WE
Vol 6 No. 2
December 2025

e-ISSN: 2583-2298

LEVERAGING E-RESOURCES AND DIGITAL KNOWLEDGE PLATFORMS FOR ENHANCING IoT AND AI-BASED INTERCROPPING SYSTEMS: ATAM-2 AND UTAUT-1 BASED CONCEPTUAL FRAMEWORK FOR SMART SUSTAINABLE AGRICULTURE

Neeraj Kumar[*]
Hemant Kumar Katiyar[**]

ABSTRACT

The digital revolution in agriculture offers a chance to transform intercropping systems with Internet of Things (IoT), Artificial Intelligence (AI), and E-Resources. In this article, we propose a conceptual model of digital knowledge platform usage in AI- and IoT-supported intercropping, drawing on the TAM2 and UTAUT1. Integrating behavioral, technical, and contextual determinants, the research describes how intercropping stakeholders, such as farmers, researchers, and agri-extension agents, engage with digital platforms to achieve sustainability and productivity objectives. Important constructs such as perceived usefulness, job relevance, facilitating conditions, and social influence are translated to agricultural use cases. The proposed conceptual model offers a platform for future empirical validation and enables the design of user-focused, scalable solutions in smart sustainable agriculture.

Keywords: *Smart Agriculture, Intercropping 4.0, E-Resources, Digital Knowledge Platforms, IoT in Farming, Artificial Intelligence, TAM-2, UTAUT-1, Technology Adoption, Sustainable Farming.*

1. INTRODUCTION

1.1 Intercropping Background in Smart Agriculture

Intercropping, or the cultivation of two or more crops together, has long been recognized as a sustainable farming method that increases biodiversity, soil quality, and land use. Done for centuries in low-input agriculture systems, intercropping is now undergoing a revolution with the use of innovative agriculture technologies, making it more data-driven, efficient, and scalable. In the name of Agriculture 4.0, intercropping is being reimagined with the help of Internet of Things (IoT) sensors, Artificial Intelligence (AI) algorithms, and real-time data analysis to enable accurate crop selection, monitor soil conditions, control pests, and predict yields.

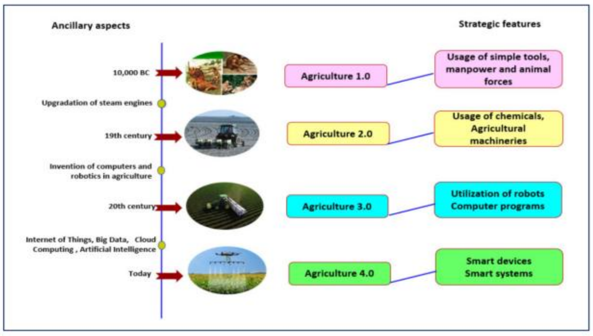

Fig. 1.1: Agricultural Decision Support System Framework

1.2 Importance of IoT, AI, and Digital Knowledge Systems

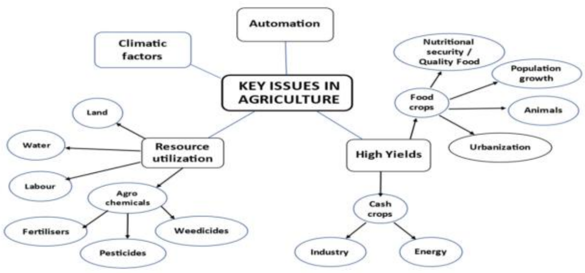

Fig. 1.2: Key Issues in Agriculture

[*]Research Scholar, DLIS, Banasthali Vidyapith, Rajasthan; Email: dheerajkumarmadal96@gmail.com
[**]Research Scholar, DLIS, Banasthali Vidyapith, Banasthali, Rajasthan

The integration of IoT and AI with agriculture has opened doors to upgrade intercropping systems with prescriptive decision-making, automatic monitoring, and adaptive resource management. IoT sensors can capture live environmental and crop conditions, and AI can analyze it to provide actionable intelligence. But the full potential of these technologies will only be unleashed when integrated with e-resources and digital knowledge platforms — such as agricultural databases, cloud-based decision support systems, weather APIs, and open-access repositories. These platforms offer context-aware knowledge and recommendations to help farmers and stakeholders implement innovative intercropping practices effectively.

