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THE DIGITAL MONSOON: HARNESSING AI TO CULTIVATE RESILIENT INDIAN AGRICULTURE

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ABSTRACT

Artificial Intelligence has the potential to fundamentally change the agricultural sector in India by making improvements to productivity, sustainability, and resilience. India has significant amounts of data and increasing investments in AI and the digital economy, but unfortunately, there is no systematic framework to harmonize AI with agriculture in particular. The study employs a literature-oriented SWOT analysis to assess the strengths, weaknesses, opportunities, and threats involved with the adoption of AI in Indian agriculture. Proposed hurdles include growing discrepancies in regulation, poor infrastructure, issues over data privacy, algorithmic bias, and threats of job losses from AI. Since regulatory experiences across different countries provide insights, India should develop sector-specific governance systems that balance innovation and the responsibilities attached to being an agent of socio-technical change. The study therefore recommends an India-focused policy blueprint that emphasizes ethical deployment of AI, trust-building mechanisms, and inclusive approaches that safeguard against the monopolization of markets, job losses, and digital inequality in agriculture.

1. INTRODUCTION

Artificial Intelligence (AI) is increasingly seen as a key enabler of economic transformation and societal growth globally. Global spending on Artificial Intelligence is projected to reach $632 billion by 2028 (IDC Research, 2024), highlighting the rapidly growing investment in AI technologies across industries. The possible scenarios of perspectives to adopt AI, emphasize the critical role of strategic decision-making, supported by effective policies and regulations, to harness AI's transformative potential responsibly and sustainably (Accenture, 2024). Several potential economic, political, and social costs are associated with the current trajectory of AI technologies (Acemoglu, 2023). In parallel, the key challenge for India's policymakers lies in navigating the development of AI by building trust while ensuring sufficient flexibility for innovation. This demands intelligent regulation to keep pace with AI's accelerated innovation cycles, balancing immediate concerns and long-term economic integration.

Despite India's potential to lead AI development, there is a lack of comprehensive, sector-specific frameworks to guide AI adoption, particularly in agriculture. This research explores the critical challenges and key considerations that should inform the development of policies for AI-driven advancement in India's agricultural sector, through a literature-led SWOT analysis, and delve into the potential of an unregulated AI. Focusing on agriculture—one of India's vital sectors—the study examines how AI can significantly enhance productivity, sustainability, and rural livelihoods (ICRIER, 2020). The study offers insights into designing AI regulations that align with India's agricultural realities, ensuring sustainable and inclusive growth. This study seeks to address the challenges by investigating supporting regulatory frameworks required for AI-driven development in agriculture in India. It goes on to examine how regulations could ensure responsible and ethical adoption of AI in a way that nurtures innovation while creating avenues for accountability. This study, by outlining the sector-specific regulatory challenges and opportunities unique to Indian agriculture, enhances the understanding of how AI adoption can be governed effectively.

2. METHODOLOGY

The present study applies an exploratory qualitative research design reliant on secondary data collection itself. The intention of this study is to use comparative policy review, content analysis, and case-based approach within the broad design in investigating trends in the adoption and regulation of artificial intelligence policy within India. The research then anchors this topic of research within the case analysis framework of SWOT of artificial intelligence. Semi-structured conversations were held with 2-3 stakeholders across the agricultural sector to ensure that the framework was grounded in real-world experience.

3. LITERATURE REVIEW

The transformation across the globe is caused by technological development, increasing investments in the global economy, and numerous applications in various industries with particular regional shapes and contexts due to differences in policies. This transformation is not only reshaping industries but also redefining the way economies and societies function on a global scale. In recent years, investments in AI have been increasing in India because now private and government sectors realize the promise of AI in spearheading economic development. India has more than 700 million web users and is one of the world's largest data repositories (Ministry of External Affairs, 2023). It all comes together to be a complete hub for the development of artificial intelligence. AI, by 2035, can make large-scale improvements to the economic performance of the nation by raising the average yearly growth rate for gross value added by up to fifty percent (Accenture, 2017). The government's strategic plans, like the National Strategy for Artificial Intelligence led by NITI Aayog, would utilize this potential of AI for national growth.

