A Study on Modernization of Agriculture and Artificial Intelligence

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Abstract

This study explores how Artificial Intelligence (AI) is gradually transforming traditional farming practices and supporting the modernisation of agriculture. It explains how AI technologies such as machine learning, precision farming, and smart irrigation are helping farmers improve productivity, efficiency, and sustainability in their daily agricultural activities. The research focuses on understanding how aware farmers are about AI tools, the extent to which they have adopted them, and what they actually think about these technologies. The study also examines how AI helps in increasing crop yield, reducing input costs, and managing risks related to climate change. At the same time, it highlights practical challenges faced by farmers, such as lack of technical knowledge, high investment costs, and poor digital infrastructure in rural areas.

Keywords: Artificial Intelligence, agricultural modernisation, precision farming, smart irrigation, crop productivity, sustainable agriculture, farmer awareness, digital agriculture.

1. Introduction

Agriculture has always been a primary source of livelihood and economic support, especially in developing countries where a large section of the population depends on farming. It plays an important role in ensuring food security, reducing poverty, and supporting rural development. However, the agricultural sector is currently facing serious challenges such as climate change, irregular rainfall, declining soil quality, shrinking agricultural land, and rising input costs. Because of these issues, modernising agriculture has become necessary to improve productivity, manage resources efficiently, and ensure long-term sustainability. The use of advanced technologies in farming is now seen as an important solution to meet the growing demand for food while protecting natural resources.

In recent years, Artificial Intelligence (AI) has started playing a significant role in agriculture by enabling farmers to make more accurate and informed decisions. AI-based tools such as machine learning techniques, precision farming methods, smart irrigation systems, drones, and sensor networks provide real-time information about crop health, soil condition, and weather patterns. These technologies help farmers predict crop diseases, estimate yield, and plan farming activities more effectively. By optimizing the use of water, fertilizers, and pesticides, AI reduces wastage, lowers production costs, and minimizes environmental damage. It also supports sustainable agriculture by promoting efficient use of resources and

reducing the carbon footprint of farming activities.

Even though AI offers many benefits, its adoption among farmers is still limited and uneven. Many small and marginal farmers are not fully aware of how AI tools work or how to use them. High initial investment costs, poor internet connectivity, and lack of digital infrastructure in rural areas further restrict the use of these technologies. Therefore, it is important to understand farmers' awareness, adoption levels, and attitudes toward AI in agriculture. This study uses a survey-based approach to collect primary data from farmers and examine how AI technologies influence productivity, efficiency, and sustainability in real farming conditions. The findings aim to provide useful insights for policymakers, agricultural extension services, and technology developers to promote effective agricultural modernization.

2. Statement of the Problem

Agriculture is currently facing serious challenges due to climate change, depletion of natural resources, rising production costs, and inefficiencies in traditional farming methods. Although Artificial Intelligence (AI) has the potential to improve productivity, efficiency, and sustainability in agriculture, its use among farmers is still limited and uneven. Many farmers are not fully aware of AI-based tools and lack the technical knowledge and access required to use them effectively. There is also limited practical evidence on how farmers actually perceive these

technologies, how far they have adopted them, and whether AI tools truly improve farming outcomes at the field level. Therefore, it becomes necessary to systematically study the role of AI in agricultural modernization, understand the real challenges faced by farmers, and assess how AI-driven technologies influence productivity and sustainability.

3. Review of Literature
Sharma and Singh (2019) observed that digital and precision technologies help farmers use water, fertilizers, and pesticides more efficiently. Their study showed that precision farming reduces wastage, protects the environment, and improves crop yield. They also noted that farmers using these technologies are able to make better decisions, which increases both profitability and sustainability [1].

Patel *et al.* (2020) explained how AI tools such as crop monitoring systems and predictive analytics help farmers in yield forecasting and pest management. Their research highlighted that AI enables real-time detection of crop stress and nutrient deficiencies, allowing timely action. However, they also pointed out that small and marginal farmers face difficulties due to limited knowledge, high costs, and poor digital infrastructure [2].