2. PROBLEM STATEMENT AND RESEARCH GAP

Though there is growing interest in smart agriculture, there remains a wide research gap in stakeholders' adoption behavior of e-resources and digital platforms, especially in the context of AI- and IoT-enabled intercropping systems. Though some literature has made passing references to technology adoption in general agricultural contexts, there is limited research that has borrowed from well-established models like Technology Acceptance Model 2 (TAM2) and Unified Theory of Acceptance and Use of Technology (UTAUT1) to examine how farmers, agronomists, and extension workers adopt digital knowledge systems in intercropping contexts. Conceptual ambiguity prevents the design of effective digital adoption plans and training programs.

3. PURPOSE OF THE STUDY AND SCOPE OF THE PAPER

This paper aims to develop a conceptual model that integrates TAM2 and UTAUT1 to describe the adoption of e-resources and digital knowledge platforms for IoT and AI-based intercropping systems. By applying psychological and social constructs to the technologies of Agriculture 4.0, the model seeks to advance understanding of user behavior and guide the design of digital tools that are easier to use, more acceptable, and more effective for sustainable agriculture. The scope of the paper is conceptual and theoretical, and it is intended to provide a foundation for empirical research, system design, and policy interventions in smart intercropping and sustainable agriculture.

4. LITERATURE REVIEW

4.1 Development of Smart Agriculture and Intercropping 4.0

Agriculture has undergone a revolutionary transformation over the past few decades, from labor-based and mechanized systems to digitally enabled smart agriculture, or Agriculture 4.0. It is characterized by the integration of high-tech technologies, such as AI, IoT, remote sensing, robots, and data analytics, into agricultural systems. In this context, intercropping 4.0 is an advanced form of traditional intercropping powered by real-time data-driven decision-making, sensor networks, and precision resource management. Innovative intercropping methods aim to enhance crop compatibility, improve land-use efficiency, and reduce reliance on chemical inputs by leveraging multi-source data and algorithmic expertise. The trend is consistent with global sustainability goals and the increasing pressure on agricultural systems to do more with less amid climate uncertainty and land degradation.

4.2 The Role of E-Resources and Digital Knowledge Platforms in Agriculture

E-resources such as digital libraries, cloud-based agronomic databases, weather-forecasting websites, mobile advisory apps, and precision agriculture portals play a critical role in contemporary agriculture. These websites provide farmers, scientists, and extension officers with real-time, location-specific, evidence-based agricultural information.

Intercropping systems require access to accurate information on crop compatibility, soil condition, pest dynamics, and environmental conditions to maximize yields. Digital knowledge systems bridge the gap between raw sensor data and valuable information. They support context-aware decision-making, training, remote diagnosis, and policy dissemination. However, the usability and effectiveness of these e-assets depend on their availability, simplicity of use, and alignment with local agronomic procedures and user routines.

4.3 IoT and AI Application in Intercropping Systems

The combination of IoT and AI in intercropping networks has gained momentum, with the potential to enhance precision and sustainability. IoT-based sensors such as soil moisture sensors, weather stations, drone-based imagery sensors, and smart irrigation controllers deliver data at a granular level, enabling micro-level decisions. AI models, ranging from machine learning algorithms to expert systems, process these datasets to provide crop advice, disease prediction, and yield prediction.

For the situation of intercropping, these technologies may assist:

a) Selecting optimum crop combinations based on microclimatic data
b) Monitoring between-species relations for nutrient exchange
c) Forecasting pest infestation and recommending control measures
d) Automation of fertilizer and irrigation delivery for meeting crop requirements

However, technology deployment needs to be followed by digital literacy, stakeholder involvement, and user trust, which calls the role of behavioral adoption models into question.

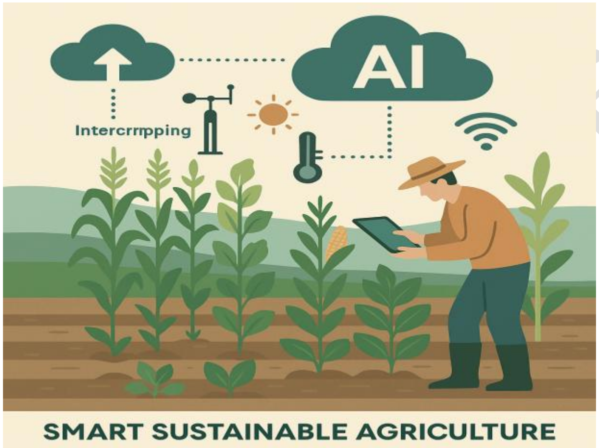

Fig. 4.3: Smart Sustainable Agriculture

4.4 Agricultural Technology Adoption: Review of TAM2 and UTAUT1

Their successful implementation in agriculture depends on environmental, behavioral, and user perception factors. Two of the most widely recognized models in this regard are:

a) TAM2 (Technology Acceptance Model 2)

