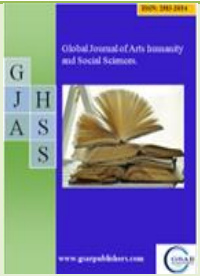


	Global Journal of Arts Humanity and Social Sciences				
	ISSN: 2583-2034				
	Abbreviated key title: Glob.J.Arts.Humanit.Soc.Sci				
	Frequency: Monthly				
	Published By GSAR Publishers				
Journal Homepage Link: https://gsarpublishers.com/journal-gjahss-home/					
Volume - 6	Issue - 10	October 2026	Total pages 1080-1089	DOI: 10.5281/zenodo.23559315	

Proposing a theoretical framework for identifying and measuring digital farmers

By

Hoang Vu Quang,

Institute of Strategy and Policy on Agriculture and Environment



Article History

Received: 10- 10- 2026

Accepted: 17- 10- 2026

Published: 19- 10- 2026

Corresponding author

Hoang Vu Quang,

Abstract

Digital transformation in agriculture has created a need to identify and assess digital farmers. However, a widely accepted definition and standardized assessment framework remain lacking. Based on a literature review and theoretical analysis, this study proposes a theoretical framework for identifying and assessing digital farmers through three dimensions: digital access, digital competence, and digital technology use. A digital farmer is defined as a farmer who has digital access, possesses the necessary digital competencies, and actually uses digital technologies in agricultural production and business activities. The proposed framework comprises 20 indicators of digital technology use across six domains, 35 digital competence indicators across seven domains, and three digital access indicators. Digital technology use and digital competence are classified into basic and advanced categories. The study further proposes a method for classifying farmers into four levels of digital technology use and four levels of digital competence, based on specified criteria and thresholds. This framework provides a basis for assessing farmers' digital development and designing targeted support policies. Further empirical research is needed to validate the proposed indicators and classification thresholds.

Keywords: digital farmer, digital access, digital competence, digital technology use, assessment framework.

1. INTRODUCTION

Digital technologies are increasingly adopted and provide numerous benefits in agricultural production and business, including higher productivity and production efficiency; improved market access; reduced postharvest losses; reduced production risks arising from weather and diseases; easier access to financial, insurance, extension and training services; more sustainable supply-chain management; savings in costs and labor; increased income; and environmental sustainability (Mwalupaso et al., 2019; CGIAR Digital Innovation Initiative, 2022; Kirui et al., 2013; Ashworth & Owens, 2025; Kandulu et al., 2025).

Farmers vary considerably in terms of their agricultural production activities, farm sizes, and the objectives of their agricultural production and business operations. These differences lead to differences in digital technology use. A wide range of digital technologies can be applied across different stages of agricultural production and business operations, including input supply, production, harvesting, storage, processing, and the marketing of

agricultural products. These technologies also differ in their levels of sophistication and technological advancement. While some farmers may adopt a single digital technology, others may simultaneously employ multiple digital technologies. To effectively apply digital technologies, farmers need digital knowledge and digital skills.

The positive impacts of digital technologies have prompted many countries to encourage and facilitate the development of digital farmers. For example, Vietnam's farmer training and capacity-building programs include initiatives aimed at developing digital farmers.

Although numerous studies have examined farmers in relation to digital technologies, the terms commonly used in this literature include farmers' digital literacy and digital competence, digital skills, digital technology adoption, digital agriculture, and digital inclusion. To date, there is no universally accepted definition and standardized measurement scale for the concept of a "digital farmer" in international research.



What, then, constitutes a digital farmer? Is the adoption of a single digital technology sufficient for a farmer to be considered a digital farmer, or is the simultaneous adoption of multiple digital technologies required? Beyond adopting digital technologies, what additional criteria should farmers meet? Establishing clear criteria for identifying digital farmers is essential not only for assessing the level of digital development among farmers in the context of the digital revolution, but also for identifying their strengths, weaknesses, and limitations. Such an assessment can inform the formulation of appropriate policies and support measures to enable farmers to develop in step with the ongoing digital revolution.