Kumar and Rao (2021) studied farmers' perceptions of AI-based agricultural tools and found that although many farmers recognize their benefits, they are often unable to adopt them due to high investment costs and lack of access to technology. The authors emphasized the need for government subsidies, awareness programs, and structured training to encourage adoption. They also suggested that institutional support can help connect technological developments with practical farming needs [3].

4. Research Gap of the Study
Many earlier studies have discussed the technical advantages of AI and modern technologies in agriculture. However, most of them focus more on theoretical benefits rather than how farmers actually understand, adopt, and use these tools in real farming conditions. Limited attention has been given to farmers' awareness, perceptions, and practical difficulties, especially among small and marginal farmers. Issues such as lack of training, affordability, and poor digital infrastructure are often mentioned but not studied in detail at the field level. There is also a lack of region-specific, survey-based research that evaluates how AI affects productivity, efficiency, and sustainability in actual farm practices. Therefore, a clear gap exists in understanding how farmers perceive and utilize AI-driven modernization, which this study attempts to address.

5. Objectives of the Study
i). To understand awareness of farmers are about Artificial Intelligence and modern agricultural technologies.
ii). To analyze farmers have adopted AI-based tools and practices in their farming activities.
iii). To examine Artificial Intelligence helps in improving agricultural productivity, efficiency, and crop management.
iv). To evaluate AI technologies contribute to cost reduction, better resource use, and sustainable farming.
v). To understand the perceptions of farmers and the challenges they face in adopting AI-driven solutions.
vi). To suggest practical measures and policy recommendations for promoting AI in agricultural modernization.

6. Methodology
This research is based on both Doctrinal and Non-Doctrinal research. The sources of data is collected from different newspaper, journals, magazine, AIR and E-resources. This research is used stratified random sampling. There are 131 sample size of the respondent is used. In this research adopted some of the statistical tools such as percentage method and average method. The duration of the research is three months.

7. Significance of the Study
i). This study helps the government understand the real situation of farmers regarding awareness and use of AI technologies in agriculture. It highlights practical challenges such as lack of infrastructure, need for training, and affordability issues. The findings can assist policymakers in framing better agricultural policies, designing subsidy schemes, improving rural digital infrastructure, and organizing effective training and extension programs for sustainable agricultural development.
ii). This study is useful to farmers as it explains how modern agricultural practices and AI tools can improve crop yield, reduce input costs, and manage risks related to climate change and pest attacks. It also brings out the practical problems faced by farmers and suggests solutions through proper training, support, and guidance. By understanding both the benefits and limitations of AI, farmers can make better decisions in adopting modern farming methods.

8. Hypothesis of the Study
This research is based on following hypothesis:
i). AI helps farmers make better farming decisions.
ii). Modern agricultural technologies contribute to sustainable farming.

9. Limitation of the Study
This study has certain limitations that should be kept in mind while interpreting the results. The research is based on responses collected from farmers through a survey, and these responses may reflect personal opinions and experiences. The sample size is limited and may not represent farmers from all regions. The study mainly focuses on farmers' awareness and perceptions of AI rather than the technical performance of AI tools. Time and resource constraints also limited deeper analysis and long-term assessment of AI adoption. Differences in literacy levels and understanding of technology among farmers may have influenced the accuracy of responses. Since AI technologies are rapidly evolving, all emerging tools could not be covered in this study.

10. Result and Discussion
Part 1:
Doctrinal Research:
From a doctrinal standpoint, existing literature, policy papers, and theoretical frameworks strongly support the idea that technology adoption in agriculture is closely linked with education, infrastructure, and institutional support. Theories such as the Diffusion of Innovation Theory, Human Capital Theory, and Sustainable Development Theory provide a strong foundation for understanding how AI can transform agriculture [4].