Unfortunately, despite these optimistic developments, several issues affect its application in India, such as the inaccessibility of expertise, the weak awareness of the industry regarding the gains of AI, and laws and regulations. According to international estimates, India's AI Preparation Index (AIPI) of 0.49 (IMF, 2023) indicates its much-delayed readiness to scale up large AI and innovation compared to many other countries in the world. The gaps in regulations are even worsened by the global advances in AI technology, which raises the fears of possible threats AI could pose, such as privacy invasion, bias through algorithms, and job loss. Too much diversity and socioeconomic complexity in India presents further complications so uniform AI policies can increasingly be very difficult to practice across regional, sectoral, and government levels. Where AI will revolutionize industries for India, the country needs to consider how different regulatory regimes are more likely to balance ethical issues against growth imperatives. In other words, it is essential to consider how AI could address sector-specific issues while adhering to economic objectives that are overall objectives India seeks to address as it constructs sound and inclusive regulatory frameworks.

4. NAVIGATING AI ADOPTION

The adoption of AI in India's agriculture sector involves a range of stakeholders, including farmers, government bodies, and industry players like agri-tech companies and food processors. It also includes labor unions, civil society organizations, and international bodies like FAO, all working together to ensure the transition is fair, sustainable, and beneficial for all. The integration of modern AI technologies requires finding a balance between innovation and more old-fashioned techniques of farming that have sustained rural communities for generations. Table 1 provides an overview of an all-encompassing SWOT analysis on AI adoption in agriculture, while Tables A1 and A2 in the appendix would break it down on a more detailed aspect-specific level, examining the nuanced challenges and prospective advantages in detail.

Table 1

Strengths (S)	Weaknesses (W)	Opportunities (O)	Threats (T)
- EfficiencyImprovements in Agricultural Practices - Improved Accuracy and Decision- Making - Sustainability Support - Resource Management Optimization - Increased Productivity and Harvest Efficiency - Enhanced Supply Chain and Market Efficiency - Data-Driven Precision	- High Initial Investment - Limited Access to Technological Resources - Need for Skilled Labor - Technological Barriers in Traditional Farming Practices - Complexity of Integrating Multiple Technologies - Insufficient Data Availability - Reliability and Robustness of AI Models	- Optimized Crop Management - Pest Control - Irrigation Management - AI-Powered Weed Detection - AI in Forest Management - Neural Networks for Rainfall Forecasting - Land Suitability Assessment - Real-Time Supply Chain Monitoring - AI Tools for Data Processing	- Infrastructure Costs - Dependence on Large Datasets - Regional Disparities - Training Requirements for Labor - Reduced Human Expertise - Farmer Adoption Challenges - High Learning Curve - Climate Sensitivity - Risk of Incorrect Predictions

Source: *Author's Compilations*

Farmers in India can now use advanced AI-driven techniques in precision farming to save more on resource utilization, which will in effect provide greater crop production with lesser input costs. (Spanaki et al., 2021) With productivity growing before the very active application of AI, this can create direct positive effects on the country financially. Smart farming uses low fertilizer and pesticide while enhancing crop quality; thus, the profit per unit area is raised even without conceptually increased input costs. Meanwhile, automation in agriculture, through drones and robotic harvesting and AI-driven monitoring, contributes to less reliance on labor, especially as it becomes costly and lacks availability. (Spanaki et al., 2021) Beyond the farm, AI creates the opportunity to improve supply chain efficiency and thus is one of India's biggest agricultural challenges-outside postharvest losses.

While AI could change the course of Indian agriculture, this isn't true because of its high initial investment costs (Banerjee et al., 2018) and barriers to both small and marginal farmers who dominate the big sector in the Indian market. Advanced AI-powered tools like precision irrigation, automated machinery, and predictive analytics remain largely inaccessible, widening the gap between large agribusinesses and small-scale farmers. (Ryan, 2023) Affordability aside, digital literacy and trust in AI technology also form even larger barriers, as farmers get their codes from generation to generation, as well as by using conventional farming practices. Without proper training and support, AI integration into daily agricultural practices can be intimidating, slow to adopt, and underutilized. Not to mention that AI and food production are already bartered with livelihood and security, so trust in technology becomes essential. (Banerjee et al., 2018) If AI is deployed to merely increase efficiency but not create systemic change to address

inequalities, it is risky for creating and strengthening size differences, thus reducing the autonomy of farmers. Rather than simply optimizing an already skewed system, AI should help build a more inclusive, resilient, and sustainable agricultural landscape. The current food system is trending into greater unsustainability and injustice; in this sense, any effort to enhance it with intelligent applications might tend to aggravate inequities instead of solving them. (Mehta et al., 2019) Thus, it is important to understand the possibilities and feasibilities of AI in agriculture, in order to optimally regulate it.

