Czech University of Life Sciences Prague

Faculty of Economics and Management

Department of Business Administration

Bachelor Thesis

Impact of New Technology & Modernization of the Agriculture Sector in Northern India on the Economy of the Region

Deepti

CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Economics and Management

BACHELOR THESIS ASSIGNMENT

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Business Administration

Thesis title

Impact of new technology and modernization of the agriculture sector in northern India on the economy of the region.

Objectives of thesis

The purpose of this thesis is to study the impact of new technology and modernization of the North Indian agricultural sector on the regional economy. Several specific goals have been identified to achieve this goal.
First, the study assesses the impact of modernization on agricultural productivity and income. This includes an analysis of how modernization has improved the efficiency and profitability of local farmers. In addition, this study assesses the impact of modernization on infrastructure development, employment, and crop diversification. By examining the extent to which modernization has brought improvements in these areas, this study provides a comprehensive understanding of the broader impact of modernization on the region's economy.

Methodology

The methodology includes a review of the literature from the Web of Science sources, a collection of data from the National Country Strategy Plan (focus on North India), from the local authorities institutions, research institutions, and data from the FAO and WB sources.

Reviewing academic publications is part of the literature review process in order to create a theoretical framework.

A questionnaire is made to gather first-hand information and answer research questions. With the aid of this thorough methodology, the research topic can be thoroughly investigated, allowing a good comprehensive understanding of the topic.

Part of the deliverables of the thesis will be a SWOT analysis that assesses the research topic's strengths, weaknesses, opportunities, and threats with an impact on the economy of the region.

The proposed extent of the thesis

40 -60 pages

Keywords

economy, agriculture, agro and environemtal engineering, India

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Recommended information sources

FAO (2017) The future of food and agriculture – Trends and challenges, ISBN 978-92-5-109551-5 (book)
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Pawan Kumar, Sehgal Foundation, India (2023), IMPORTANCE of MODERN TECHNOLOGY IN AGRICULTURE IN INDIA (scientific article)

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The Bachelor Thesis Supervisor

doc. Ing. Vladimír Krepl, CSc.

Supervising department

Department of Economics

Electronic approval: 7. 11. 2023

prof. Ing. Lukáš Čechura, Ph.D.

Head of department

Electronic approval: 27. 11. 2023

doc. Ing. Tomáš Šubrt, Ph.D.

Dean

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Declaration

I have worked on my bachelor thesis titled "Impact of New Technology and Modernization of the Agriculture Sector in Northern India on the Economy of the Region" by myself. I have used only the sources mentioned at the end of the thesis. As the author of the bachelor thesis, I declare that the thesis does not break any copyrights.

In Prague on 15.03.2024 _____

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Impact of New Technology & Modernization of the Agriculture Sector in Northern India on the Economy of the Region

Abstract

This research explores the adoption and modernization of technology in the agriculture sector, focusing on the regions of Punjab and Haryana in Northern India. The study aims to understand the impact of new technology and modernization, including production efficiency, operational efficiency, infrastructure development, and socioeconomic factors. The study uses a descriptive research design and a sample of 194 local micro-farms in Punjab and Haryana. The findings reveal that technological integration in farming practices varies, with many farmers using digital tools in their daily operations. The impact of agricultural technologies is influenced by household income, farm size, farming experience, education level, production, operational efficiencies, and infrastructure development. The recommendations include bolstering government research and development efforts to introduce modern technologies tailored to the agricultural context, fostering collaborative initiatives among farmers, and pooling resources to enhance their capacity for adopting and integrating new agricultural technologies effectively. By understanding the complex interplay between technology, socioeconomic factors, and agricultural outcomes, this research contributes to a deeper understanding of the opportunities and challenges inherent in modernizing the agricultural sector in Northern India. Through informed policy interventions and grassroots initiatives, the region can harness the transformative potential of technology to ensure sustainable agricultural development and enhance rural livelihoods.

Keywords: Agriculture, Technology, Modernization, Northern India, Production Efficiency, Operational Efficiency, Infrastructure Development, Socioeconomic Factors

Dopad nových technologií a modernizace zemědělského sektoru v severní Indii na ekonomiku regionu

Abstrakt

Tento výzkum zkoumá přijetí a modernizaci technologií v zemědělském sektoru se zaměřením na regiony Paňdžáb a Harijána v severní Indii. Cílem studie je porozumět dopadu nových technologií a modernizace, včetně efektivity výroby, provozní efektivity, rozvoje infrastruktury a socioekonomických faktorů. Studie využívá deskriptivní výzkumný design a vzorek 194 místních mikrofarem v Paňdžábu a Haryaně. Zjištění ukazují, že technologická integrace v zemědělských postupech se liší, přičemž mnoho zemědělců používá digitální nástroje ve svých každodenních operacích. Dopad zemědělských technologií je ovlivněn příjmem domácností, velikostí farmy, zemědělskými zkušenostmi, úrovní vzdělání, produkcí, provozní efektivitou a rozvojem infrastruktury. Doporučení zahrnují posílení vládního výzkumného a vývojového úsilí o zavedení moderních technologií přizpůsobených zemědělskému kontextu, podporu společných iniciativ mezi zemědělci a sdružování zdrojů pro zvýšení jejich kapacity pro efektivní přijímání a integraci nových zemědělských technologií. Tím, že tento výzkum porozumí složité souhře mezi technologií, socioekonomickými faktory a zemědělskými výsledky, přispívá k hlubšímu pochopení příležitostí a výzev spojených s modernizací zemědělského sektoru v severní Indii. Prostřednictvím informovaných politických intervencí a místních iniciativ může region využít transformační potenciál technologií k zajištění udržitelného zemědělského rozvoje a zlepšení obživy venkova.

Klíčová slova: Zemědělství, Technologie, Modernizace, Severní Indie, Efektivita výroby, Provozní efektivita, Rozvoj infrastruktury, Socioekonomické faktory

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List of Abbreviations

AgTech - Agricultural Technology

AIF - Agriculture Infrastructure Fund

APMC - Agricultural Produce Market Committee

FAO - Food and Agriculture Organization of the United Nations

FPO - Farmer-Producer Organizations

GDP - Gross Domestic Product

GMO - Genetically Modified Organisms

GPS - Global Positioning System

HYV - High-Yielding Varieties

ICAR - Indian Council of Agricultural Research

ICT - Information Communication Technology

KVK - Krishi Vigyan Kendras

NAP - National Agricultural Policy

NMSA - National Mission for Sustainable Agriculture

PM-KISAN - Pradhan Mantri Kisan Samman Nidhi

R&D - Research and Development

UAV - Crewless Aerial Vehicles

WB - World Bank

1. Introduction

The agricultural sector is crucial for global economies, providing food to the population. The Green Revolution in Asia improved agricultural yields and food security. Israel is the world's leading country in the agriculture technology sector, with over 500 companies providing advanced data imaging, collection, and analysis techniques. Agriculture is responsible for 90% of the food consumed in Asian countries, with local Indian farmers playing a significant economic role. (Norton et al., 2021)

However, low productivity levels have hindered its development, necessitating the incorporation of technology into farming systems. In India, agriculture is the central pillar of the economy, contributing over 20 percent to GDP and over 50% of exports. Approximately 70% of the population is involved in agriculture, making it the largest employer. The government highly regards the sector as it promotes national development. Increasing agricultural productivity is essential for achieving Vision 2030 and universal living standards. (Pawlak & Kołodziejczak, 2020)

New agricultural technology can be developed and disseminated to farmers to improve their yields. Technology-based farming applications have helped reduce information gaps farmers face, such as market price and condition variations, new farming technologies, weather patterns, and knowledge of where to buy farm inputs. By providing necessary information, technology can increase farm yields in irrigated food production areas. Punjab and Haryana, with fertile soil and good farming conditions, are at the forefront of agriculture in the country. (Mapiye et al., 2023)

Technology is a body of knowledge that creates methods, tools, and systems for human application in various industries. Agricultural technology (AgTech) plays a central role in food matters, focusing on machinery and systems that increase efficiency during farming. There are multiple agricultural technologies: mechanical, biotechnology, nanotechnology, biological and biochemical, and indigenous technology. The digitalization of agricultural systems has increased resource management, individualization, optimization, and intelligence impact. (Gao et al., 2020)

This data-driven system allows for accurate management of different fields, crops, and animals, leading to more reliable food security, profitability, and sustainability. Agricultural technologies have been crucial in shaping agriculture in the past and present times. Information communication technology (ICT) has been identified as one of the most impactful solutions to issues within the agricultural industry, such as weak market links, poor information management, low production levels, low income, and low levels of diversity. (Ojo et al., 2020)

In countries like China, India, and Vietnam, 80% of farmers use mobile phones to connect with traders to estimate market demand and selling prices. Socioeconomic factors, institutional impassiveness, access to credit, infrastructure development, and expected benefits are critical predictors of the impact of modern agricultural technologies. Access to digital technology in rural and underdeveloped areas provides links between suppliers, farmers, and businesses, enabling users to access talent, strategic partnerships, training facilities, legal services, and financial assistance. (Murali & Prathap, 2020)

The study aimed to identify the impact of new technology and modernization on farmers in Punjab and Haryana. The research focused on production efficiency, operational efficiency, infrastructure development, socioeconomic factors, and the impact of these technologies on local farmers. Production efficiency refers to the ability of organizations to combine resources and renew core competencies over time. Low impact rates of technologies have been positively linked to poor access to credit and loan facilities by farmers, as they often need more financial resources to meet the high initial start-up cost.

This measure is essential to understand the availability and efficiency of necessary resources to aid technology impact. Operational efficiency refers to firms' expertise, management capacities, and processes to plan and implement programs and activities to achieve superior performance. The absence of essential Operational skills and Efficiency may hinder technological impact. The study sought to determine if operational efficiency affects the effects of technology.

Infrastructure development is organized systems facilitating farmers, other organizations, and those marketing agricultural products to access agricultural knowledge and information about the market and farming skills. In recent years, agricultural infrastructure development has shifted from production-oriented to market-oriented approaches. Socioeconomic factors include an individual's social standing or class measured by indicators such as education, income, occupation, or a combination.

1.1 Research Problem

India, a regional innovation hub, has seen a significant increase in digitalization, but the impact of technology in the agriculture sector has not been as substantial as in other sectors. The low technological impact of local farmers has hindered higher agricultural productivity. Integrating new technologies can disrupt the value chain, leading to efficiency, market-driven innovation, enterprise development, new farming techniques, and climate-smart seeds. However, this has yet to be achieved in India's local farms, which continue to have low productivity and technology impact. Factors such as lack of resources, poor Operational skills, government policy, infrastructure development, and personnel competencies also affect the impact of agricultural technologies. Despite the dissemination of technologies, their impact at individual farm levels remains low, and productivity still needs to improve. The current study aims to expand on existing empirical evidence by analyzing the impact of new technology and modernization among selected local farmers in Punjab and Haryana, India.