Doctrinal analysis reveals that technological modernization in agriculture has historically improved productivity, but AI introduces a new dimension by enabling predictive, data-

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driven, and precision-based farming practices. Literature also emphasizes that without proper training, infrastructure, and policy intervention, technological benefits remain unevenly distributed among farmers [5].

The empirical findings show that most respondents belong to the middle-age group and are actively engaged in farming as their primary occupation. A large proportion are small and marginal farmers with limited landholdings. Educational qualifications vary, but many possess only basic or secondary education. These socio-economic factors significantly influence awareness, access, and adoption of AI tools. This finding aligns with earlier studies which state that farm size and education are critical determinants of technology adoption. Smaller landholdings and limited literacy restrict farmers' ability to invest in and understand advanced technologies [6].

The study reveals that although many farmers have heard about AI through government programs, mobile applications, and extension services, detailed technical understanding remains low. Awareness is higher regarding smart irrigation and weather forecasting, while knowledge of machine learning and predictive analytics is minimal. This indicates that awareness alone does not guarantee adoption. Structured digital literacy programs are required to bridge this knowledge gap [7].

Actual adoption of AI tools is considerably lower than awareness levels. Farmers mostly rely on partially modernized practices rather than fully AI-driven systems. High cost, complexity, lack of confidence, and poor digital infrastructure are major barriers. This slow adoption pattern reflects the principles of Diffusion of Innovation Theory, especially among small and marginal farmers [8].

Farmers using AI tools reported improvements in crop yield, irrigation scheduling, pest management, and overall farm efficiency. AI advisory systems reduced guesswork and improved accuracy in farm operations. Smart irrigation systems reduced water consumption, and AI-based pest detection minimized chemical usage. These findings confirm that AI contributes to precision agriculture, enhancing both productivity and sustainability [9].

AI tools provide early warnings regarding weather changes, pest outbreaks, and drought conditions. Farmers using such tools are better prepared to manage climate-related risks. However, access to such technologies remains limited in remote rural areas. This supports climate-smart agriculture literature which emphasizes AI as a tool for resilience [10].

The study highlights the importance of government subsidies, infrastructure development, and training programs in promoting AI adoption. Farmers who benefited from government schemes showed higher adoption rates. Agricultural extension services act as knowledge bridges between technology and farmers. Policy-driven modernization and public-private partnerships are essential for large-scale AI implementation [11].

Farmers with higher education levels and larger landholdings exhibit greater adoption of AI technologies. In contrast, women farmers show limited participation due to restricted access to devices, training, and socio-cultural barriers. Gender-sensitive policies and inclusive training programs are necessary for equitable modernization [12].

Adoption levels are higher in regions with better internet connectivity and institutional support. Remote regions lag due to poor infrastructure. This digital divide limits the reach of AI-driven agriculture and calls for region-specific policy interventions [13].

AI adoption leads to increased income through improved yield, reduced input costs, and better market planning. AI tools provide price forecasts and demand trends, strengthening farmers' bargaining power. This aligns with economic efficiency theory [14].

Farmers expressed mixed trust in AI recommendations. Concerns regarding data privacy, reliability, and maintenance costs were observed. The effectiveness of AI depends heavily on data quality and localized datasets. Ethical frameworks and data protection policies are necessary for responsible AI usage [15].

Farmers who received training from extension services demonstrated higher confidence and effective use of AI tools. Demonstration farms and hands-on sessions reduce fear of technology and build trust. Continuous skill development is essential for sustained adoption [16].

The study suggests that AI should complement, not replace, traditional farming knowledge. A hybrid model combining indigenous practices with AI recommendations yields better acceptance and results among farmers [17].