5. RISKS, ETHICS AND RIGHTS

Data

- Data is the foundation of AI adoption, enabling machine learning, automation, and decision-making across sectors.
- AI performance depends on availability, quality, and diversity of data, but faces challenges related to interoperability, accessibility, and standardization.
- Agriculture AI relies on IoT sensors, satellite imagery, and yield records, but inconsistent data collection and digitization disparities limit its effectiveness (Ryan, 2023).
- Building trust in AI-driven food technologies is essential, and collaboration with diverse growers and producers can improve data quality and reduce bias (Alexander et al., 2024).
- Open data policies, standardized frameworks, and collaborative data-sharing agreements are essential for scalable, ethical, and trustworthy AI adoption.

Data Security and Privacy: Protecting People, Not Just Information

- Every data point represents an individual’s identity, choices, and privacy.
- Ethical handling, privacy protection, and accountability must take precedence to prevent identity theft, surveillance misuse, and AI-driven discrimination.
- Strong encryption, transparent data policies, and usage control are essential to ensure AI empowers individuals

rather than exploits them.

- AI-enabled precision farming, yield prediction, and supply chain analytics raise concerns over data ownership, as large agribusinesses often control and manipulate farmers' data, leading to fears of exploitation and price manipulation (Ryan, 2023).

Trust

- Trust is a key pillar in AI adoption, influencing user acceptance, reliability, and ethical deployment.
- Lack of transparency in AI decision-making creates distrust, as black-box algorithms make predictions difficult to interpret.
- Farmers struggle to trust AI-driven weather, soil, and yield predictions due to opaque models and unexplained recommendations (Marda, 2018).

Explainability

- Explainability is crucial for AI's social acceptance, but trust, accountability, and ethical compliance remain challenges with black-box models (Barton et al., 2019).
- Agriculture AI in crop yield prediction and soil monitoring lacks transparency, preventing farmers from verifying insights.

Freedom, Justice, and Fairness

- AI adoption raises concerns about freedom, fairness, and justice, as opaque algorithms and biased models risk reinforcing social inequalities.
- Corporate control of AI-driven agricultural data limits farmers' freedom to access and utilize their own information.
- Rapid technological advancements have created uncertainty in IPR, particularly regarding data ownership, AI-generated works, and patent eligibility (Khan, 2024).
- In agriculture, AI-driven crop models rely on farmer data, yet agrochemical companies claim ownership, limiting farmers' control over AI outputs.