1.2 Research Significance

The agricultural sector is crucial for economic growth and development. The study's results will help policymakers and field extension experts design new policies for modernization. It will also support innovations and digital solutions in the agriculture sector. The findings will benefit agricultural dealership firms and research centers, helping them integrate technological solutions into their services. The findings will also help bridge knowledge gaps and create reference material for future research. Overall, the study's findings will be valuable for various stakeholders in the agricultural sector.

1.3 Research Scope

The research focused on the agriculture sector in Punjab and Haryana, examining how internal and external factors like production efficiency, Operational Efficiency, infrastructure development, and socioeconomic factors are impacted by technology and modernization among local farmers. The study used a quantitative approach with a structured research questionnaire, analyzing local farmers within the study area, and aimed to understand the theoretical and practical aspects of technology, organization, and ecological theory.

2. Objectives and Methodology

2.1 Research Objectives

This thesis aims to study the impact of new technology and modernization of the North Indian agricultural sector on the regional economy. Several specific goals have been identified to achieve this goal. First, the study assesses the impact of modernization on agricultural productivity, such as production efficiency, operational efficiency, infrastructure development, and socioeconomic factors, such as income. This includes an analysis of how modernization has improved the efficiency and profitability of local farmers. By examining the extent to which modernization has brought improvements in these areas, this study provides a comprehensive understanding of the broader impact of modernization on the region's economy.

2.2 Research Methodology

The research study aimed to analyze the impact of new technology and modernization on local farmers in India. The study adopted a positivist approach based on shared assumptions and values. The methodology includes a review of the literature from Web of Science sources, collecting data from the National Country Strategy Plan (focus on North India), local authority and research institutions, and FAO and WB sources. Reviewing academic publications is part of the literature review process to create a theoretical framework. The target population was registered local farmers in Punjab and Haryana. Data collection was conducted using structured questionnaires based on the Likert scales, where the author visited the farmers personally to collect the data. The study sought ethical clearance from the institute, and the author recorded the data in forms based on the conversation with the farmers in the native local language. The sample size for the research was determined to be 200 farmers from Punjab and Haryana, but finally, 194 responses were considered for further steps. Data analysis involved descriptive and hypothesis statistics, and the study tested for linear regression analysis. The participation was voluntary, and farmers were made aware of the broad research topic during the conversation with the author. This thorough methodology allows the research topic to be thoroughly investigated, allowing an excellent comprehensive understanding.

3. Literature Review

3.1 Trends in Agricultural Technology & Modernization

3.1.1 Technology Advancements

Technological advancements are driving a significant transformation in the agricultural sector. The worldwide patterns in agricultural technology and advancement, explicitly focusing on precision agriculture, drone technology, and biotechnology, can be seen as the most effective. The advancements could transform agricultural practices by enhancing efficiency, productivity, and sustainability. (Hrustek, 2020)

Precision agriculture utilizes advanced technologies to maximize crop yields and minimize inputs like water, fertilizer, and pesticides. Precision agriculture is advancing by combining sensors, GPS technology, and data analytics to oversee and control field differences. It allows farmers to use data to make decisions about planting, irrigation, and fertilization, resulting in better resource distribution and increased yields.

The global expansion of precision agriculture techniques is driven by the need to increase productivity with limited resources and the affordability of precision agriculture technologies. Artificial intelligence and machine learning advancements improve precision agriculture systems by allowing real-time data analysis and predictive modeling for better decision-making. (Lockie et al., 2020)

Drones (crewless aerial vehicles (UAVs) have become valuable assets in contemporary agriculture. These uncrewed aerial vehicles, outfitted with cameras and sensors, provide farmers with an aerial perspective of their fields, facilitating quick and thorough data gathering. Specialized agricultural drones are a significant trend in drone technology, designed for crop monitoring, aerial spraying, and crop mapping.

Drones in agriculture are transforming conventional methods by offering farmers practical information on crop health, nutrient deficiencies, and pest infestations. Advancements in drone technology, including better battery life, increased payload capacity, and improved imaging Efficiency, are increasing their use in the agricultural industry. Regulatory obstacles and privacy and data security concerns continue to impede the widespread use of drones in agriculture. (Alam et al., 2023)

Biotechnology is crucial in modernizing agriculture through genetic engineering and bioprocessing to enhance crop traits, boost resistance to pests and diseases, and improve nutritional content. Genetically modified organisms (GMOs) have sparked significant debate but are still widely used in many regions, especially in large-scale commodity crops like corn, soybeans, and cotton.

Current biotechnology trends involve creating genetically edited crops through CRISPR-Cas9, allowing for accurate and specific changes to plant genomes without adding foreign DNA. These advancements show potential in tackling worldwide issues like climate change, food security, and malnutrition by developing crops with enhanced resilience, increased yields, and improved nutritional value. (Birner et al., 2021)

3.1.2 Socio-economic Factors

Agricultural technological advancements have boosted global productivity and efficiency. Farmers can increase productivity while minimizing labor and resources through mechanization, precision farming methods, and biotechnological advancements. This has helped ensure food security by meeting the needs of an expanding population. Modern agricultural practices have helped smallholder farmers join global value chains, giving them access to markets and economic development opportunities. (Hemathilake et al., 2022)

Sustainable agricultural practices like conservation agriculture and agroecology have reduced environmental degradation and increased climate change resilience. These practices protect natural resources and improve agricultural systems, securing livelihoods. However, agricultural modernization often leads to inequalities in benefits distribution, particularly for small-scale farmers in developing nations. Addressing these disparities is crucial for global agricultural growth and sustainable development. Large commercial farms benefit from technological progress, but small-scale farmers often need help to obtain and pay for resources.

India offers a distinctive opportunity to study how technological progress affects farming communities due to its extensive agricultural terrain and varied socio-economic conditions. The Green Revolution in the 1960s and 1970s was pivotal in Indian agriculture, bringing in high-yield crop varieties, irrigation systems, and chemical fertilizers. Although these interventions initially resulted in significant agricultural productivity and food production improvements, they created various socio-economic challenges. (Krupnik et al., 2021)

The Green Revolution led to a significant disparity between large-scale and smallholder farmers. Wealthier landowners with resources benefited more from adopting modern agricultural practices, leading to increased inequalities in rural areas. Excessive utilization of chemical fertilizers and pesticides has led to environmental deterioration, soil degradation, and water contamination, which present enduring threats to agricultural sustainability. (Hamdan et al., 2022)

Recent agricultural technological advancements provide opportunities to tackle these challenges and promote inclusive growth in Indian agriculture. Efforts like digital farming, precision agriculture, and the advocacy of organic farming methods are becoming more popular for enhancing resource efficiency, cutting input costs, and improving market access for small-scale farmers. Government initiatives such as Pradhan Mantri Kisan Samman Nidhi (PM-KISAN) and the National Mission for Sustainable Agriculture (NMSA) aim to empower farmers by providing financial support and capacity-building programs. (Khan et al., 2021)

3.1.3 Policy Frameworks

Policymakers in different countries have created diverse policy frameworks and support systems to aid agricultural modernization. In India, a nation with a substantial agricultural industry, policymakers have enacted various strategies to tackle the issues and possibilities in agricultural modernization. The mechanisms incentivize farmers to embrace contemporary technologies like machinery, fertilizers, and irrigation systems. Subsidies for inputs, equipment, and infrastructure development are common in agricultural policies globally. (Dev, 2021)

Research and Development (R&D) efforts are essential for advancing agricultural modernization. Governments allocate resources to agricultural research institutions and partnerships with private sectors to create high-yield crop varieties, durable seeds, and cutting-edge farming methods. Global collaborations and partnerships are essential for progressing agricultural research. In India, organizations such as the Indian Council of Agricultural Research (ICAR) and multiple state agricultural universities lead agricultural research efforts.

Infrastructure development is crucial for the efficient operation of agricultural systems. This encompasses transportation systems, storage infrastructure, and connections to markets. Governments invest in infrastructure such as roads, cold storage facilities, and market yards to decrease post-harvest losses and enhance market access for farmers. In India, programs such as the Agriculture Infrastructure Fund (AIF) focus on improving infrastructure in rural regions to facilitate agricultural modernization. (Khatri et al., 2023)

Flexible and adaptive policy frameworks are essential to meet the changing requirements of the agricultural sector. Policymakers frequently implement policy reforms to eliminate obstacles to modernization, simplify regulatory procedures, and improve market efficiency. The reforms may involve alterations in land tenure systems, trade policies, and agricultural extension services. India has undergone substantial policy changes, including enacting the Agricultural Produce Market Committee (APMC) Act reforms and enforcing the National Agricultural Policy (NAP) to advance agricultural modernization and enhance farmer earnings.

Capacity building and extension services, which consist of training programs and services, are crucial for spreading technology and enhancing skills among farmers. Governments, NGOs, and agricultural institutions organize workshops, seminars, and demonstration farms to educate farmers on modern agricultural practices, resource management, and risk mitigation strategies. These initiatives enhance farmers' capacity to integrate new technologies and improve their agricultural methods. In India, programs such as Krishi Vigyan Kendras (KVKs) and farmer-producer organizations (FPOs) offer extension services and capacity-building assistance to farmers nationwide. (Sahoo et al., 2021)

3.2 Historical Perspective of Agriculture in Northern India

Punjab and Haryana, situated in the northwestern part of India, have a long agricultural history that dates back thousands of years. Agriculture has been the foundation of the region's economy and culture since ancient civilizations such as the Indus Valley Civilization. The agricultural revolution in Punjab and Haryana is a complex story characterized by resilience, innovation, and obstacles. The region has experienced significant changes in agricultural practices, technologies, and socio-economic structures from ancient times to the modern Green Revolution. (Gulati et al., 2021)

Punjab and Haryana have agrarian origins dating back to ancient times, with evidence of advanced farming techniques from the Harappan civilization. The fertile plains of the region, nourished by perennial rivers such as the Indus and its tributaries, created an ideal environment for early farming communities to thrive. Throughout history, various groups such as the Aryans, Mauryas, Guptas, and Mughals have influenced the development of agricultural methods and a variety of crops in the area.