This article presents a theoretical framework for identifying and measuring digital farmers. Specifically, it reviews the literature on digital farmers and proposes a definition, criteria, indicators, and a method for categorizing and assessing digital farmers.

2. LITERATURE REVIEW

Farmers increasingly use digital technologies in agricultural production and business. Numerous studies have examined farmers in the process of digital transformation. However, there is no unified, standardized definition or measurement scale for digital farmers in international research. Some development reports use the term “digital farmer,” whereas scientific articles more commonly use farmers’ digital literacy or competence, digital skills, digital technology adoption, digital agriculture, and digital inclusion. Internationally, three approaches related to digital farmers can be identified: digital competence, digital technology use, and digital farmer profiles.

One of the most common research approaches examines farmers’ digital literacy. Magesa et al. (2023) examined smallholders’ digital literacy through their ability to process agricultural information in the digital environment. The study used 23 questions to assess six groups of abilities: accessing, managing, interpreting, evaluating, creating, and communicating digital agricultural information. A survey of 257 smallholder households in Tanzania showed that digital literacy involves not only searching for information but also assessing its reliability, managing it, and using it.

European Commission developed the Digital Competence Framework for Citizens (DigComp), providing a comprehensive framework for assessing individual digital competence across five domains comprising 21 competencies (Vuorikari et al., 2022). Hui et al. (2026) applied DigComp to assess farmers’ digital competence in China. However, the framework does not adequately capture agriculture-specific digital competencies, particularly those related to agricultural data management, digital technology applications in farming, and data-driven decision-making.

Chandra et al. (2024) developed a digital literacy scale specifically for farmers. The authors identified three broad dimensions: digital knowledge, digital attitudes, and digital competence. Digital competence comprises seven components: device use, communication and collaboration, content creation and sharing, digital safety, problem-solving, digital marketing, and digital

payments.

Yang et al. (2025), by contrast, divided farmers’ digital literacy into two dimensions: digital access and digital application. Digital application comprises information competence, social competence, business competence, and problem-solving competence. Their measurement system contains 17 indicators.

Possessing digital competence does not necessarily mean that farmers actually apply technologies in agricultural production and business. In a review of 27 studies in sub-Saharan Africa, Choruma et al. (2024) found that smallholders used various technologies, including digital extension services and digital agricultural marketing. However, adoption remained constrained by Internet connectivity, digital literacy, infrastructure, costs, and gender inequality. Gumbi et al. (2023) likewise found that, despite the development of numerous digital agricultural solutions, a substantial proportion of smallholders remained excluded because digital ecosystems were insufficiently developed. Such ecosystems comprise six main components: digital platforms, business model innovation, digital literacy, digital infrastructure, technologies, and affordability.

A study by Uy et al. (2025) in Vietnam showed that farmers used digital tools in agriculture. The authors found that educational attainment, farm size, digital experience, knowledge exchange, access to digital information, and Internet costs were associated with digital technology adoption.

Gray (2018) approached “digital farmers” from the perspective of digital profiles. Data on farmers and farms can be collected, stored, analyzed, and combined with other data sources to provide more appropriate services to farmers. Thus, farmers in the digital environment are both users and producers of data for the agricultural ecosystem. This approach broadens the concept of a digital farmer from a “device user” to an actor in an information and data ecosystem.

The reviewed literature indicates that digital farmers are addressed through three dimensions: digital access, digital competence, and digital technology use. These are distinct but interrelated concepts. Digital farmers should be identified through digital conditions, capabilities, and behaviors. Device ownership, Internet use, or digital skills alone cannot fully capture farmers’ participation in digital transformation. Conversely, measuring technology use alone does not reflect their autonomy in the digital environment.

3. METHOD FOR DEVELOPING DIGITAL-FARMER CRITERIA

The method for developing digital-farmer criteria is based on a review of secondary literature, analysis, and deductive reasoning to propose indicators measuring digital technology use, digital competence, and digital access.