TAM2 was developed by Venkatesh and Davis in 2000 and extends the original TAM with some extra constructs, including:

a) Subjective Norm: Social norms' effect
b) Image: The emergence of professional status
c) Job Relevance and Output Quality: Perceived usefulness in some tasks
d) Result Demonstrability: Tangibility of benefits

TAM2 is particularly relevant in farm environments, where peer pressure, organizational support, and experiential outcomes strongly influence the uptake of tools.

b) UTAUT1 (Unified Theory of Acceptance and Use of Technology)

UTAUT1, by Venkatesh et al. (2003), brings together eight earlier models into a single framework, providing:

a) Performance Expectancy
b) Effort Expectancy
c) Social Influence
d) Facilitating Conditions

This model is especially appropriate for studying the adoption of e-resources in intercropping systems, particularly in rural or resource-constrained settings where infrastructure and training shape behavior and use.

4.5 Gaps in Existing Research

Although some studies investigate the benefits of innovative agriculture technologies and behavior adoption models individually, few have combined these approaches in the context of AI- and IoT-based intercropping. There is a clear gap in:

a) Theoretical simulation of the possibility of using TAM2 and UTAUT1 together to study the adoption of digital knowledge platforms in agriculture
b) Recognizing the behavioral drivers and deterrents of adopting e-resources for smart intercropping
c) Regionally flexible frameworks that account for socio-technical dynamics.
d) This paper fills such gaps by suggesting an integrated conceptual framework that aligns TAM2 and UTAUT1 constructs with the digital transformation of intercropping systems in the adoption of e-resources.

5. THEORETICAL BASIS

5.1 Technology Acceptance Model 2 (TAM2): Salient Constructs and Relevance

Venkatesh and Davis (2000) developed the Tech Acceptance Model 2 (TAM2), an extension of the original TAM, to provide a more detailed explanation of why users adopt or reject technology. TAM2 adds cognitive and social influence processes as further determinants of technology use.

a) Important Concepts of TAM2

i) **Perceived Usefulness (PU):** An expectation that the use of a technology will improve job performance.
ii) **Perceived Ease of Use (PEOU):** The perception that a technology will be easy to use.
iii) **Subjective Norm:** Pressure from others to use or not use a technology.
iv) **Image:** The degree to which the application of technology is seen to enhance an individual's standing within a social hierarchy.
v) **Job Relevance:** The extent to which the technology is relevant to the job of the user.
vi) **Output Quality:** The qualitative aspect of the output generated by the system.
vii) **Result Demonstrability:** The extent to which the outcomes of employing the system are apparent.

b) Relevance to the Adoption of E-Resources in Intercropping

In the context of smart intercropping, TAM-2 explains how farmers and stakeholders view digital platforms, mobile apps, and AI-based decision support systems. For instance, if digital platforms are viewed as offering quality, verifiable benefits (e.g., higher yields or cost reductions), perceived usefulness rises, and adoption follows. Likewise, if farmers perceive social approval (from agricultural extension officers or cooperatives), subjective norms can facilitate adoption.

5.2 Unified Theory of Acceptance and Use of Technology (UTAUT1): Major Constructs and Relevance

Venkatesh et al.'s (2003) Unified Theory of Acceptance and Use of Technology (UTAUT1) synthesizes aspects of eight leading models to provide a better explanation of user behavior and intention. UTAUT1 is specifically appropriate for public sector, organizational, and rural adoption.

a) Key Constructs of UTAUT1

i) **Performance Expectancy (PE):** The extent to which the technology adoption will be beneficial in carrying out specific activities.
ii) **Effort Expectancy (EE):** Would it be easy to use the system?
iii) **Social Influence (SI):** The extent to which individuals think that significant others believe they ought to use the system.
iv) **Facilitating Conditions (FC):** The extent to which someone feels that there is an organizational and technical infrastructure to facilitate use.

b) Relevance to Intercropping Adoption of E-Resources

UTAUT1 is particularly appropriate for assessing the effects of infrastructure, technical support, and peer support on the adoption of digital systems among rural farmers. For instance, the roll-out of mobile internet, government subsidies, or agri-extension services is highly related to enabling conditions. Performance expectancy is associated with the belief that digital tools will enhance crop management or profitability.