Before India gained independence in 1947, Punjab and Haryana were mainly agrarian societies known for subsistence farming and traditional agricultural practices. Villages were self-contained entities, with agriculture serving as the primary foundation of the rural economy. Farmers grew crops, such as wheat, barley, pulses, sugarcane, and cotton, well-suited to the local agro-climatic conditions. The agrarian landscape was influenced by a mutually beneficial relationship among landowners, tenants, and agricultural laborers, with social and economic systems strongly tied to rural customs. (Sharma et al., 2020)

The partition of British India in 1947 had significant consequences for agriculture in Punjab and Haryana. The violent turmoil during the partition caused a large-scale migration of populations across the newly established borders, leading to the displacement of millions of people. The extensive transfer of agricultural land during the turmoil disturbed the agrarian economy. The partition led to communal tensions in rural communities, impacting agricultural practices and social unity. (Sharma, 2021)

3.2.1 Green Revolution

The 1960s marked the beginning of the Green Revolution, a significant agricultural transformation that profoundly affected Punjab and Haryana due to technological advancements. The Green Revolution, led by innovative agronomists like Dr. Norman Borlaug and Dr. M.S. Swaminathan, sought to increase agricultural productivity by using high-yielding seed varieties, chemical fertilizers, pesticides, and advanced irrigation methods. (Prasad & Shivay, 2022)

The Green Revolution in Punjab and Haryana significantly increased crop yields, especially for wheat and rice, which became the primary focus of the region's agricultural economy. Implementing dwarf wheat varieties like Mexican Sonora and high-yielding rice varieties such as IR8 transformed crop production, allowing for multiple cropping cycles and a substantial increase in farm output. Adopting mechanized farming techniques, such as tractors, tube wells, and combine harvesters, significantly improved agricultural productivity and yield.

The Green Revolution resulted in significant socio-economic transformations in Punjab and Haryana. The rapid growth in agricultural productivity led to increased incomes for farmers, better living conditions, and improved food security for the growing population. Small and marginal farmers could enhance their yields and escape poverty by utilizing a high-yielding variety of seeds and modern agricultural inputs. (Dixit et al., 2020)

The advantages of the Green Revolution were unevenly distributed in rural areas. Wealthy landowners and innovative farmers with ample capital and resources received most of the benefits, worsening socio-economic disparities in rural areas. The automation of farming also caused a shift in the agricultural workforce, resulting in migration from rural to urban areas and the rise of agricultural problems in specific regions.

Despite its early achievements, the Green Revolution model encountered substantial challenges, especially regarding sustainability and environmental consequences. Excessive utilization of chemical fertilizers and pesticides has resulted in soil degradation, water contamination, and reduced biodiversity, which present enduring challenges to agricultural sustainability. Excessive dependence on groundwater for irrigation due to the widespread use of tube wells led to aquifers' exhaustion and water scarcity in specific areas. (Gururani, 2020)

The dominance of high-yielding crop varieties, mainly wheat and rice, resulted in ecological imbalances and heightened vulnerability to pests and diseases. Soil erosion, salinization, and nutrient depletion have become urgent issues, requiring a reassessment of agricultural practices and policies to guarantee the sustainability of farming systems in Punjab and Haryana.

The Green Revolution, which began in the 1960s, marked a significant turning point in the agricultural history of Punjab and Haryana. This initiative aimed to enhance agricultural productivity by implementing high-yielding seed varieties, mechanization, and the application of fertilizers and pesticides. New technologies revolutionized Punjab and Haryana, turning them into the primary food-producing regions of India by significantly increasing crop yields and food output. (Tokas et al., 2021)

3.2.2 Recent Initiatives

The development of vast canal networks in Punjab and Haryana during the British colonial period established the basis for irrigated agriculture in the area. The canal systems allowed farmers to grow crops in regions with scarce natural water resources, helping them expand their agricultural activities and grow valuable cash crops. Over time, there has been a slow transition from conventional cereal-focused cropping systems to a broader range of agricultural practices in Punjab and Haryana. (Xing & Tang, 2022)

Government policies promoting diversification and evolving consumer preferences have prompted farmers to consider growing fruits, vegetables, and cash crops in addition to traditional crops such as wheat and rice. After independence, the land reforms in Punjab and Haryana were intended to rectify land ownership and distribution disparities. The redistribution of land to landless farmers and reforms in tenancy were crucial in changing the agrarian system of the area, resulting in higher agricultural productivity.

Modern agricultural technologies such as precision farming, drip irrigation, and crop monitoring systems have transformed farming practices in Punjab and Haryana. These technological advancements have increased productivity and encouraged sustainable farming methods by improving resource efficiency and reducing environmental harm. Farmers have been encouraged to embrace modern agricultural techniques and enhance their quality of life through subsidies on fertilizers, seeds, farm machinery, and crop price support systems. (Jain et al., 2022)

Groundwater depletion is a significant challenge for agriculture in Punjab and Haryana. Excessive use of groundwater for irrigation and ineffective water management has caused a substantial drop in water levels. Consequently, farmers are experiencing water scarcity, especially during crucial crop-growing periods. Relying too much on groundwater has also raised soil salinity, worsening agricultural productivity. (Sidhu et al., 2021)

Intensive farming methods, such as the overuse of chemical fertilizers and pesticides, have caused soil degradation and reduced fertility in Punjab and Haryana. Consistent cultivation of a single crop, mainly wheat and rice, has depleted vital nutrients from the soil, gradually reducing its productivity. Soil erosion, compaction, and depletion of organic matter exacerbate the difficulties in preserving soil health and productivity. (Pal et al., 2022)

Monoculture, specifically the rice-wheat cropping system, is a significant agricultural constraint in Punjab and Haryana. Relying on a limited number of high-yielding varieties has decreased crop diversity, heightened susceptibility to pests and diseases, and environmental harm. The common practice of burning crop residue, particularly after the rice harvest, worsens air pollution and health risks, adding to the difficulties experienced by farmers.

Farmers in Punjab and Haryana frequently encounter market instability and price fluctuations, impacting their income and livelihoods. Insufficient marketing infrastructure and limited access to markets and information make farmers susceptible to exploitation by intermediaries and traders. Furthermore, the global integration of agricultural markets has made it challenging for small-scale farmers to obtain fair crop prices due to heightened competition and price fluctuations. (Bhattarai et al., 2021)

The agriculture sector in Punjab and Haryana has been sluggish in implementing diversification strategies and agricultural innovations that could improve resilience and sustainability. Constraints such as restricted credit access, lack of technical knowledge, and insufficient institutional support hinder farmers from experimenting with different crops and practices suitable for their local agro-climatic conditions. Risk-averse attitudes and cultural norms maintain the current situation, impeding the acceptance of contemporary farming techniques and technologies. (Sahoo et al., 2021)

3.3 Impact of New Technology & Modernization

3.3.1 Production Efficiency

Recently, the implementation of specific technologies in agriculture, like high-yielding varieties (HYVs), precision irrigation, and mechanization, has been a critical focus for improving production efficiency. High-yielding varieties created using advanced breeding techniques have demonstrated considerable potential in enhancing crop yields. These varieties are genetically modified to have beneficial characteristics like disease resistance, drought tolerance, and improved nutrient absorption, resulting in higher productivity per unit of land. (Das et al., 2023)

Precision irrigation methods are becoming more popular because they can efficiently use water and enhance crop productivity. Precision irrigation optimizes resource efficiency by accurately providing plants with water and nutrients according to their needs, reducing water wastage and the likelihood of over-irrigation. This approach can help maintain or increase crop yields. (Dong, 2021)

Mechanization in modern agriculture utilizes machinery and equipment to automate farming tasks. Mechanization simplifies agricultural operations by automating tasks such as plowing, planting, harvesting, and post-harvest processing. It decreases the need for manual labor and allows for quicker and more efficient task completion. This boosts efficiency and eases labor limitations, especially in areas needing more agricultural workers. Multiple studies have confirmed the beneficial effects of these technologies on crop yields and resource utilization efficiency.

Widespread use of High-Yielding Varieties (HYVs) has led to significant increases in crop yields in different crops, which have positively impacted food security and economic development in numerous agricultural economies. Precision irrigation technologies have been proven to enhance water productivity, enabling farmers to achieve increased yields using the same or less water. Moreover, mechanization has resulted in substantial decreases in labor needs per unit of land, allowing human resources to be reallocated to other productive tasks and enhancing overall farm efficiency. (Singh, 2022)

New technologies significantly affect land productivity, labor needs, and production expenses in agriculture. High-yielding varieties increase crop yields, improve land productivity, and optimize the use of arable land. This enhances agricultural productivity and supports the sustainable intensification of farming systems, enabling farmers to increase yields without expanding cultivated land.

Furthermore, implementing mechanization decreases the necessity for manual labor, thus reducing labor demands per unit of land. The move towards mechanized farming methods may impact rural employment patterns, causing changes in the agricultural labor market. This could require skill enhancement and vocational training investments to facilitate a seamless transition for affected workers. (Shaikh et al., 2022)

Although technology adoption can enhance productivity and efficiency, it also involves specific costs, both initial and ongoing. Initial investment costs for equipment, seeds, and irrigation systems can hinder adoption, especially for smallholder farmers with restricted financial means. Furthermore, continuous maintenance and operational costs are part of the total production expenses and require careful management to maintain profitability and sustainability.

Due to access, affordability, and capacity building, new agricultural technologies need help achieving widespread adoption. Smallholder farmers in developing countries, who comprise a large part of the agricultural labor force, frequently need access to necessary resources like credit, extension services, and market information. These resources are crucial for adopting and efficiently using modern technologies.

Furthermore, the cost-effectiveness of cutting-edge technologies is a significant issue, especially for farmers with limited resources working on small plots of land. Challenges like high initial expenses and restricted financing opportunities hinder the implementation of advanced technologies like precision irrigation systems and mechanized equipment, which in turn sustain inequalities in productivity and income among various farm sizes and socioeconomic classes. (Singh, 2020)

Capacity building and extension services are crucial in helping farmers overcome obstacles by equipping them with the essential knowledge, skills, and assistance to embrace and adjust to new technologies. Efficient extension programs can aid in technology transfer, encourage optimal practices, and enable farmers to make well-informed decisions regarding technology adoption tailored to their individual needs and situations.

New technology and modernization in agriculture have various effects on production efficiency. Specific technologies like high-yielding varieties, precision irrigation, and mechanization can increase crop yields, optimize resource utilization, and enhance farm productivity. Access, affordability, and capacity-building challenges must be addressed to utilize modern agricultural technologies for sustainable and inclusive development fully. This is crucial for all farmers, especially smallholders and marginalized groups. (Sanghera, 2021)

3.3.2 Operational Efficiency

The incorporation of new technology in farm management has transformed the agricultural industry, leading to a significant change in decision-making, supply chain efficiency, and logistical procedures. Farmers now use data-driven decision-making tools to make informed choices about crop selection, planting schedules, irrigation management, and pest control strategies. Farmers can improve efficiency and profitability by using data analytics to allocate resources effectively, increase yields, and reduce operational costs. (Arora et al., 2022)

Technology is crucial for optimizing supply chain operations in the agricultural industry. Farmers can effectively oversee inventory, monitor goods' movement, and promptly manage logistics using sophisticated monitoring and tracking systems. Optimizing supply chain processes reduces waste and ensures timely delivery of agricultural produce to markets, enhancing market competitiveness and consumer satisfaction.