As conceptualized in this study (see Section 4), digital farmers must not only use digital technologies but also possess digital competence and digital access. Therefore, the criteria for digital farmers must cover all three dimensions. To use digital technologies, farmers

need digital access and digital competence. In other words, digital competence underpins farmers' ability to use digital technologies. Accordingly, our approach begins by identifying digital technologies currently used in agricultural production and business worldwide and then determining the digital competencies and access conditions farmers need to use those technologies. Digital technologies are diverse and continually changing. A technology that does not exist today may emerge within a few months. Therefore, to facilitate assessment, we group technologies by application area, such as digital technologies supporting farmers' information searches or financial transactions and payments. Digital technologies also vary in complexity: many can be used by farmers with basic competence, whereas more complex technologies require advanced digital competence. We therefore classify agricultural digital technologies into basic and advanced digital applications.

To use all currently available agricultural digital technologies, farmers need a wide range of knowledge and digital skills. Some skills are relatively simple and easy to learn and apply, while other digital competencies are complex and difficult to acquire and use. Accordingly, we also classify farmers' digital competencies into basic and advanced categories.

A farmer may have high digital competence but, without using any digital technology, cannot be considered a digital farmer. In such a case, calculating an aggregate score from indicators to determine farmers' digital level would appear inappropriate. To identify farmers' levels of digital competence and technology use and inform measures to develop digital farmers, we classify farmers into groups separately for the competence and technology-use dimensions. The digital-access dimension is not used for this classification because digital technology use necessarily requires access to devices and the Internet. These are mandatory conditions for digital farmers.

4. PROPOSED CRITERIA FOR DIGITAL FARMERS

This section proposes a definition of digital farmers and criteria reflecting their digital technology use, digital competence, and digital access.

4.1 Definition of digital farmers

The review of academic literature and Vietnamese policy documents indicates that three interrelated dimensions characterize digital farmers: digital access, digital competence, and digital technology use. On this basis, the study proposes the following definition:

"A digital farmer is a farmer who has digital access, possesses the necessary digital competence, and actually uses digital technologies in agricultural production and business activities."

This definition has four components: being a farmer, digital access, digital competence, and digital technology use in agricultural production and business. Its central point is that digital farmers cannot be equated with farmers who possess devices and Internet

connectivity (digital access) or digital skills; they must actually use digital technologies in their own or their household's agricultural production and business.

4.2 Criteria of digital technology use

Farmers' digital technology use refers to farmers' actual use of digital technologies, tools, platforms, or digitally enabled services to support agricultural production, farm management, decision-making, market transactions, value-chain coordination, financial activities, and access to agricultural and public services. Drawing on the international literature on digital agriculture, ICT4Ag, precision agriculture, digital extension, farm management information systems, digital agricultural platforms, e-commerce, and digital financial services, this study conceptualizes farmers' digital technology use as a multidimensional construct comprising six domains and 20 observable digital uses.

Domain 1. Agricultural information search, advisory services and learning: Reflects farmers' use of digital technologies to search for and use information on production techniques, weather, pests and diseases, markets and agricultural prices; access digital agricultural extension services; and participate in learning and training to improve knowledge and skills for agricultural production and business.

Domain 2. Production and business management and decision support: Reflects farmers' use of digital technologies to record, manage and use production data; manage resources, costs and business outcomes; plan and support decisions; and manage agricultural production and business activities.

Domain 3. Precision agriculture, monitoring and automation: Reflects farmers' use of digital technologies to monitor crops, livestock and production resources such as soil, water and the environment; and their use of sensors, IoT, drones, artificial intelligence (AI) and automation technologies in agricultural production.

Domain 4. Markets, trade and value-chain linkages: Reflects farmers' use of digital technologies to search for and purchase agricultural inputs; promote, market and sell agricultural products; implement traceability; and connect, communicate and transact with cooperatives, enterprises, customers and other agricultural value-chain actors.

Domain 5. Digital finance, payments and insurance: Reflects farmers' use of digital technologies to make payments in agricultural production and business and access and use digital financial services such as credit, loans, savings and digital agricultural insurance.