5.3 Comparative Analysis: TAM2 and UTAUT1 in Agricultural Technology Adoption

Table 5.3: TAM2 and UTAUT1 in Agricultural Technology Adoption

Aspect	TAM 2	UTAUT 1
Focus	Individual user beliefs and perception	Organizational and social influence
Core Strength	Describes usefulness and social image	Highlights the infrastructure and outer
Support Social Influence Factor	Subjective norm, image	Social influence construct
Cognitive Processing	Output quality, result demonstrability	Performance and effort expectancy
Ease of Application	Simple and centered on internal belief systems	More comprehensive and more suitable for group or rural research
Use in Agriculture	Often used to talk of individual farmer action	Suitable for understanding ecosystem readiness

In agriculture, UTAUT1 best captures abstract socio-technical drivers such as climate change, government programs, social norms, and internet-based knowledge—especially in developing nations. TAM2 best captures individual experience and motivation in agriculture.

5.4 Integration of TAM2 and UTAUT1 in the Context of Adopting E-Resources

To comprehensively examine e-resource uptake in IoT and AI-based intercropping systems, existing research proposes a hybrid conceptual framework that integrates key elements of TAM2 and UTAUT1. The incorporation offers a multi-faceted assessment that considers:

a) **Cognitive Beliefs:** (PU, PE, Job Relevance, Output Quality) of TAM2
b) **Social Influences:** (Subjective Norm, Image, Social Influence) of both models
c) **Technical & Organizational Support:** (Facilitating Conditions, Infrastructure Readiness) of UTAUT1
d) **User Effort & Experience:** (PEOU, EE) usability measurement & user training requirements
e) **Behavioral Intention:** Ultimate driver of e-resource actual use in intercropping contexts

This integrated framework represents both individual-level technology awareness and system-level adoption facilitators, making it suitable for modeling digital technology use among smallholder, commercial, or institutional farms.

6. CONCEPTUAL FRAMEWORK

6.1 Suggested Framework for Adoption of E-Resources in Smart Intercropping

The proposed conceptual model integrates the behavioral and technological elements of TAM2 and UTAUT1 to predict and explain the adoption of e-resources by agricultural stakeholders in IoT- and AI-based intercropping systems. This model recognizes that effective implementation depends not only on user attitudes (e.g., ease of use, usefulness) but also on environmental factors (e.g., social influence, infrastructure), in the context of the digital revolution in agriculture. The model categorizes e-resources (sensor dashboards, decision support systems, mobile platforms, digital libraries) as the drivers of innovative technologies (AI, IoT, Big Data) and sustainable intercropping outcomes.

6.2 TAM2 and UTAUT1 Constructs Mapping to Agricultural Stakeholders

Different agricultural stakeholders—e.g., cooperatives, agri-extension officers, smallholder farmers, researchers, policymakers—utilize digital knowledge systems based on their roles, capacities, and social contexts. Below is the mapping of the most important constructs of TAM2 and UTAUT1 to the stakeholders:

Table 6.2: Mapping TAM2 and UTAUT1

Construct	Definition	Agricultural Stakeholder Application
Perceived Usefulness (TAM2)	Perception that e-resources enhance farming/intercropping productivity	Farmers embrace mobile platforms if they perceive higher yields

Perceived Ease of Use (TAM2)	Perception that the system is easy to use	Extension workers like using easy-to-use apps
Subjective Norm (TAM2)	Social expectation influence	Cooperation pressure can influence adoption
Image (TAM2)	Tech use enhances status	Early adopters gain social acknowledgment
Job Relevance (TAM2)	Would the technology be relevant to everyday tasks	Researchers measure the agronomic value of platforms
Output Quality (TAM2)	Belief that the system delivers high-quality outputs	Stakeholders believe in platforms with precise weather/yield information
Performance Expectancy (UTAUT1)	Technology helps achieve higher productivity	All stakeholders adopt tools expecting improved farming outcomes
Effort Expectancy (UTAUT1)	Simplicity of learning and system usage	Apps should be easy to use for farmers with minimal tech literacy
Social Influence (UTAUT1)	Peer, leader, or institution influence	Peer support enhances adoption
Facilitating Conditions (UTAUT1)	Infrastructure, training, support availability	Internet access, extension support critical for rural uptake
Behavioral Intention	System use willingness	Depicts future or planned adoption of e-resources