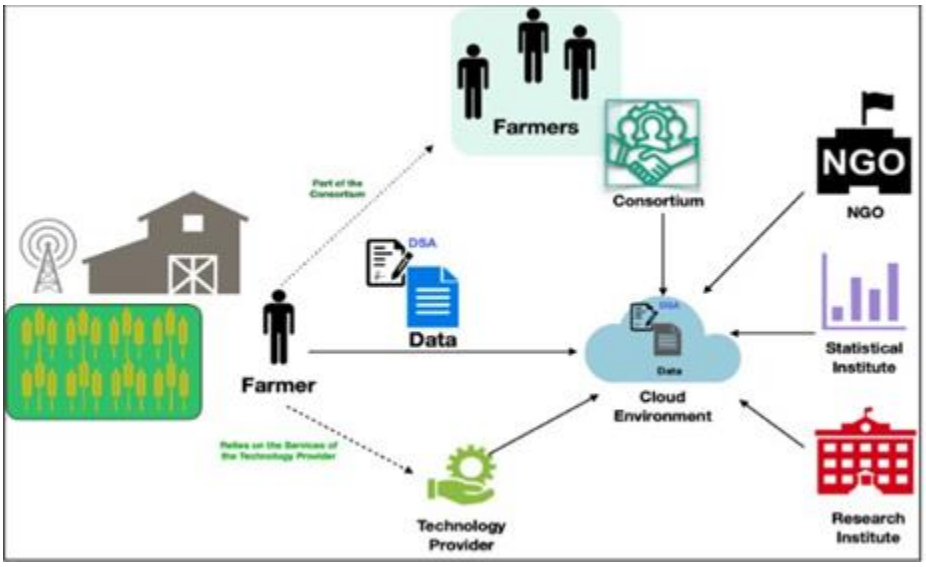
6. POLICY BLUEPRINT

- AI models should be interpretable and auditable, particularly in high-risk sectors such as healthcare, criminal justice, and finance. Policies should mandate clear documentation and explainable AI models in critical sectors like agriculture. (EU AI Act, 2021)
- AI must be free from systemic bias, requiring diverse datasets and fairness audits before deployment. (UNESCO)
- AI adoption should comply with India's Digital Personal Data Protection Act, ensuring data minimization, encryption, and user consent mechanisms. (parallel to EU General Data Protection Regulation)
- In agriculture, data generated by AI-enabled precision agriculture and supply chain analytics are under the control of agribusiness corporations to a great extent, with very little control left in the hands of farmers. (Ryan, 2023)
  - Farmers will retain ownership and control over their data in the establishment of AI-supported agricultural data repositories nationwide. Farmers generate and share data under a Data Sharing Agreement (DSA). (Spanaki et al., 2021)

- The data is stored in a cloud environment for accessibility. A consortium of farmers, NGOs, and research bodies ensures ethical use.
- Technology providers support farmers with digital tools and services.
- The system enables research, policymaking, and better farming practices.
- Mandate interpretable AI algorithms for yield forecasting, soil monitoring, and pest control.

7. IMPLEMENTATION STRATEGY

- Establishment of AI Governance & Regulatory Body to oversee AI implementation across all sectors. (eg.: National AI Ethics Council of India, which now doesn't exist)



Source: *(Spanaki et al., 2021)*

- Set up sector-specific AI governance units in agriculture, and law enforcement.
- Expertise-in-need policies should include upskilling practices, interdisciplinary studies, and hands-on learning to prime the up-coming AI professional.
- Partnership between the educationalists, policy leaders, and business sector professionals, without bridging the AI and workforce big chasm, favoring innovation along with retention of a nature-centered approach in AI.
- Expert involvement at all stages of data handling-from collection and processing through analysis and advisory-ensures accuracy, transparency, and ethical compliance on the decisions being made with that data. Thus having sector specific data repositories, with ethical considerations.
- Public-Private Collaboration & AI Talent Development
- Integrate AI education and hands-on learning into workforce training programs.
- Encourage AI research collaborations between government, academia, and industry.
- Promote AI Startup Ecosystems with funding for ethical AI innovations.

8. INDIA'S CURRENT AI USAGE AND STAKEHOLDER'S WORDS

The Indian government has allocated a significant budget for AI Research Centres of Excellence (CoE) in Artificial Intelligence (AI) in 2025, marking a watershed moment for the ethical way forward for AI, risk containment, and regulatory supervision. KissanAI is revolutionizing Indian agriculture with AgriCopilot, which combines various data into a singular platform. It has a multilingual, voice-enabled interface that makes it accessible to farmers-motivating those literally disadvantaged and enabling them to use the service. It partnered with the UNDP and launched a Climate-Resilient Agriculture chatbot, giving real-time weather and resource management information. Besides, the deep vision-language models from KissanAI- Dhenu Improved significantly help in crop disease detection. In effect, it is all about optimal input usage, healthier crops, and reduced climate and market risk for productivity, sustainability, and better decisions in the whole Indian agricultural sector.

Stakeholders are quite receptive and optimistic to adapt AI in respective sectors. However they urge us to focus on Need vs Want in all sectors. For example, is it really a need in the Agricultural sector to adopt AI in minor tasks and expertise, where traditional knowledge is already efficient and cheaper. Since India is dominated by small and marginal farmers, it is difficult to implement high cost AI gpu in fields. But for someone to start farming as a new plan, these opportunities could help.

9. CONCLUSION

India is at a very crucial crossroads in which AI must be adopted in a human-centric, ethical and inclusive manner-as far as innovation should not compromise any fairness from privacy or well-being to society. Agriculture-oriented sector-wise AI governance centers, with accompanying standardized repositories, regulatory oversight, and guidelines, will be instrumental in bridging the rural digital divide, waylaying algorithmic bias, and giving power to smallholders and indeed saving their livelihoods. Therefore, these centers should encourage collaborations between AI practitioners, policymakers, agronomists, and legal practitioners to develop intelligible and trustworthy AI tools specific to the diverse Indian agricultural landscape. Responsible AI should focus on strengthening farmers instead of countering traditional knowledge systems. Ethical governance of AI in agriculture will see India emerge as an international model for how technology can provide sustainable and inclusive development for farming communities. AI decisions can perpetuate differences, can be non-transparent, and can have unsafe outcomes when misused. For keeping AI workable and under control continuous adaptation, ethical policies, and collaboration with all actors are important.