Domain 6. Digital production services and public services: Reflects farmers' use of digital platforms to search for, book or hire, and use agricultural production, mechanization, transport and logistics services; access and use public services; complete administrative procedures; and access agricultural support programs and policies in the digital environment.

Digital applications are divided into basic and advanced categories. Basic digital applications involve farmers' use of digital technologies for routine agricultural production and business activities such as information searches, learning, communication, transactions, payments, service access and simple data recording. These activities mainly require basic digital skills and do not demand in-depth data analysis or the operation of complex technologies. By contrast, advanced digital applications emphasize data utilization, decision support, and specialized technologies in

agricultural production, management, and business, generally requiring advanced digital skills. Advanced applications include technologies for managing, using, and analyzing data; planning and decision support; and monitoring and automating agricultural production and business. Of the 20 proposed digital applications, 14 are basic, and six are advanced.

The table below presents digital applications in each domain, classifies them into basic and advanced categories, and provides evidence of technologies already used in practice.

Table 1. Classification of agricultural digital applications

Domain	Digital technology	Level	Sources
1. Digital agricultural information, advisory and learning	1. Search for and use information on weather, pests, diseases, and production techniques.	Basic	Camacho & Conover (2019); Singh et al. (2023); Mittal et al. (2010); Uy et al. (2023); Hoang et al. (2022).
	2. Obtain information on markets, market requirements, and agricultural product prices.	Basic	Camacho & Conover (2019); Mittal et al. (2010); Hoang (2020a, 2020b); Uy et al. (2023)
	3. Access and use digital agricultural extension services/applications.	Basic	Singh et al. (2023); Cole & Fernando (2021); Uy et al. (2023); Bui et al. (2022)
	4. Participate in education, training, and skills development for agricultural production and business through digital platforms.	Basic	Singh et al. (2023); Uy et al. (2023); Bui et al. (2022)
2. Digital farm management and decision support	5. Record and manage electronic production logs.	Basic	Gabriel & Gandorfer (2023); Fountas et al. (2015)
	6. Manage and use crop/livestock data on digital platforms.	Advanced	Fountas et al. (2015); Tummers et al. (2019)
	7. Use digital tools and data for production planning and decision support.	Advanced	Fountas et al. (2015); Schulze Schwering et al. (2022)
	8. Use digital maps/GPS/GIS for production management.	Advanced	Lowenberg-DeBoer & Erickson (2019); Barnes et al. (2019)
	9. Use digital tools to manage farm/household economic activities: inputs, costs, labor, output, inventories, revenue, profit, etc.	Advanced	Fountas et al. (2015); Schulze Schwering et al. (2022)
3. Digital monitoring, precision agriculture and automation	10. Monitor crops, livestock and production resources (soil, water, environment, etc.) using digital technologies.	Advanced	Zarco-Tejada et al. (2014); Gabriel & Gandorfer (2023)
	11. Apply sensors, IoT, drones, AI, and automation in production.	Advanced	Barnes et al. (2019); Lowenberg-DeBoer & Erickson (2019); Gabriel & Gandorfer (2023)
4. Digital markets, e-commerce and value-chain linkages	12. Search for and order production inputs online.	Basic	Uy et al. (2023)
	13. Promote, market and sell agricultural	Basic	Feng (2024); Liu et al. (2025)

	products in the digital environment.		
	14. Use QR codes and traceability systems.	Basic	Gonçalves et al. (2025)
	15. Connect, communicate and transact with cooperatives, enterprises, customers and value-chain actors in the digital environment.	Basic	Agyekumhene et al. (2018, 2020); Dawson et al. (2024)
5. Digital payments, finance and insurance	16. Use digital payments in agricultural production and business.	Basic	Grossman & Tarazi (2014); Mattern & Ramirez (2017)
	17. Access and use digital financial services (credit, loans, savings, etc.).	Basic	Grossman & Tarazi (2014); Mattern & Ramirez (2017)
	18. Access and use digital agricultural insurance services.	Basic	Grossman & Tarazi (2014)
6. Digital production and public services	19. Search for, book/hire and use production, mechanization, transport and logistics services through digital platforms.	Basic	Ngissah et al. (2025)
	20. Access and use public services, administrative procedures and agricultural support programs/policies in the digital environment.	Basic	Reissig et al. (2022)

Source: Compiled and proposed by the author.