6.3 How IoT, AI, and Big Data Support the Adoption Framework

In the proposed architecture, IoT, AI, and Big Data are technology pillars that offer, process, and analyze agricultural data regarding intercropping systems. Their roles are:

a) IoT enables real-time data collection (Soil Moisture, Temperature, Crop Condition)
b) AI facilitates automated decision-making (Crop Selection, Yield Estimation, Pest Identification)
c) Big Data delivers contextual analytics (Identification of Patterns, Risk Analysis and Past Patterns)

These technologies are directed toward e-resources (mobile advisory platforms, knowledge portals) that serve as stakeholders' user interfaces to gain insights. TAM2 and UTAUT1 constructs regulate the adoption of these e-resources' behavior. In fact:

Technological Inputs (IoT, AI, Big Data) → processed through E-Resources → driven by Behavioral Constructs (TAM2, UTAUT1) → yields Adoption and Sustainable Intercropping Outcomes

6.4 Conceptual Model Diagram and Description

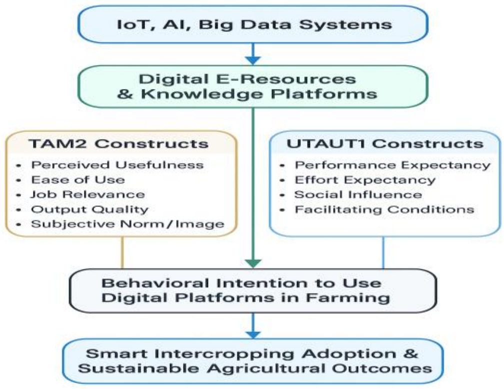

Fig. 6.4: Smart Sustainable Agriculture

Explanation:

a) Smart technologies (IoT, AI, Big Data) are operational backbones.
b) E-resources are the stakeholders' interface for delivery.
c) Adoption behavior is determined by infrastructural, social, and psychological determinants, as introduced in TAM2 and UTAUT1.
d) The result is the successful implementation of intelligent intercropping techniques that promote sustainability, productivity, and the digitalization of agriculture.

7. DISCUSSION

7.1 Policy and Practice Implications for Agriculture

The intersection of TAM2 and UTAUT1-based models on the use of digital platforms in intercropping provides lessons for agricultural extension services and policy. Policymakers can use the model to develop evidence-based interventions that increase technology adoption by:

a) Encouraging farmer-focused platforms that are suitable, simple to use, and culturally adapted.
b) Investment in digital infrastructure, especially in rural disadvantaged regions.
c) Institutionalizing digital literacy initiatives, using extension officers and farmer-producer organizations to build confidence and create behavioral intention.

Intercropping, supported by intelligent systems via IoT, AI, and digital knowledge systems, aligns with climate-smart agriculture policy by maximizing resource use, enhancing resilience to weather variability, and improving productivity.

7.2 Opportunities for Digital Adoption in Rural Agriculture

a) Approved Local Digital Content: Translation of e-content to regional languages and local contexts may make it more usable and valuable.
b) Peer Digital Champions: Using successful adopters and community leaders as role models or champions (social influence) to facilitate subjective norms and image.
c) Integrated Support Systems: Providing IoT devices with embedded access to e-resources, support networks, and training increases facilitating conditions and performance expectancy.
d) Incentive-Based Programs: Subsidy or certification programs rewarded to early adopters can enhance behavioral intention.

If well-implemented, these strategies can create digital ecosystems that make innovative intercropping practices more accessible and sustainable.

7.3 Challenges and Obstacles to the Use of E-Resources and Intelligent Tools

a) Digital Divide: The majority of rural populations are still not internet-connected or mobile-covered, hence weakening enabling conditions.
b) Low Digital Literacy: Farmers could lack training and confidence to utilize advanced e-resources or interpret AI output.
c) Perceived Relevance: Without a direct connection of online platforms with higher yield, perceived usefulness and job relevance are low.
d) Interface and Language Barriers: Most platforms are not localized or user-friendly for low-literacy users.
e) Privacy and Trust of Information: Farmers distrust mechanisms of data gathering using sensors or AI, which affects their intention to behave.

These barriers highlight the need for context-aware design and stakeholder participation in digital agricultural interventions.

7.4 Implications for Research and Theoretical Contributions

a) Integrating TAM2 and UTAUT1 into a shared framework designed explicitly for e-resource adoption in smart intercropping.
b) Expanding the application of technology acceptance models to sustainability-based multi-crop agricultural systems.
c) Providing a basis for empirical testing in different geographies, agricultural communities, and technological maturity levels.
d) Offering stakeholder-specific mapping to guide further research into adoption behavior in the agri-tech industry.