Technology has dramatically improved post-harvest management, storage, and marketing of agricultural produce and enhanced on-field operations. Automated sorting and grading systems help farmers maintain product quality uniformity, meet market requirements, and improve market appeal. Furthermore, utilizing IoT devices and sensors allows for immediate monitoring of storage conditions like temperature, humidity, and air quality, helping to reduce post-harvest losses by spoilage. (Mukherjee et al., 2022)

Moreover, advancements in technology related to packaging, preservation, and transportation have prolonged the lifespan of agricultural products, allowing farmers to reach faraway markets and meet various consumer demands. By using cold chain infrastructure and controlled atmosphere storage facilities, farmers can maintain their produce's freshness and nutritional quality, leading to increased market opportunities and revenue.

Despite its many advantages, small and marginal farmers need help utilizing and obtaining the benefits of technology. The main challenge is the digital literacy gap, where many farmers need more skills and knowledge to use technology-enabled solutions effectively. This hinders their capacity to fully utilize digital tools for farm management, market access, and financial management. (Liu et al., 2020)

Furthermore, there needs to be more infrastructure, such as adequate electricity, internet access, and transportation services, which present significant obstacles to implementing technology in rural agricultural regions. Due to unreliable infrastructure support, farmers need help accessing online market platforms, using precision farming equipment, and adopting IoT-based solutions for post-harvest management.

Small and marginal farmers need help accessing mainstream markets because of limited market connections, insufficient transportation infrastructure, and price fluctuations. Intermediaries' dominance in agricultural value chains worsens market access issues, decreasing profitability and economic insecurity for small-scale producers.

Ultimately, technology has the potential to improve efficiency and productivity in agriculture. Still, overcoming challenges such as the digital divide, infrastructure limitations, and market access constraints is essential to achieve inclusive and sustainable growth in the agricultural industry. They promote digital literacy, enhance infrastructure connectivity, and enable market integration for small and marginal farmers to utilize technology's transformative potential in agriculture fully. (Khandelwal et al., 2021)

3.3.3 Infrastructure Development

Rural infrastructure development has changed significantly in recent years due to technological advancements and modernization efforts. Traditional irrigation methods have been slowly substituted with more effective and sustainable systems. Drip irrigation and precision farming techniques have become popular among farmers for maximizing water efficiency and improving crop production. Incorporating sensors and remote monitoring systems allows for real-time data collection, improving decision-making. (Cowie et al., 2020

Rural storage facilities have improved significantly by implementing innovative solutions like modular storage units and climate-controlled warehouses. These advancements aid in preserving agricultural produce and decreasing post-harvest losses, ultimately enhancing efficiency and profitability for farmers.

Modern technologies like GPS tracking, route optimization algorithms, and vehicle telematics have significantly transformed transportation networks. The progress has improved the connectivity of rural areas, facilitating the transportation of goods and services to markets. Moreover, incorporating self-driving vehicles and drones can enhance transportation efficiency in isolated areas. (Shamdasani, 2021)

Communication technology has been crucial in reducing the gap between rural and urban areas by granting access to critical information and services. The widespread availability of mobile phones and internet connectivity has enabled farmers to access market prices, weather forecasts, and agricultural best practices. Rural broadband expansion projects have helped to promote e-commerce and online trading platforms, creating new opportunities for rural economic growth.

Improving infrastructure in rural areas has significantly affected agricultural logistics, market access, and the integration of value chains. Enhanced transportation systems have decreased travel times and transportation expenses, allowing farmers to reach remote markets more effectively. Improved connectivity has helped smallholder farmers join larger value chains, enabling them to access more profitable markets and receive higher product prices.

Investments in storage facilities have reduced post-harvest losses and enhanced the quality of agricultural products. These facilities help farmers deliver top-quality produce by minimizing spoilage and preserving freshness, boosting their competitiveness and market appeal. (Majid, 2020)

Modern technology in agricultural logistics has increased traceability and transparency in the value chain. Stakeholders can monitor the entire process of agricultural products from production to consumption to guarantee compliance with food safety and quality regulations. Enhancing traceability at this level boosts consumer trust and creates possibilities for premium pricing and niche market access. (Pulicherla et al., 2022)

Challenges persist in guaranteeing fair access to upgraded infrastructure, especially for marginalized communities and remote areas. Resource allocation disparities, insufficient maintenance, and limited institutional capacity can impede the effectiveness of infrastructure development initiatives. A comprehensive strategy must be implemented to tackle these challenges effectively, considering rural areas' specific requirements and limitations. This should be coupled with robust governance systems to guarantee fair resource allocation and sustainable infrastructure management.

Improving rural regions' infrastructure can stimulate agricultural change, improve market reach, and foster comprehensive growth. Policymakers can maximize the potential of rural economies and enhance the livelihoods of millions of people who rely on agriculture by utilizing new technologies and implementing a thorough infrastructure planning and management strategy. (Saif et al., 2022)

Allocating resources for rural infrastructure development is frequently restricted by conflicting priorities and insufficient financial resources. Governments and development agencies must balance investments across sectors while meeting pastoral infrastructure needs. The fragmented governance structures can cause inefficiencies and duplications in resource allocation, which can impede the effectiveness of infrastructure development initiatives.

Managing rural infrastructure maintenance is a significant challenge due to insufficient funding and technical expertise, which can lead to the decline of assets and underperformance. Infrastructure assets are susceptible to deterioration and may only provide the expected benefits in the long run if appropriately maintained. Rural areas frequently need more skilled technicians and trained personnel, which worsens the issue of infrastructure deterioration due to the need for more routine maintenance and repairs. (Sadyrova et al., 2021)

Ensuring fair access to upgraded infrastructure is still a significant challenge, especially for disadvantaged communities and isolated areas. Socioeconomic inequalities and institutional obstacles can obstruct access to fundamental services like water, electricity, and transportation, thus prolonging disparities and impeding rural development initiatives. Vulnerable groups like women, indigenous populations, and smallholder farmers are significantly impacted by insufficient infrastructure, which hinders their participation in economic activities and access to essential services. (Arora et al., 2020)

To tackle these challenges effectively, a comprehensive strategy is needed that emphasizes increasing resource mobilization, bolstering institutional capacity, and advocating for inclusive development policies. Governments must focus on investing in rural infrastructure, providing sufficient resources, and implementing creative financing methods to address the infrastructure deficit. Capacity-building initiatives and technology transfer programs can help local communities take control of infrastructure assets and be involved in decision-making.

3.3.4 Socio-Economic Factors

Punjab and Haryana, the "breadbasket" of India, have experienced substantial agricultural modernization in recent decades. The modernization process includes incorporating new technologies, enhanced irrigation systems, mechanization, and the utilization of agrochemicals. The main effect of this modernization has been on agricultural households' income levels. Research indicates a consistent rise in incomes attributed to enhanced crop yields, improved market access, and increased efficiency in production methods. Modernization has only benefitted some rural population segments equally, resulting in income disparities. (Jaiswal et al., 2020)

Agricultural modernization has impacted livelihood security, including income, access to basic amenities, education, and healthcare. Modernization has enhanced access to specific resources and opportunities and heightened reliance on external inputs like fertilizers and pesticides. This has made farmers more vulnerable to market fluctuations and environmental hazards. The transition to cash crops and commercial agriculture has marginalized some traditional livelihood practices, which could worsen rural poverty.

Agricultural modernization has had a varied impact on rural poverty. Although it has helped elevate many individuals from poverty by enhancing productivity and expanding income streams, it has also played a role in the marginalization of small-scale farmers and agricultural workers without land. Advancements in farming technology have reduced the need for manual labor, leading to high levels of unemployment and underemployment in rural regions. Additionally, the expensive nature of contemporary resources has led numerous small-scale farmers into debt cycles, exacerbating their poverty. (Krishna et al., 2022)

Technology in agriculture has changed how people work in rural households. Mechanization has decreased the need for manual labor, displacing agricultural workers, especially men who traditionally worked on farms. This has significant consequences for household incomes and livelihood security, as displaced workers frequently face challenges in securing new sources of employment.

Furthermore, technology integration has increased disparities in skills among agricultural communities. Some people, especially those with education and resources, have successfully adjusted to technological progress and broadened their skills. However, women and marginalized communities have yet to experience the same level of progress. This discrepancy in skill advancement worsens current disparities and continues to isolate specific segments of the population. (Singha et al., 2021)

Technology adoption has influenced gender dynamics in agricultural households. Although mechanization and automation have reduced some of the physical tasks typically performed by women in agriculture, they have only sometimes led to increased empowerment or decision-making power. Women still need help obtaining and managing productive resources like land, credit, and technology, hindering their involvement and gains from modernization efforts.

Agricultural modernization has brought economic advantages and sparked concerns about environmental sustainability, soil health, and water resource management. Excessive utilization of agrochemicals, such as fertilizers and pesticides, has resulted in soil deterioration, nutrient exhaustion, and water pollution. This undermines agricultural land's long-term productivity and presents health hazards to farmers and consumers. (Jat et al., 2021)

4. Practical Part

The study's practical part revealed the analysis results of research data collected from 194 farmers in Punjab and Haryana. The study results were presented through demographic, descriptive, and hypothesis analyses to establish the relationship between the research variables.