REFERENCES

Accenture. (2017). REWIRE FOR SUCCESS: BOOSTING INDIA'S AIQ.

Accenture. (2024). *Work, workforce, workers: Reinvented in the age of generative AI.*

Acemoglu, D. (2023, 7 18). Harms of AI. *The Oxford Handbook of AI Governance*, 660-706. https://doi.org/10.1093/oxfordhb/9780197579329.013.65

A. H. Manek and P. K. Singh, "Comparative study of neural network architectures for rainfall prediction," 2016 IEEE Technological Innovations in ICT for Agriculture and Rural Development (TIAR), Chennai, India, 2016, pp. 171-174, doi: 10.1109/TIAR.2016.7801233. Alexander, S. C., Yarborough, M., & Smith, A. (2024). Who is responsible for 'responsible AI'?: Navigating challenges to build trust in AI agriculture and food system technology. Precision

Agriculture, 25(1), 146–185. https://doi.org/10.1007/s11119-023-10063-3

Banerjee, G., Sarkar, U., Das, S., & Ghosh, I. (2018). Artificial Intelligence in Agriculture: A Literature Survey. International Journal of Scientific Research in Computer Science Applications and Management Studies, 7(3). www.ijsrcsams.com

Barton, N.T.-L., Resnick, Paul, Genie, 2019. Algorithmic Bias Detection and Mitigation: Best Practices and Policies to Reduce Consumer Harms.

European Commission (2021). Artificial Intelligence Act Proposal. European Commission

Garske, B., Bau, A., & Ekardt, F. (2021). Digitalization and aid in European agriculture: A strategy for achieving climate and biodiversity targets? Sustainability (Switzerland), 13(9). https://doi.org/10.3390/su13094652

Google Cloud. (n.d.). *What is Artificial Intelligence?* Google cloud. https://cloud.google.com/learn/what-is-artificial-intelligence#artificial-intelligence-defined

IDC Research. (2024, 8 19). *Worldwide Spending on Artificial Intelligence Forecast to Reach $632 Billion in 2028*. https://www.idc.com/getdoc.jsp?containerId=prUS52530724

IMF. (2023). AI Preparedness Index. IMF. https://www.imf.org/external/datamapper/AI_PI@AIPI/ADVEC/EME/LIC

Khan, A. (2024). THE INTERSECTION OF ARTIFICIAL INTELLIGENCE AND INTERNATIONAL TRADE LAWS: CHALLENGES AND OPPORTUNITIES. In IIUM LAW JOURNAL (Vol. 32, Issue 1).

Marda, V. (2018). Artificial intelligence policy in India: a framework for engaging the limits of data-driven decision-making. Phil. Trans. R. Soc. http://dx.doi.org/10.1098/rsta.2018.0087

Mehta, L., Huf, A., & Allouche, J. (2019). The new politics and geographies of scarcity. Geoforum, 101, 222–230. https://doi.org/10.1016/j.geoforum.2018.10.027.

Ministry of External Affairs. (2023, 3 16). *India had over 700 mn active internet users by Dec '22: Report*. India had over 700 mn active internet users by Dec '22: Report. https://indbiz.gov.in/india-had-over-700-mn-active-internet-users-by-dec-22-report/#:~:text=I
ndia%20had%20over%20700%20million,areas%2C%20with%20295%20million%20users.

Ngozi, C. E.-C. (2019). Applications of Artificial Intelligence in Agriculture: A Review. In Technology & Applied Science Research, 9(4). www.etasr.com

Spanaki, K., Karafili, E., & Despoudi, S. (2021). AI applications of data sharing in agriculture 4.0: A framework for role-based data access control. International Journal of Information Management, 59. https://doi.org/10.1016/j.ijinfomgt.2021.102350

Sparrow, R., Howard, M., & Degeling, C. (2021). Managing the risks of artificial intelligence in agriculture. NJAS: Impact in Agricultural and Life Sciences, 93(1), 172-196. https://doi.org/10.1080/27685241.2021.2008777

Ryan, M. (2023). The social and ethical impacts of artificial intelligence in agriculture: mapping the agricultural AI literature. AI and Society, 38(6), 2473-2485.