In addition, the study provides a scalable theoretical framework that can be extended to other areas, such as digital irrigation, climate prediction tools, or robotized pest control systems.

8. CONCLUSION

This theoretical paper offers a comprehensive framework for explaining the adoption of e-resources and digital knowledge platforms in the context of IoT and AI-powered intercropping systems. Based on the Technology Acceptance Model 2 (TAM2) and the Unified Theory of Acceptance and Use of Technology (UTAUT1), the framework links technological innovation to behavioral and contextual variables to explain how different stakeholders in agriculture interact with intelligent farming tools. The research stresses that the practical application of innovative intercropping practices is not merely a technological issue but also a user experience, digital preparedness, and enabling-system concern. Perceived usefulness, effort expectancy, job relevance, social influence, and facilitating conditions are significant constructs affecting behavioral intention and digital platform utilization. By highlighting the significance of behavioral adoption models in agricultural digital transformation, this study offers an original contribution to assessing and enhancing technology-driven sustainability interventions. It also prompts the design of more inclusive, user-centered, and effective agricultural technologies embedded in a real farm context.

9. FUTURE DIRECTIONS

To build upon this theoretical foundation, follow-up research would seek to:

a) Empirical testing of the framework developed through field surveys, formal surveys, and interviews of farmers, agri-extension agents, and platform developers.
b) Pilot implementation of local digital platforms for intercropping, complemented with TAM-2/ UTAUT-1 informed user behavior observation and feedback systems.
c) Comparative cross-regional analyses to assess the role of socioeconomic, infrastructural, and cultural variables in the adoption of e-resources in various agro-ecological zones.
d) Creation of digital readiness indices to measure readiness and gaps at the institutional and community levels for the adoption of innovative intercropping solutions.

This study provides the foundation for a scalable, sustainable shift to digital agriculture driven by behaviorally informed solutions and human-centered design.

REFERENCES

Eastwood, C., Klerkx, L., Ayre, M., & Dela Rue, B. (2019). Managing socio-ethical challenges in the development of smart farming: From a fragmented to a comprehensive approach for responsible research and innovation. *Journal of Agricultural and Environmental Ethics*, 32(5-6), 741-768.

Fielke, S., Taylor, B., & Jakku, E. (2020). Digitalisation of agricultural knowledge and advice networks: A state-of-the-art review. *Agricultural Systems*, 180, 102763.

Food and Agriculture Organization (FAO). (2021). *Digital agriculture: Harnessing the power of data for smallholder farmers*. Rome: FAO.

Gebbers, R., & Adamchuk, V. I. (2010). Precision agriculture and food security. *Science*, 327(5967), 828-831.

Kamilaris, A., Kartakoullis, A., & Prenafeta-Boldú, F. X. (2017). A review on the practice of big data analysis in agriculture. *Computers and Electronics in Agriculture*, 143, 23-37.

Klerkx, L., Jakku, E., & Labarthe, P. (2019). A review of social science on digital agriculture, smart farming, and agriculture 4.0: New contributions and a future research agenda. *NJAS - Wageningen Journal of Life Sciences*, 90-91, 100315.

Lioutas, E. D., & Charatsari, C. (2020). Smart farming and short food supply chains: Are they compatible? *Land Use Policy*, 94, 104541.

Rogers, E. M. (2003). *Diffusion of Innovations* (5th ed.). New York: Free Press.

Tornatzky, L. G., & Klein, K. J. (1982). Innovation characteristics and innovation adoption-implementation: A meta-analysis of findings. *IEEE Transactions on Engineering Management*, 29(1), 28-45.

United Nations. (2021). *The role of digital technologies in achieving the Sustainable Development Goals (SDGs)*. New York: UN Department of Economic and Social Affairs.

Venkatesh, V., & Davis, F. D. (2000). A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Management Science*, 46(2), 186-204.

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly*, 27(3), 425-478.

Weersink, A., Fraser, E., Pannell, D., Duncan, E., & Rotz, S. (2018). Opportunities and challenges for big data in agricultural and environmental analysis. *Annual Review of Resource Economics*, 10, 19-37.

World Bank (2019). *Digital dividends in agriculture: Bridging the gap between technology and adoption*. Washington, DC: World Bank Group.

Zhang, X., Zhang, J., & Li, Y. (2020). Applications of IoT and AI in smart farming: A systematic review. *IEEE Access*, 8, 187814-187833.