4.1 Demographic Analysis

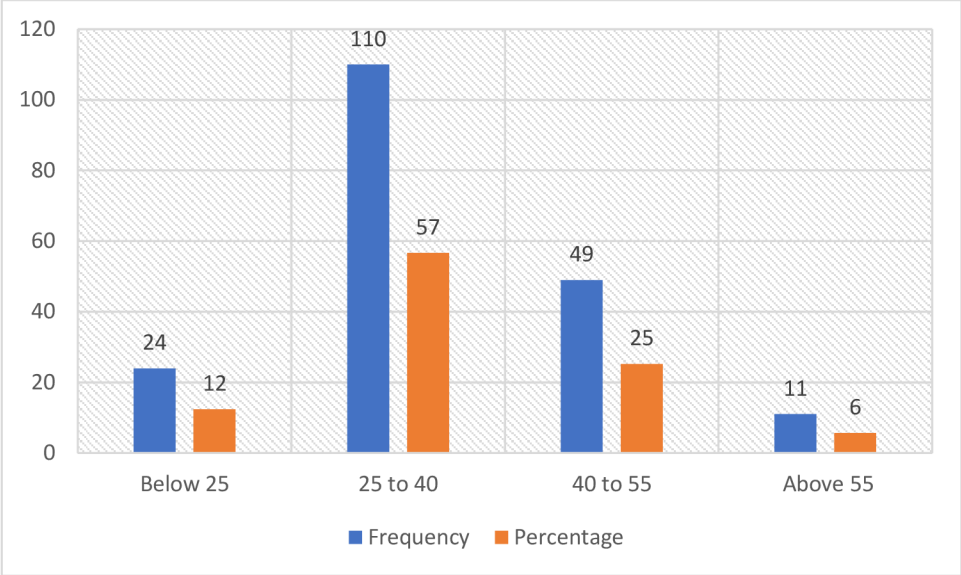
The age distribution of local farmers in Punjab and Haryana is diverse, with 57% falling within the 25-40 age group. This suggests a potential trend of younger farmers engaging in agricultural activities due to technology and modernization. The smaller percentage of farmers above 55 means they remain active in the sector, potentially adapting to technological advancements.

Table 1 Age Group (Source: Self)

Age Group	Frequency	Percentage
Below 25	24	12
25 to 40	110	57
40 to 55	49	25
Above 55	11	6
Total	194	100

Source - Based on the primary data collected from farmers

Figure 1Age Group (Sourse: Self)



Source - Based on the primary data collected from farmers

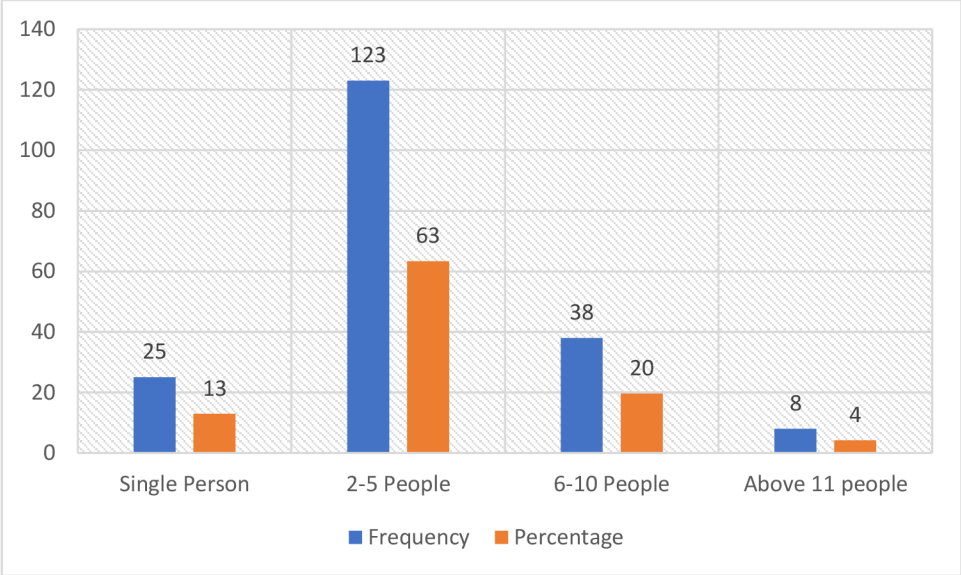
The descriptive analysis of household size data from 194 farmers in Punjab and Haryana reveals that 13% have a single-person household, 63% have 2-5 people, 20% have 6-10 people, and 4% have 11 people. This data reveals varying resource allocation, labor availability, and social dynamics in farming communities. Understanding these dynamics is crucial for policymakers and agricultural stakeholders to effectively tailor interventions and support programs.

Table 2 Household Size (Sourse: Self)

Household Size	**Frequency**	**Percentage**
Single Person	25	13
2-5 People	123	63
6-10 People	38	20
Above 11 people	8	4
Total	194	100

Source - Based on the primary data collected from farmers

Figure 2 Household Size (Sourse: Self)



Source - Based on the primary data collected from farmers

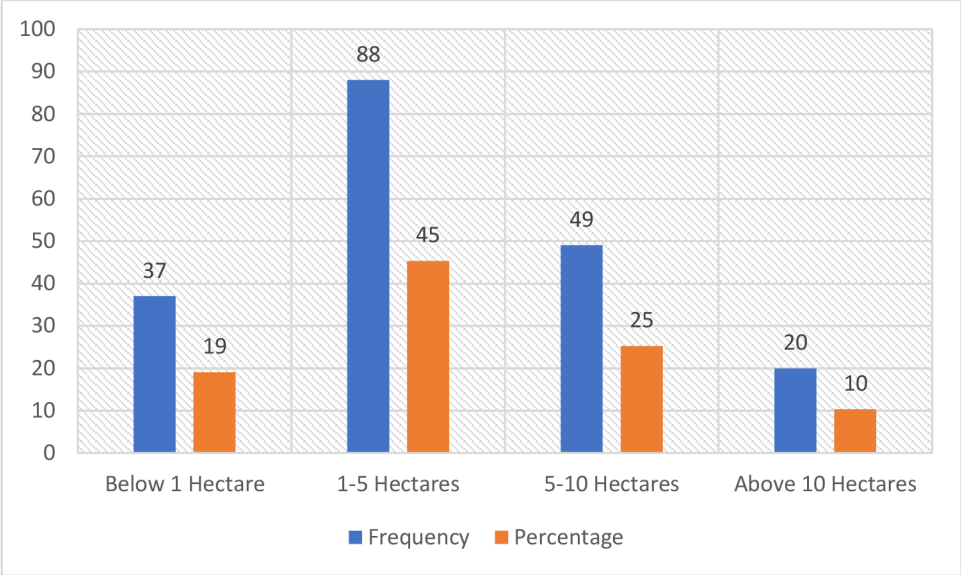
The analysis of farm size distribution among local farmers in Punjab and Haryana reveals a prevalence of small-scale agriculture, with 64% of farms operating smaller than 5 hectares. Most farmers fall within the 1-5 hectare range, with a smaller percentage of farms more significant than 10 hectares. This data provides insights into the agricultural landscape in the region.

Table 3 Farm Size (Sourse: Self)

Farm Size	**Frequency**	**Percentage**
Below 1 Hectare	37	19
1-5 Hectares	88	45
5-10 Hectares	49	25
Above 10 Hectares	20	10
Total	194	100

Source - Based on the primary data collected from farmers

Figure 3 Farm Size (Sourse: Self)



Source - Based on the primary data collected from farmers

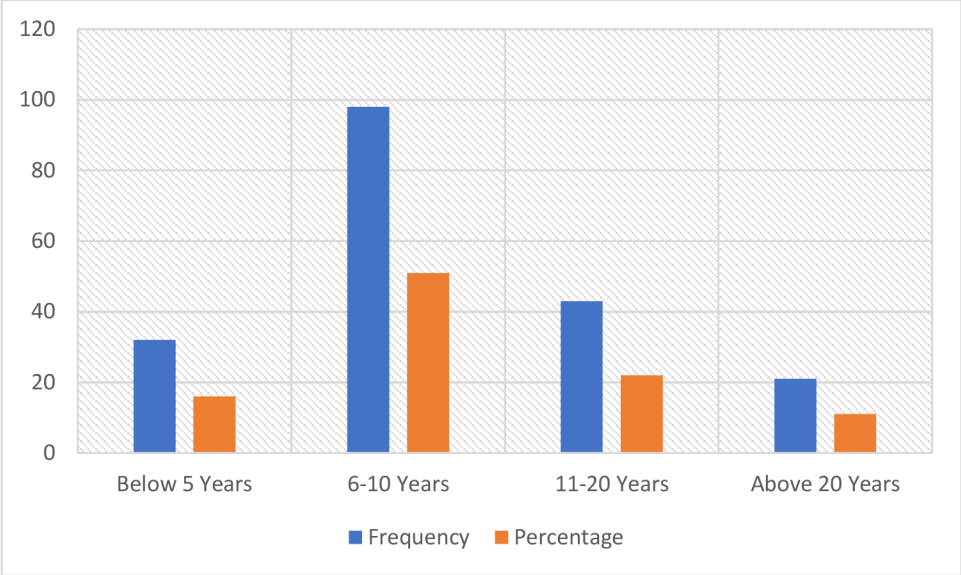
The analysis of local farmers in Punjab and Haryana reveals that most have 6-10 years of experience, accounting for 51% of the sample. This suggests that farmers with 6-10 years of experience are more open to adopting new technologies, offering knowledge transfer opportunities. However, more contemporary farmers may require additional support and training. Further analysis could explore the relationship between experience levels and economic indicators.

Table 4 Expereience Years (Sourse: Self)

Experience Years	Frequency	Percentage
Below 5 Years	32	16
6-10 Years	98	51
11-20 Years	43	22
Above 20 Years	21	11
Total	194	100

Source - Based on the primary data collected from farmers

Figure 4 Experience years (Sourse: Self)



Source - Based on the primary data collected from farmers

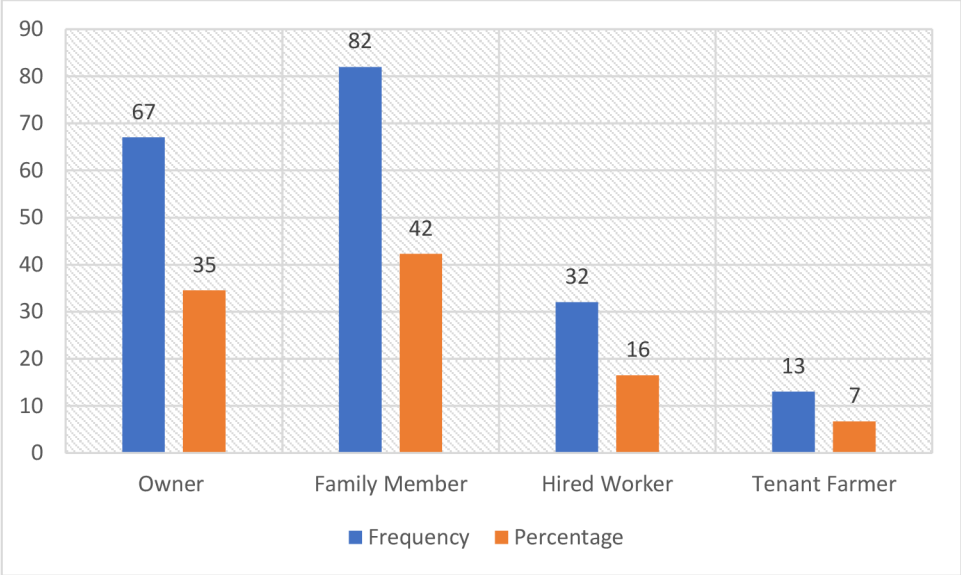
The survey of local farmers in Punjab and Haryana revealed that the majority are owners or family members, with 67 farmers accounting for 35% of the total sample. Family members, comprising 42%, work on land owned by family members, contributing labor but having less control. Hired workers, including 16%, are employed by landowners or larger enterprises with limited decision-making power. Tenant farmers, accounting for 7%, rent land from landowners, highlighting the diversity of land tenure arrangements.