4.3 Criteria of digital competence

Farmers' digital competence includes knowledge, skills and attitudes that enable farmers to use digital technologies effectively, safely, responsibly and appropriately to perform tasks, solve problems, make decisions and adapt to changes in agricultural production and business. Digital competence influences digital technology use. We therefore propose seven domains of digital competence comprising 35 digital skills required for the applications described above: (1) operating digital devices and technologies; (2) searching for, collecting and evaluating digital information and data; (3) digital communication and collaboration; (4) digital content creation and management; (5) digital safety, security and responsibility; (6) problem-solving, decision-making and technological adaptation; and (7) transactions and economic activities in the digital environment.

Digital competence indicators are classified as basic or advanced.

Basic digital competence comprises the knowledge and skills that are necessary prerequisites; without them, farmers would find it difficult to carry out basic digital applications that do not require in-depth data analysis or the operation of complex technologies. Examples include connecting to the Internet, searching for information, communicating, creating documents, protecting passwords, selecting applications, and making digital payments.

Advanced digital competence comprises the knowledge and skills enabling farmers to use and combine specialized digital tools and technologies to organize, manage, use, and analyze data; solve complex problems; support decision-making; and operate and adapt to advanced digital technologies in agricultural production and business. These skills build on basic digital skills and mainly serve advanced digital applications.

Not every digital competence domain must include both basic and advanced competencies. The indicators for each domain are presented in the table below.

Table 2. Proposed digital competence indicators for digital farmers

Domain	Digital competence indicator	Level
Operating digital devices and technologies	Use basic functions of smartphones, computers or tablets.	Basic
	Connect to and use the Internet, Wi-Fi and mobile data.	Basic
	Install, update and use applications/software; create and manage digital accounts.	Basic
	Manage files, images, documents and data on devices or online storage.	Basic

Connect, configure and operate digital devices/technologies for work and resolve routine technical problems.	Advanced
<i>Digital competence indicator</i>	<i>Level</i>
Identify information needs and search for information/data on the Internet or digital platforms.	Basic
Filter, select and compare information from different sources.	Basic
Assess the reliability, accuracy, currency and relevance of information.	Basic
Collect, enter, organize, store, update and retrieve digital data.	Basic
Read, interpret, analyze and use information/data for planning and decision support.	Advanced
Communicate via messages, email, voice/video calls and digital platforms.	Basic
Share information, documents, images and data in the digital environment.	Basic
Participate and interact in online groups, social networks or communities.	Basic
Collaborate, coordinate work and exchange information with various parties in the digital environment.	Basic
Select appropriate digital communication channels, tools and methods for the purpose, audience and context.	Basic
Create and edit text documents, presentations, spreadsheets, forms and digital documents.	Basic
Create/edit and share basic images, audio or video.	Basic
Enter, post, edit and update content on digital platforms.	Basic
Combine information, data and different content types to create new content for work or agricultural production and business.	Advanced
<i>Digital competence indicator</i>	<i>Level</i>
Use digital/AI tools to create, edit and manage content while complying with copyright and content-use rights.	Advanced
Protect devices and accounts with passwords, authentication and appropriate security measures.	Basic
Protect personal information, data and privacy in the digital environment.	Basic