11. Relevant Case Law

Monsanto Canada Inc v Schmeiser (Supreme Court of Canada, 2004): In this case, Percy Schmeiser, a small canola farmer in Saskatchewan, discovered herbicide-resistant canola growing in his fields. He harvested and replanted this crop year after year. Monsanto, the biotech company that developed genetically engineered (GE) canola, sued Schmeiser for patent infringement. Schmeiser argued he owned the seed he planted and shouldn't have to pay Monsanto because he hadn't sprayed the herbicide — so he hadn't "used" the patented invention. The Supreme Court held 5-4 that Schmeiser did use Monsanto's patented invention by growing and cultivating the GE canola, even if he didn't spray the herbicide. However, because he didn't gain any profit from the patented trait (he didn't benefit from Roundup), the Court *did not* award Monsanto damages beyond declaring infringement [18].

Monsanto Co. v. Geertson Seed Farms (United States Supreme Court, 2010): In this case, Monsanto developed genetically modified alfalfa that could tolerate herbicide spraying. The U.S. Department of Agriculture (USDA) deregulated the crop, which meant farmers could plant it. Environmental groups and smaller seed farms feared the GE alfalfa would contaminate ordinary crops and sought a court order blocking the deregulation until a full environmental impact review was completed. The U.S. Supreme Court ruled that the district court went too far by issuing a nationwide injunction without proper evidence of harm. They allowed partial deregulation to proceed, while still requiring environmental review [19].

Bowman v. Monsanto Co. (United States Supreme Court, 2013): In this case, Vernon Bowman, a soybean farmer, bought patented glyphosate-resistant seeds and was licensed to plant them only once per season. Later, Bowman bought commodity soybeans (not licensed seed) from a grain elevator and planted them anyway. Those beans were genetically similar to the patented ones. Monsanto sued Bowman for patent infringement, claiming he "made" new seeds without permission. The Supreme Court unanimously held that patent exhaustion doesn't let Bowman replant or reproduce patented seeds simply because he bought them once. The act of growing new plants from harvested seed counts as "making" the patented invention without a license — so Bowman infringed the patent [20].

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Part 2: Non-Doctrinal Research

Table 1: Which area of agriculture can AI improve the most.

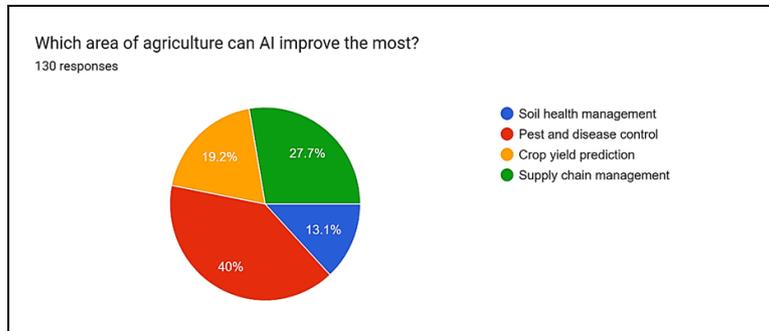| Indicators	Crop Yield Prediction	Pest and Disease Control	Soil Health Management	Supply Chain Management	Total
Rural	4(16)	6(11.53)	4(23.52)	9(25)	23(17.69)
Semi-urban	9(36)	8(15.38)	3(17.64)	8(22.22)	28(21.53)
Urban	12(48)	38(73.07)	10(58.82)	19(52.77)	79(60.76)
Total	25(19.23)	52(40)	17(13.07)	36(27.69)	130(100.00)

Source: Primary data

Table No.1 shows the areas in agriculture where respondents feel AI can make the greatest difference. Most participants point to pest and disease control 40 percentage of the respondent as the top area, followed by supply chain management 27.69 percentage of the respondent. Fewer respondents chose crop yield prediction 19.23 percentage of the respondent and soil health management 13.07 percentage of the respondent. This shows that respondents mainly view AI as a tool for protecting crops and improving the movement and distribution of agricultural produce.