Table 5 Farmer Position (Sourse: Self)

Farmer Position	Frequency	Percentage
Owner	67	35
Family Member	82	42
Hired Worker	32	16
Tenant Farmer	13	7
Total	194	100

Source - Based on the primary data collected from farmers

Figure 5 Farmers position (Sourse:Self)



Source - Based on the primary data collected from farmers

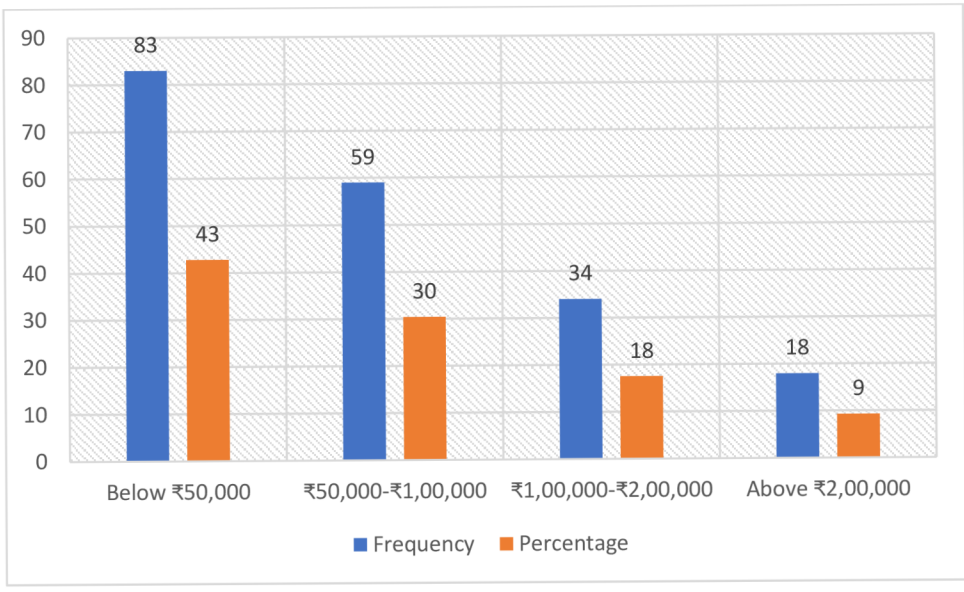
The data from farmers reveals a significant income disparity, with 43% reporting a family income below ₹50,000. This disparity affects the economic status of farmers, with a substantial portion earning below ₹50,000. Understanding this income distribution is crucial for designing policies and interventions to promote agricultural development and reduce income inequality. Further research is needed to explore factors influencing income disparities.

Table 6 Yearly Family Income (Sourse: Self)

Yearly Family Income	Frequency	Percentage
Below ₹50,000	83	43
₹50,000-₹1,00,000	59	30
₹1,00,000-₹2,00,000	34	18
Above ₹2,00,000	18	9
Total	194	100

Source - Based on the primary data collected from farmers

Figure 6 Yearly Family Income (Sourse:Self)



Source - Based on the primary data collected from farmers

4.2 Descriptive Analysis

SDA - Strongly Disagree

DA - Disagree

NT - Neutral

AG - Agree

SA - Strongly Agree

SD - Standard Deviation

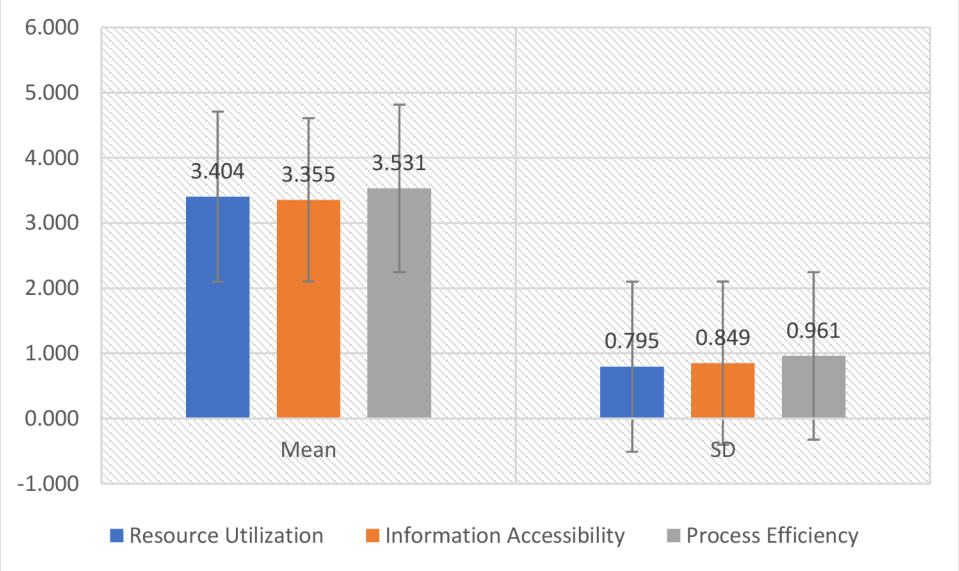
The data on the perception of production efficiency among local farmers in Punjab and Haryana reveals that, on average, farmers in the region perceive positive impacts of adopting new technology and modernization in the agricultural sector. However, the variability in responses suggests that perceptions of production efficiency vary among individual farmers, potentially influenced by factors such as the type of technology adopted, farm size, access to resources, and personal experiences. Further investigation into these factors may provide deeper insights into the nuances of farmers' perceptions and experiences with modernization in the region.

Table 7Production Efficiency (Sourse:Self)

Production Efficiency	SDA	DA	NT	AG	SA	Mean	SD
Resource Utilization	26	44	28	3	0	3.404	0.795
Information Accessibility	31	41	25	4	0	3.355	0.849
Process Efficiency	28	34	30	8	1	3.531	0.961

Source - Based on the primary data collected from farmers

Figure 7 Production Efficiency (Sourse:Self)



Source - Based on the primary data collected from farmers

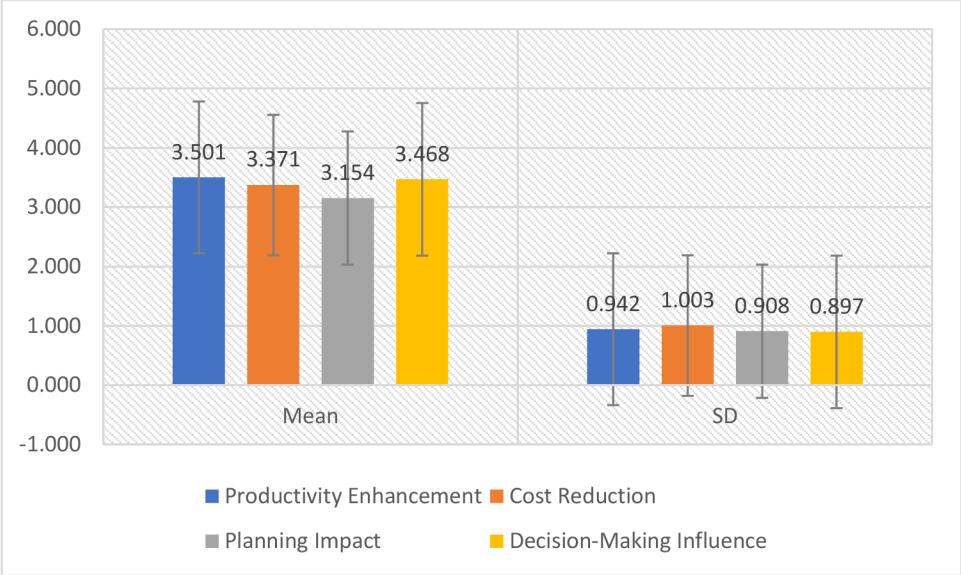
The analysis revealed that, on average, farmers agree that efficient Operational practices have improved farm productivity. However, opinions vary, with some strongly agreeing and others disagreeing. Effective management has reduced operational costs, but many views exist. Proper planning and organization lead to better crop yields, but opinions vary widely. Simplified decision-making processes contribute to overall farm profitability. Overall, while there is general agreement on the positive impact of efficient Operational practices, there is notable variability in opinions, possibly influenced by factors such as farm size, specific management practices, and individual circumstances.

Table 8 Operational Efficiency (Sourse:Self)

Operational Efficiency	SDA	DA	NT	AG	SA	Mean	SD
Productivity Enhancement	27	37	28	7	1	3.501	0.942
Cost Reduction	36	33	22	7	2	3.371	1.003
Planning Impact	44	35	17	3	1	3.154	0.908
Decision-Making Influence	26	42	26	5	1	3.468	0.897

Source - Based on the primary data collected from farmers

Figure 8 Operational Efficiency (Sourse: Self)



Source - Based on the primary data collected from farmers

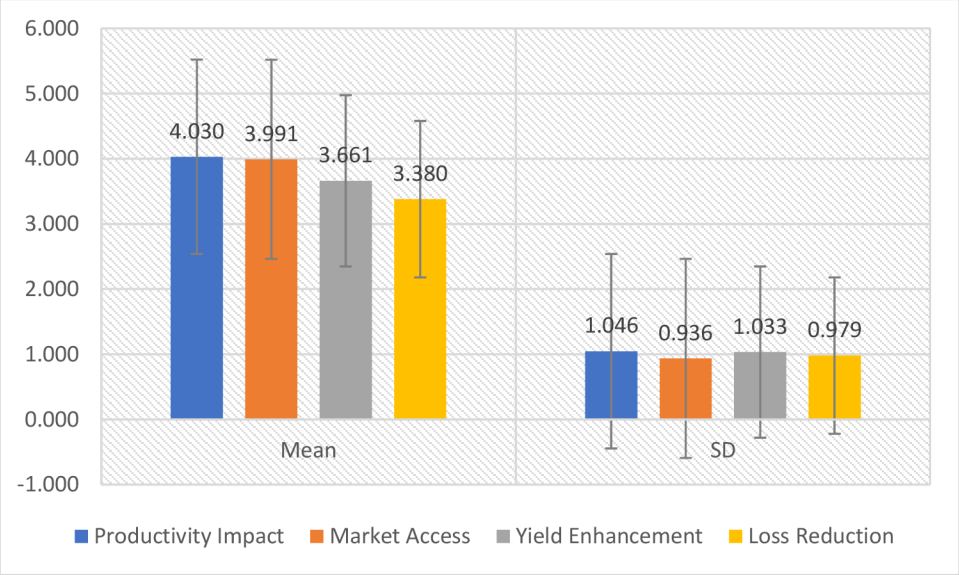
The results showed moderate agreement that improved infrastructure positively affects agricultural productivity. However, there was variability in opinions, with some farmers agreeing or strongly agreeing and others remaining neutral. Upgrading transportation facilities facilitated better market access for produce, but notable variations remained. Farmers showed moderate agreement about the contribution of enhanced irrigation infrastructure to increased crop yields, but there was a wide range of opinions. Modernized storage facilities also helped reduce post-harvest losses, but some farmers remained neutral or disagreed, indicating potential challenges or limitations in their effectiveness.

