilience in rural communities.

Support and Incentives

To facilitate the adoption of digital technologies in agriculture, there is a critical need for targeted support and incentives. One of the primary areas of support is financial assistance.

Farmers often face significant initial costs when integrating digital tools into their operations. To mitigate this financial burden, it is essential to provide subsidies or low-interest loans. These financial aids can significantly reduce the upfront expenses, making it more feasible for farmers to invest in new technologies that can enhance productivity and efficiency.

In addition to financial assistance, there is a pressing need for robust technical support. Establishing local support centers and helplines dedicated to offering ongoing technical assistance and troubleshooting can address this need effectively. Such support infrastructures would ensure that farmers have continuous access to expert advice and technical solutions, thereby reducing the barriers to effective technology utilization. This combination of financial and technical support can play a crucial role in promoting the widespread adoption of digital tools in agriculture, ultimately leading to improved agricultural practices and outcomes.

Policy and Regulation

Addressing data privacy concerns is paramount in fostering trust among farmers, necessitating the implementation of robust data protection policies. By ensuring the confidentiality and security of farmers' data, stakeholders can mitigate fears of data misuse and build a foundation of trust essential for the widespread adoption of digital technologies. Additionally, enhancing market access through the development and promotion of e-market platforms can significantly improve farmers' ability to reach broader markets and secure fair pricing for their products. These digital marketplaces not only expand the potential customer base but also provide transparency and competitive pricing, which are crucial for equitable trade practices. Moreover, the regulation of digital service providers is essential to safeguard farmers from exploitation and ensure ethical conduct within the digital agriculture ecosystem. By establishing and enforcing fair practice standards, regulators can prevent unfair practices and promote a balanced and just environment for all stakeholders involved in the agricultural sector.

Additional Observations

Study reveals pertinent insights into the adoption of digital technologies in agriculture. Participants demonstrated a keen interest in acquiring knowledge about new technologies, reflecting a positive attitude towards innovation. However, they emphasized the critical importance of ongoing and dependable support systems to effectively integrate these technologies into their farming practices. This highlights a significant barrier wherein the initial enthusiasm for technological adoption is contingent upon sustained assistance and guidance to navigate complexities and ensure practical application in real-world agricultural settings. Moreover, the local environmental context emerged as a crucial determinant influencing the adoption and efficacy of digital tools among participants. Factors such as water availability, soil conditions, and climatic variations were identified as pivotal considerations shaping the feasibility and impact of technology deployment in agriculture. Participants recognized that digital solutions must be adaptable to local environmental conditions to optimize resource management, mitigate risks associated with environmental variability, and maximize agricultural productivity sustainably.

These findings underscore the multifaceted nature of technology adoption in agriculture, where behavioural insights and environmental considerations play integral roles in shaping the outcomes and success of technological integration. Addressing these insights necessitates tailored approaches that combine technological innovation with robust support mechanisms and adaptive strategies aligned with local environmental dynamics. Such approaches are essential to fostering resilient agricultural systems capable of harnessing the full potential of digital advancements while addressing the unique challenges posed by diverse environmental contexts.

To windup, the adoption of digital technologies in agriculture presents a transformative opportunity for small villages like Hiware Bazaar. These technologies, including AI, ML, and IoT, have the potential to significantly enhance agricultural productivity, optimize resource use, and promote environmental sustainability. Despite the promising benefits, several challenges hinder their widespread adoption, such as limited digital literacy, high initial costs, and socio-cultural resistance among farmers. Addressing these challenges requires a multifaceted approach. Government policy interventions and regulatory support are crucial to create an enabling environment for technology adoption. Additionally, product and service provisioning companies, along with startups, must play an active role in providing tailored solutions and fostering awareness among farmers. Educational institutions should update their curricula to include relevant technological training and support research and development initiatives. Collaborative efforts, may be in PPP mode involving each stakeholder can create a supportive ecosystem that facilitates the integration of digital technologies into agricultural practices. This will not only enhance agricultural productivity and sustainability but also contribute to reducing rural poverty by providing farmers with the tools and knowledge needed to improve their livelihoods. A successful adoption of digital technologies in agriculture requires a holistic approach that combines policy support, private sector innovation, and community engagement. By addressing the specific needs and challenges of small villages like Hiware Bazaar, it is possible that these communities can leverage technological advancements to achieve higher productivity, and economic resilience and contribute to food security.

6. Declarations

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