https://doi.org/10.1007/s00146-021-01377-9 https://www.unesco.org/en/artificial-intelligence/recommendation-ethics

https://kissan.ai/

APPENDIX

Table A1: Agriculture- AI's Strengths and Opportunities

Strengths (S)	Opportunities (O)
Efficiency Improvements in Agricultural Practices	- AI-powered crop management optimizes pest control, fertilization, boosting yields while minimizing resource waste. (Alexander et al., 2024) - Emerging AI-driven robots aid in crop scouting, pest control, pruning, spraying, milking, and sorting but are not yet widely commercialized. (Ngozi, 2019) - Machine vision and image recognition systems facilitate automated fruit picking, weed detection, handling, processing, and packaging of agricultural goods. (Sparrow et al., 2021)
Improved Accuracy and Decision- Making	- AI tools like COTFLEX, COMAX, neural networks, and imaging systems highlight AI's ability to process agricultural data for better decisions. (Banerjee et al., 2018) - AI predicts pest and disease spread, enhancing prevention strategies. (Garske et al., 2021) AI-powered vehicles and robots precisely detect and remove pests and weeds. (Banerjee et al., 2018) - Neural network models enhance rainfall forecasting using atmospheric data, supporting efficient water resource management. (Manek & Singh, 2016)
Sustainability Support	- AI aids in monitoring peatlands, tracking deforestation, and improving forest management for conservation and carbon storage. (Sparrow et al., 2021) - AI-integrated digital platforms aggregate data to optimize agricultural decision-making while measuring ecological footprints. (Garske et al., 2021)
Resource Management- Optimization	- AI-driven irrigation models optimize micro-irrigation systems, ensuring efficient water usage. AI enhances soil moisture estimation using artificial neural networks, improving irrigation scheduling and reducing water wastage. (Banerjee et al., 2018)
Increased Productivity	- AI models improve land suitability assessment by leveraging fuzzy logic-based systems to recommend appropriate crops based on soil and Harvest Efficiency climate conditions. (Banerjee et al., 2018)
Enhanced Supply Chain and Market Efficiency	- AI facilitates real-time monitoring of agricultural supply chains, reducing inefficiencies and optimizing logistics. (Sparrow et al., 2021)
Data-Driven Precision	- AI integrates satellite imagery, IoT sensors, and predictive analytics to enhance real-time decision-making, improving overall farm management. (Garske et al., 2021)

Source: *Author's Compilations*

Table A2: Agriculture- AI's Weaknesses and Threats

Weaknesses (W)	Threats(T)
High Initial Investment	- Advanced AI models, such as Takagi-Sugeno-Kang fuzzy inference systems, require high computational resources, making them expensive to implement, especially for small-scale farmers. (Banerjee et al., 2018) - The adoption of deep learning and hybrid AI models demands significant investment in computational power and supporting infrastructure, making it financially burdensome for resource-constrained farms. (Garske et al., 2021)
Limited Access to Technological Resources	- AI models require extensive training on large datasets, which may not always be available for all crops and regions, limiting their effectiveness. (Alexander et al., 2024) - Farmers in remote or underdeveloped areas may lack access to AI-driven agricultural tools due to poor internet connectivity, limited infrastructure, and inadequate financial resources. (Banerjee et al., 2018)
Need for Skilled Labor	- AI-driven models often require technical expertise, making it challenging for traditional farmers to adopt them without proper training programs. (Ryan, 2023) - With too much reliance on AI automation for such tasks as pest control and irrigation, human diligence and expertise may evolve to become passive, thus diminishing their ability to adapt in unforeseen conditions. (Banerjee et al., 2018)
Technological Barriers in Traditional Farming Practices	- Many traditional farmers may resist AI adoption due to its complexity, requiring tailored awareness programs and user-friendly interfaces to facilitate integration. (Ryan, 2023)
Complexity of Integrating Multiple Technologies	- AI integration with existing farming technologies, such as IoT sensors, satellite imagery, and automated machinery, may require advanced compatibility solutions, increasing implementation complexity. (Garske et al., 2021) - Combining multiple AI-driven systems for irrigation, pest detection, and crop management necessitates significant learning efforts, delaying adoption in certain agricultural sectors. (Sparrow et al., 2021)
Insufficient Data Availability	- AI models need continuous updates with region-specific data, and insufficient or outdated datasets may reduce their accuracy and reliability. (Garske et al., 2021)
Reliability and Robustness of AI Models	- AI-driven irrigation and crop prediction models may struggle with extreme weather variability, and reliance on AI without human oversight can lead to inaccurate pest control and fertilization decisions, impacting crop health. (Banerjee et al., 2018)

Source: *Author's Compilations*