Table 9 Infrastructure Development (Sourse:Self)

Infrastructure Development	SDA	DA	NT	AG	SA	Mean	SD
Productivity Impact	15	26	37	18	4	4.030	1.046
Market Access	12	30	40	17	1	3.991	0.936
Yield Enhancement	23	37	26	12	3	3.661	1.033
Loss Reduction	36	33	24	7	1	3.380	0.979

Source - Based on the primary data collected from farmers

Figure 9 Infrastructure Development (Sourse:Self)



Source - Based on the primary data collected from farmers

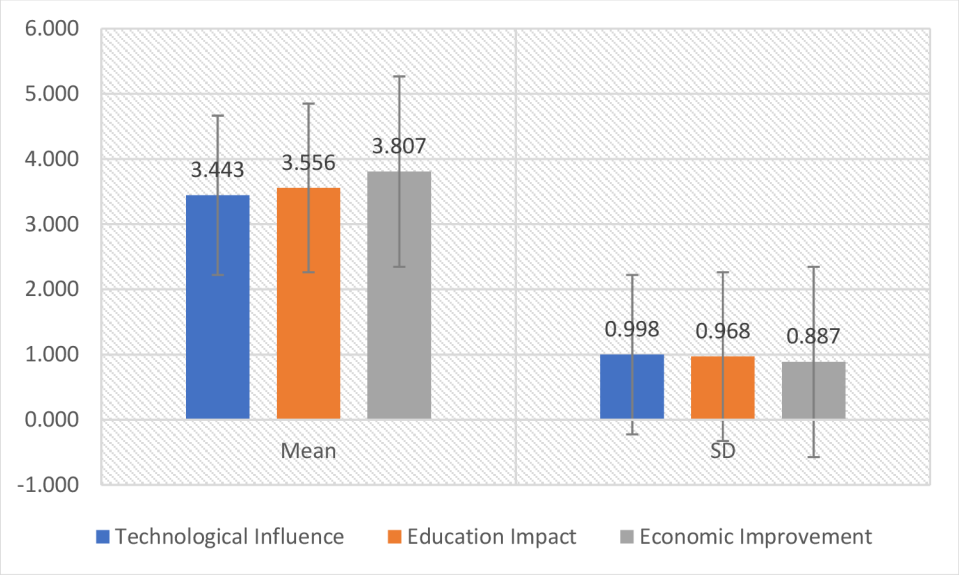
The study reveals a mixed but generally positive outlook among surveyed farmers in Northern India regarding the impact of new technology and modernization on their agricultural practices and economic outcomes. The mean response for the effects of education is slightly higher, with most farmers strongly disagreeing. The mean response for financial improvement is the highest, suggesting a more substantial agreement among farmers about the economic benefits of access to modern farming equipment. Despite some disagreement and variability, many farmers acknowledge the potential benefits of technological advancements and access to modern farming equipment on their farming practices and economic status.

Table 10 Socioeconomic Factors

Socioeconomic Factor	SDA	DA	NT		AG	SA	Mean	SD
Technological Influence	32	36	25		6	3	3.443	0.998
Education Impact	26	36	30		6	2	3.556	0.968
Economic Improvement	13	38	40		8	2	3.807	0.887

Source - Based on the primary data collected from farmers

Figure 10 Socioeconomic Factors (Sourse:Self)



Source - Based on the primary data collected from farmers

4.3 Hypothesis Analysis

The correlation analysis for your thesis reveals a strong positive correlation between the perceived impact of technology and other factors analyzed. Farmers with better Production Efficiency, Operational Efficiency, and improved infrastructure tend to perceive a higher effect of technology on agriculture. A moderate positive correlation was observed between Production Efficiency and technology impact. A strong positive correlation was found between Operational Efficiency and technology impact.

Improved infrastructure was also associated with a higher perception of technology's impact on agriculture. A moderate positive correlation was observed between infrastructure development and technology impact. A weak negative correlation between socioeconomic factors and technology impact was observed, but it was not statistically significant at conventional levels. The analysis reveals a consistent pattern of positive correlations between technology impact and various factors, suggesting that farmers with better resources and operational skills and operating in areas with improved infrastructure tend to perceive a higher effect of technology on agriculture.

However, the weak correlation with socioeconomic factors implies that other variables not included in this study might influence how technology is perceived in the agricultural sector. These results provide valuable insights into the relationship between technology adoption and various factors affecting the agriculture sector in Northern India. Further discussion and interpretation of these findings can enhance understanding of the economic implications of modernization in the region.

Table 11 Correlation Analysis (sourse:Self)

Correlation Analysis		Technology Impact	Production Efficiency	Operational Efficiency	Infrastructure Development	Socioeconomic Factors
Technology Impact	**Pearson Correlation**	1				
	Sig. (2-tailed)	0.000				
	N	194				
Production Efficiency	**Pearson Correlation**	0.277	1			
	Sig. (2-tailed)	0.000				
	N	194	194			
Operational Efficiency	**Pearson Correlation**	0.334	0.757	1		
	Sig. (2-tailed)	0.000	0.000			
	N	194	194	194		
Infrastructure Development	**Pearson Correlation**	0.182	0.534	0.581	1	
	Sig. (2-tailed)	0.000	0.000	0.000		
	N	194	194	194	194	
Socioeconomic Factors	**Pearson Correlation**	-0.086	0.123	-0.042	-0.035	1
	Sig. (2-tailed)	0.078	0.056	0.593	0.841	
	N	194	194	194	194	194

Source - Based on the primary data collected from farmers

The regression analysis reveals a moderate positive linear relationship between new technology and modernization of the agriculture sector in Northern India and the region's economy. The model's correlation coefficient (R) of 0.442 suggests a moderate impact. The adjusted R^2 indicates that the independent variables can explain 19.6% of the region's variance. The standard error of the estimate is 2.217 units. The coefficients of the independent variables represent the change in the dependent variable (economy of the region) for a one-unit change in each independent variable. Positive coefficients indicate a positive impact on the region's economy, while negative coefficients indicate a negative effect. Residual analysis helps assess the assumption of homoscedasticity and linearity of the model. The study provides valuable insights into the impact of new technology and modernization on the economy of Northern India, contributing to the existing literature on agricultural development and economic growth.

Table 12 Regression Analysis (Sourse:Self)

Model	R	R Square	Adjusted R Square	Standard Error
1	0.442	0.196	0.176	2.217

Source - Based on the primary data collected from farmers

The regression analysis reveals that the new technology and modernization of the agriculture sector in Northern India significantly impact the region's economy. The model includes eight independent variables, with a significant F-test indicating that at least one of these variables is statistically significant in predicting the dependent variable. The F-statistic and coefficient of determination indicate that the model is statistically significant in explaining the region's economic variability. Further analysis is needed to understand the specific contributions of individual factors to this impact.

Table 13 ANOVA Analysis (Sourse:Self)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	401.993	8.000	51.569	9.897	0.000
	Residual	1981.580	186.000	3.922		
	Total	2391.662	194.000			

Source - Based on the primary data collected from farmers

The analysis of regression coefficients from 194 local farmers in Punjab and Haryana reveals that new technology and modernization significantly impact the agriculture sector in Northern India. The model includes four independent variables: Production Efficiency, Operational Efficiency, Infrastructure Development, and Socioeconomic Factors. The dependent variable, not explicitly stated, appears to be related to the economic performance or productivity of the farmers in the region. The constant coefficient represents the baseline financial performance, while the coefficient for Production Efficiency is -0.214. An improvement in Operational Efficiency positively influences economic performance, with a one-unit increase in performance by approximately 0.459 units. Infrastructure Development has no significant relationship with financial performance, and Socioeconomic Factors have no significant association. The findings provide valuable insights for policymakers, agricultural practitioners, and researchers aiming to enhance the economic outcomes of the agriculture sector through targeted interventions and investments in operational efficiency.

Table 14 Regression Coefficient (Sourse:Self)

Model		Unstandardized Coefficients		Standardized Coefficients	t Value	Significance
1	**Constant**	3.938	1.144		4.384	0.000
	Production Efficiency	-0.214	0.283	-0.204	-0.079	0.988
	Operational Efficiency	0.459	0.286	0.589	4.311	0.000
	Infrastructure Development	-0.229	0.275	-0.228	-0.198	1.204
	Socioeconomic Factors	0.244	0.245	0.291	1.151	0.588

Source - Based on the primary data collected from farmers

5. Results and Discussion

5.1 Key Findings

The study focuses on the impact of new technology and modernization on small farms in India. It found that farmers had access to adequate financial resources, modern farming equipment, support staff, and technological infrastructure. However, resource capabilities did not have a statistically significant influence on the impact of these technologies within local farms. Managerial capabilities were found to be moderately influential, with farmers collaborating with more farmers to improve decision-making capacity. There was adequate experience in modern farming among farmers and adequate technological knowledge. The level of farming experience and off-farm activity participation was also critical to enhancing the integration of new technologies among local farmers. The study also found that, to some extent, farms had undertaken managerial training in the past and gained exposure to various farming technologies. Infrastructure development was essential for farmers' access to information from farmers' unions, government institutions, and private farms. Most farmers participated in agriculture training programs and accessed relevant market information. Infrastructure development was a key contributor to the transfer of knowledge on agri-techs and the impact of emerging technologies. To some extent, farmers had access to advisory and logistic support services. Socioeconomic factors were also found to have no significant influence on the impact of digital technology on small farms in India. Farmers' education did not significantly influence the impact of digital technology, contrary to previous evidence suggesting that education level and farmers' behavior are critical predictors of ICT impact in farming. Education level and farming experience were also found to be essential to the effect of technology on agriculture. Despite the prevalence of digital technology in agriculture, the study revealed that the age and education level of farmers only minimally influenced its impact. Younger and more educated farmers exhibited a slightly higher propensity to adopt digital tools, though the effect was not significant. Surprisingly, the study found that extensive farming experience had a notable adverse effect on the adoption of digital technology among local farmers. This suggests that seasoned farmers may be more resistant to incorporating digital solutions into their traditional practices. While household income, size, and gender were expected to play a significant role in digital technology adoption, the study concluded that their influence was positive yet statistically insignificant. This implies that factors such as higher income, larger household size, and gender had limited impact on farmers' decisions to adopt digital tools. The study highlights the importance of resource capabilities, managerial capabilities, and

socioeconomic factors in determining the effects of new technology and modernization on small farms in India.