<i>Recognize and avoid unsafe websites/links/applications, scams, phishing, fraud and malware.</i>	Basic
<i>Back up, protect and restore data and assess risks before sharing information or conducting transactions.</i>	Advanced
<i>Use data, content, AI and digital technologies responsibly, lawfully and ethically.</i>	Basic
<i>Identify needs and select suitable digital tools/applications to perform tasks.</i>	Basic
<i>Find instructions and independently resolve routine technical problems.</i>	Basic
<i>Combine multiple tools, information sources and digital data to solve problems.</i>	Advanced
<i>Use digital/AI tools for analysis, problem-solving and decision support, and verify the results provided.</i>	Advanced
<i>Recognize gaps in one's skills, learn independently and adapt to new digital technologies.</i>	Basic
<i>Search for, compare and select products, services, buyers/sellers or suppliers in the digital environment.</i>	Basic
<i>Place orders, book/hire services and track online transactions.</i>	Basic
<i>Make payments, receive money and check/confirm digital transactions.</i>	Basic
Digital competence indicator	Level
<i>Check partners' reliability, manage invoices/documents and understand terms, commitments and contracts in electronic transactions.</i>	Basic
<i>Complete online applications/procedures and recognize, prevent and address risks or errors in digital transactions.</i>	Basic

Source: Proposed by the author.

4.4 Criteria of digital access

Two basic conditions for digital technology use are access to a device and the ability to connect to the Internet. Internet-enabled devices include smartphones, tablets, desktop computers, laptops, and certain other devices (televisions). Internet access may be provided through LAN, mobile networks, or Wi-Fi. Another factor affecting digital access is Internet connection quality (bandwidth, latency, and stability). For simplicity, we propose three indicators of farmers' digital access:

1. Possession of an Internet-enabled device (smartphone, computer, or tablet).
2. Internet connectivity (LAN, Wi-Fi or mobile network).

3. Adequate connection quality (stable, high-speed connectivity).

5. DETERMINING FARMERS' DIGITAL LEVEL

The two basic conditions for digital technology use are having a device and Internet connectivity. Without these conditions, digital applications cannot be carried out. Internet connection speed enables digital applications to be performed quickly. Therefore, digital farmers must essentially have a device and Internet access. Farmers' digital level encompasses three dimensions (digital access, digital competence, and digital technology use), with classification focusing specifically on competence and technology use. As clarified in the definition, farmers who do not use any digital

technology cannot be called digital farmers. In other words, digital farmers must use at least one digital application.

5.1 Levels of digital technology use

Based on basic and advanced digital technology use, we propose classifying farmers into four groups: Group 1. Farmers with advanced digital technology use: Farmers who use at least 50% of basic digital applications and at least one advanced digital application.

Group 2. Farmers with moderate digital technology use: Farmers who use at least 50% of basic digital applications but no advanced digital applications.

Group 3. Farmers with low digital technology use: Farmers who do not meet the criteria for advanced or moderate digital technology use but use at least one digital technology in agricultural production and business.

Group 4. Farmers with no digital technology use: Farmers who do not use any digital application.

It is noted that the 50% threshold and the requirement to use at least one advanced digital technology are proposed on theoretical and feasibility grounds; they are not standardized thresholds.

5.2 Levels of digital competence

Based on the achievement of digital competence indicators, we propose classifying farmers into four digital competence groups:

- Group 1. Farmers with high digital competence: Farmers who simultaneously meet three conditions: (1) achieve 50% of basic digital competencies; (2) possess at least one basic digital competence in each of the seven domains; and (3) achieve at least 30% of advanced digital competencies.
- Group 2. Farmers with moderate digital competence: Farmers who do not meet the criteria for high digital competence but simultaneously meet two conditions: (1) achieve 50% of basic digital competencies; and (2) possess at least one basic digital competence in each of the seven domains.
- Group 3. Farmers with low digital competence: Farmers who do not meet the criteria for moderate digital competence but possess at least one digital competence.
- Group 4. Farmers with no digital competence: Farmers who do not possess any digital competence.

The proposed 50% threshold for basic digital competence is based on two considerations: (1) not all digital competencies are equally necessary for every farmer, as digital technology needs differ by production type, scale, and business model; and (2) the threshold is consistent with the concept of basic digital competence. Farmers need not master most competencies to be considered to possess basic digital competence. Being able to perform at least half of the competencies may be regarded as a minimum competence level. The proposed 30% threshold for advanced digital competence reflects the fact that advanced skills tend to be specialized and

depend on production and business needs. Farmers do not need to possess all advanced skills; rather, they need certain relevant skills to perform complex digital tasks. It should be noted that the 50% and 30% thresholds are proposed on theoretical and feasibility grounds and have not been standardized.