Table 2: What is the biggest challenge in adopting AI in agriculture

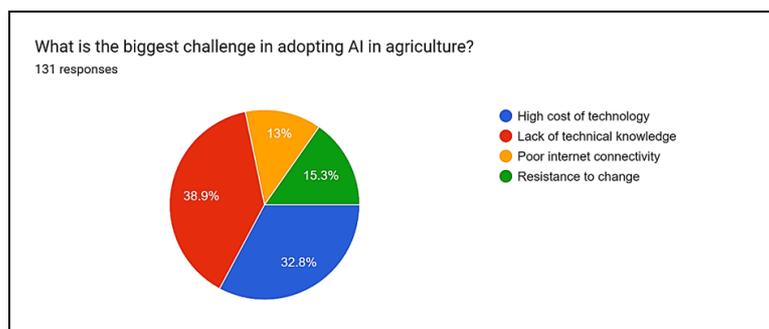| Indicators	High Cost of Technology	Lack of Technical Knowledge	Poor Internet Connectivity	Resistance to Change	Total
Rural	2(4.65)	13(25.49)	4(23.52)	4(20)	23(17.55)
Semi-urban	5(11.62)	11(21.56)	5(29.41)	7(35)	28(21.37)
Urban	36(83.72)	27(52.94)	8(47.05)	9(45)	80(61.06)
Total	43(32.82)	51(38.93)	17(12.97)	20(15.26)	131(100.00)

Source: Primary data

Table No.2 shows the key difficulties faced in adopting AI in agriculture. The most common problem identified by respondents is the lack of technical knowledge 38.93 percentage of the respondent followed by the high cost of technology 32.82 percentage of the respondent. Some respondents also mentioned resistance to change 15.26 percentage of the respondent and poor internet connectivity 12.97 percentage of the respondent. This suggests that the main barriers to using AI in agriculture are limited knowledge and financial constraints.

Table 3: AI helps farmers make better farming decisions

Indicators	Agree	Disagree	Neutral	Strongly agree	Strongly disagree	Total
Rural	4(22.22)	4(19.04)	8(11.59)	3(13.04)	4(40)	23(17.55)
Semi-urban	5(27.77)	5(23.80)	15(21.73)	2(8.69)	1(10)	28(21.37)
Urban	9(50)	12(57.14)	36(52.17)	18(78.26)	5(50)	80(61.06)
Total	18(13.74)	21(16.03)	69(52.67)	23(17.55)	10(7.63)	131(100.00)

Source: Primary data

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AI helps farmers make better farming decisions
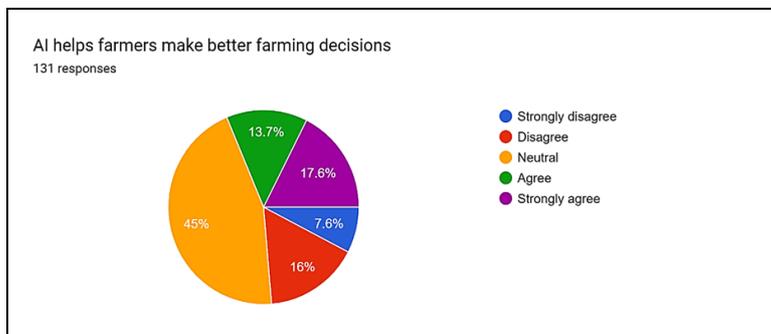131 responses

Table No.3 shows the respondents' views on whether AI helps farmers make better farming decisions. More than half of the participants 52.67 percentage of the respondent remain neutral on this point. About 31.29 percentage of the respondent agree that AI supports better decision-making, while 23.66 percentage of the respondent disagree with this idea. This shows that many respondents are still uncertain about how AI can assist farmers in making informed decisions.