5.2 Research Implications

The country faces food insecurity, a significant challenge to maintaining a sustainable food supply. To address this, government policymakers need to implement a comprehensive reform process in the agriculture industry, integrating agricultural technologies. This includes supporting research and development in local agriculture, decentralizing infrastructure development, and creating programs to fund entrepreneurs and software developers to develop successful technologies. The government should also provide additional legal support to increase access to globally accessible innovations in agricultural productivity. Practice recommendations include more research on incorporating technology into farming and value chain activities to enhance productivity at the farm level and during food distribution. Farmers' unions and extension offices should support managerial training and raise awareness of various technologies for farmers to adopt in India. Farmers should seek collaboration with stakeholders to expand training and capacity-building opportunities. For farmers with less than 1,00,000 rupees annual income, pooling resources and purchasing modern equipment and machinery in groups can help them adopt modern agricultural technologies. Improving education and training on emerging agricultural technologies is crucial for the impact of technology on farming activities.

5.3 Research Directions

The study was conducted exclusively on local farms in two counties in India, potentially restricting the generalizability of the findings to other counties. The study only examined the effects of specific applications on farmers in Punjab and Haryana, potentially excluding farmers who may be using different types of new technology and modernization. The study results showed a particular influence of the chosen modern agricultural technologies. This study proposes conducting a comprehensive investigation into farm-level factors influencing the adoption of modern technologies among farmers in India.

5.4 SWOT Analysis

Strengths

- ✓ **Increased Efficiency** - Adopting new technologies such as precision agriculture, drones, and IoT devices can increase farming practices' efficiency, resulting in higher yields.
- ✓ **Diversification of Crops** - Modernization efforts can facilitate the diversification of crops, enabling farmers to cultivate high-value cash crops alongside traditional crops, thus reducing dependency on a single crop and enhancing resilience to market fluctuations.
- ✓ **Improved Resource Management** - Implementing modern farming techniques allows for better water, fertilizers, and pesticide utilization, reducing wastage and environmental sustainability.
- ✓ **Enhanced Market Access** - Integration of technology in agriculture can improve market access for farmers by providing them with real-time market information, enabling better decision-making and potentially higher profits.
- ✓ **Skills Enhancement** - Modernization initiatives often include training programs to equip farmers with the necessary skills to adopt new technologies effectively, thereby enhancing human capital in the agricultural sector.

Weaknesses

- ✓ **High Initial Investment** - Adopting new technologies often requires significant initial investment in equipment, infrastructure, and training, which may pose a barrier to entry for small-scale farmers with limited financial resources.
- ✓ **Technological Divide** - There is a risk of exacerbating the technological divide between large commercial farms and smallholder farmers, potentially widening existing disparities in income and access to resources.
- ✓ **Dependency on External Inputs** - Reliance on modern inputs such as hybrid seeds, chemical fertilizers, and machinery can make farmers vulnerable to price fluctuations in input markets. It may increase their dependency on external suppliers.
- ✓ **Resistance to Change** - Some farmers may resist adopting new technologies due to risk aversion, lack of awareness, or attachment to traditional farming practices.
- ✓ **Environmental Concerns** - If not appropriately managed, intensive use of agrochemicals and mechanization can have adverse environmental impacts, including soil degradation, water pollution, and biodiversity loss.

Opportunities

- ✓ **Government Support** - Government policies and incentives promoting modernization and technology adoption in agriculture, such as subsidies for machinery and extension services, present opportunities for farmers to upgrade their practices.
- ✓ **Market Demand for Quality Produce** - Increasing consumer demand for safe and sustainably produced food allows farmers to capitalize on premium markets by adopting modern practices that enhance product quality and traceability.
- ✓ **Export Potential** - Modernization efforts can enable farmers to meet international quality standards and tap into export markets for agricultural products, thereby diversifying revenue streams and contributing to foreign exchange earnings.
- ✓ **Rural Employment Generation** - Adopting modern agricultural technologies often creates employment opportunities in agribusiness, agri-tech startups, and agricultural extension services, contributing to rural economic development.
- ✓ **Climate Resilience** - Some modern agricultural practices, such as conservation agriculture and drip irrigation, can enhance climate resilience by mitigating the impacts of climate change, such as droughts and erratic rainfall patterns.

Threats

- ✓ **Market Volatility** - Fluctuations in global commodity prices and market demand can expose farmers to price volatility and income insecurity, particularly if they lack access to risk management tools such as insurance and futures markets.
- ✓ **Land Degradation** - Intensive farming practices associated with modernization, such as monocropping and excessive use of agrochemicals, can accelerate soil erosion, nutrient depletion, and degradation of arable land over time.
- ✓ **Water Scarcity** - Increasing water scarcity due to climate change and over-extraction of groundwater threatens agricultural productivity, especially in regions dependent on irrigation for crop cultivation.
- ✓ **Loss of Traditional Knowledge** - The rapid adoption of modern technologies may lead to the erosion of traditional knowledge and farming practices that have sustained agricultural communities for generations, risking the loss of valuable indigenous wisdom.
- ✓ **Cybersecurity Risks** - There is a risk of cybersecurity threats such as data breaches, hacking, and ransomware attacks targeting farm management systems and IoT devices, potentially disrupting agricultural operations.

6. Conclusion

Several sectors in the Indian economy have experienced a rise in digitalization and dependence on technologies for daily operations. However, this trend has yet to be observed in the agriculture sector, which significantly contributes to economic growth and is a source of livelihood for many families. This study aimed to investigate the factors that influence the impact of digital technology on local farmers in Punjab and Haryana. The study analyzed the effects of new technology and modernization on production efficiency, operational efficiency, and infrastructure development.

The study was based on the technology, organization, and environment framework. This approach assists in determining how internal and external factors of the farms work together to enhance the effectiveness of new technology and modernization. The study employed a positivist research philosophy and utilized a descriptive research design. The study focused on farmers selected from the two regions. The study utilized a quantitative methodology and collected data using a semi-structured questionnaire. The research data was analyzed utilizing descriptive statistics, Spearman correlation, and regression analysis.

The study shows that most farmers had received education for at least 11 years and owned an average land size of 2 acres. The findings show that most farmers have engaged in farming for at least 14 years, earning an average annual income of 1,00,000 rupees. The study's results show that production efficiency, operational efficiency, and infrastructure development positively and significantly influence the implementation of new technology and modernization.

The regression analysis results indicate that 20% of the variations in the impact of new technology and modernization are influenced by gender, household income, household size, age, farming experience, farmers' education, production efficiency, operational efficiency, and infrastructure development. The study concludes that there has been a partial increase in adopting different technologies among local farmers. The study found that the ability of farms to embrace agricultural technologies was influenced by their resource capacity, managerial capacity, and infrastructure development.

The study found that the resource capabilities of local farmers did not significantly affect the impact of new technology and modernization. The research concludes that improving collaboration and connections between farms, increasing managerial training, and enhancing the level of experience in running farms are crucial for the effectiveness of agricultural technologies. The study found that infrastructure development only significantly affects the adoption of new technology and modernization among local farmers.

The study found that the age and education level of the farmer had a minimal yet beneficial effect on the impact of digital technology. The study found that farming experience has notable and adverse effects on adopting digital technology in local farms. The study ultimately determines that household income, household size, and gender have a positive yet statistically insignificant impact on the influence of digital technology.

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Appendix

Name -

Age Group - (A) Below 25 (B) 25 to 40 (C) 40 to 55 (D) Above 55

Household Size - (A) Single person (B) 2-5 people (C) 6-10 people (D) Above 11 people

Farm Size - (A) Below 1 hectare (B) 1-5 hectares (C) 5-10 hectares (D) Above 10 hectares

Experience Years - (A) Below five years (B) 6-10 years (C) 11-20 years (D) Above 20 years

Farmer Position - (A) Owner (B) Family member (C) Hired worker (D) Tenant farmer

Yearly Family Income - (A) Below ₹50,000 (B) ₹50,000-₹1,00,000 (C) ₹1,00,000-₹2,00,000 (D) Above ₹2,00,000

Production Efficiency

(A) Strongly Disagree (B) Disagree (C) Neutral (D) Agree (E) Strongly Agree

Do you agree that adopting new agricultural practices has reduced resource wastage on your farm? (Resource Utilization)

Do you agree that access to timely information has improved decision-making on your farm? (Information Accessibility)

Would you agree that modernization has streamlined production processes on your farm? (Process Efficiency)

Operational Efficiency

(A) Strongly Disagree (B) Disagree (C) Neutral (D) Agree (E) Strongly Agree

To what extent do you agree that efficient Operational practices have improved farm productivity? (Productivity Enhancement)

Do you agree that effective management has reduced operational costs on your farm? (Cost Reduction)

Proper planning and organization lead to better crop yields. (Planning Impact)

Do you believe that streamlined decision-making processes contribute to overall farm profitability? (Decision-Making Influence)

Infrastructure Development

(A) Strongly Disagree (B) Disagree (C) Neutral (D) Agree (E) Strongly Agree

To what extent has improved infrastructure positively affected your agricultural productivity? (Productivity Impact)

Do you agree that upgraded transportation facilities have facilitated better market access for your produce? (Market Access)

Has enhanced irrigation infrastructure contributed to increased crop yields on your farm? (Yield Enhancement)

Do you believe that modernized storage facilities have helped reduce post-harvest losses? (Loss Reduction)

Socioeconomic Factor

(A) Strongly Disagree (B) Disagree (C) Neutral (D) Agree (E) Strongly Agree

Do you agree that technological advancements have influenced your decision to adopt new agricultural practices? (Technological Influence)

Education level significantly affects agricultural productivity and income generation. (Education Impact)

To what extent do you agree that access to modern farming equipment has improved your economic status? (Economic Improvement)