Table 4: Modern agricultural technologies contribute to sustainable farming

Indicators	Agree	Disagree	Neutral	Strongly agree	Strongly disagree	Total
Rural	5(23.80)	3(20)	8(14.03)	3(9.67)	4(57.14)	23(17.55)
Semi-urban	4(19.04)	3(20)	16(28.07)	3(9.67)	2(28.57)	28(21.37)
Urban	12(57.14)	9(60)	33(57.89)	25(80.64)	1(14.28)	80(61.06)
Total	21(16.03)	15(11.45)	57(43.51)	31(23.66)	7(5.34)	131(100.00)

Source: *Primary data*

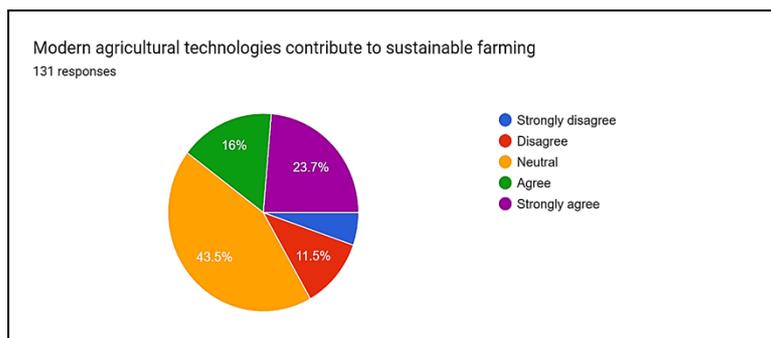Modern agricultural technologies contribute to sustainable farming
131 responses

Table No.4 shows the respondents' views on whether modern agricultural technologies support sustainable farming. A large portion of respondents remain neutral 43.51 percentage of the respondent. However, 39.69 percentage of the respondent (agree + strongly agree) believe that modern technologies contribute to sustainability, while 16.79 percentage of the respondent (disagree + strongly disagree) do not share this view. This shows that although many respondents are still uncertain, a considerable number recognize the role of modern technologies in promoting sustainable farming.

12. Testing of Hypothesis
Primary data Table 3 said that there are 31.29 percentage of respondents agree that AI helps in better farming decisions, while 23.66 percentage of the respondent disagree and 52.67 percentage of the respondent remain neutral. Since the percentage of agreement is higher than disagreement, it indicates a positive opinion towards the role of AI in decision-making. Hence, Alternative Hypothesis (H_1) is accepted and Null Hypothesis (H_0) is rejected.
Table 4 said that there are 39.69 percentage of respondents agree that modern technologies contribute to sustainable farming, whereas only 16.79 percentage of the respondent disagree and 43.51 percentage of respondent are neutral. The higher agreement shows recognition of the importance of modern technologies in sustainable agriculture. Hence, Alternative Hypothesis (H_1) is accepted and Null Hypothesis (H_0) is rejected.

13. Conclusion
This study combines doctrinal and non-doctrinal research to give a complete picture of how AI is shaping agriculture. The doctrinal part, based on theories, policies, literature, and case laws, explains why AI has the potential to improve productivity, sustainability, and climate resilience when supported by proper education, infrastructure, and legal safeguards. It highlights the importance of government support, extension services, and ethical regulation. In contrast, the non-doctrinal findings show the real situation of farmers on the ground. Many farmers are aware of modern tools, but actual adoption is low due to cost, lack of digital literacy, and poor infrastructure. The survey also reveals gender gaps and regional digital divides. Farmers who received training showed more confidence in using AI tools. While AI helps in better irrigation, pest control, and decision-making, practical barriers slow its use. Together, both approaches show that AI should support, not replace, traditional farming knowledge.

14. Suggestion
i). Farmers need simple, practical training to understand how AI tools work in real farming conditions. Hands-on workshops, demonstration farms, and guidance through

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extension services can reduce fear and improve confidence in using technology.

ii). Reliable internet connectivity and access to digital devices are essential for AI-based farming. Strengthening mobile networks and rural digital infrastructure will make these tools accessible to more farmers.

iii). High initial costs prevent small and marginal farmers from adopting AI technologies. Government subsidies, low-interest loans, and shared equipment models can make these tools affordable.

iv). Many farmers are comfortable using mobile phones. Simple AI advisory apps in regional languages can improve understanding and encourage wider adoption.

v). Extension officers should act as a bridge between technology providers and farmers by offering continuous support, guidance, and follow-up assistance.

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