6. AREAS FOR FUTURE EMPIRICAL RESEARCH

The proposed criteria and method for identifying digital farmers are based on a literature review and theoretical reasoning and have not yet been empirically tested. Further empirical research is therefore needed in the following areas:

First, validating indicator relevance and comprehensiveness: Empirical studies should assess the relevance of digital access, digital competence, and digital technology use indicators to agricultural production and business in practice, and identify indicators that should be added, modified or removed according to commodity, scale, and production method.

Second, verifying the basic-advanced classification: Future research should examine differences in basic and advanced levels. Assess differences in complexity, skill requirements, and farmers' ability to perform each indicator, and adjust the classification to reflect practical conditions.

Third, evaluating classification thresholds: Researchers should test the appropriateness of the 50% thresholds for basic competence and technology use, the 30% threshold for advanced competence, and the advanced-application condition, thereby establishing empirically grounded classification thresholds.

Fourth, exploring multidimensional interactions: Studies should analyze the reciprocal relationships among digital access, digital competence, and digital technology use. Analyze the roles of access conditions and digital competence in digital technology use and examine whether technology use can, in turn, improve farmers' digital competence.

7. CONCLUSION

This study proposes a theoretical framework and a method for identifying digital farmers based on three closely interrelated dimensions: digital access, digital competence, and digital technology use. Based on a review of scientific literature, analysis of policy orientations and theoretical reasoning, the study establishes that a digital farmer is not simply someone who possesses devices, Internet connectivity or digital skills, but someone who actually uses digital technologies in agricultural production and business.

Starting from digital technology applications in agriculture, the study identifies the digital competencies and access conditions that farmers need to use these applications. Accordingly, the proposed framework comprises 20 digital technology use indicators across six activity domains, 35 digital competence indicators across seven competence domains, and three digital access indicators. Technology use and competence indicators are classified into basic and advanced levels, reflecting differences in the nature and

complexity of technologies and skills.

Regarding the assessment method, the study proposes classifying farmers into four groups by level of digital technology use and four groups by level of digital competence, based on specific conditions and quantitative thresholds, rather than using a composite score. This method distinguishes the ability to use technologies from actual technology-use behavior and identifies differences in digital proficiency among farmers.

The proposed framework and method provide an initial scientific basis for identifying, classifying, and assessing the development of digital farmers; identifying limitations in competence and technology use; and thereby informing training programs and digital transformation support tailored to different farmer groups. The framework can also support research, surveys, and monitoring of farmers' digital transformation. However, the classification of indicators and the proposed assessment thresholds are currently based on theoretical reasoning and require empirical testing and adjustment to ensure relevance, reliability, and practical applicability.

REFERENCES

1. Agyekumhene, C., de Vries, J. R., van Paassen, A., Macnaghten, P., Schut, M., & Bregt, A. (2018). Digital platforms for smallholder credit access: The mediation of trust for cooperation in maize value chain financing. *NJAS - Wageningen Journal of Life Sciences*, 86–87, 77–88. <https://doi.org/10.1016/j.njas.2018.06.001>.
2. Agyekumhene, C., de Vries, J. R., van Paassen, A., Schut, M., & Macnaghten, P. (2020). Making smallholder value chain partnerships inclusive: Exploring digital farm monitoring through farmer-friendly smartphone platforms. *Sustainability*, 12(11), 1–11. Ashworth, A., & Owens, P. (2025). Benefits and evolution of precision agriculture. U.S. Department of Agriculture. Accessed on 10 Oct 2026 at <https://www.ars.usda.gov/oc/utm/benefits-and-evolution-of-precision-agriculture/>.
3. Barnes, A. P., Soto, I., Eory, V., Beck, B., Balafoutis, A., Sánchez, B., Vangeyte, J., Fountas, S., van der Wal, T., & Gómez-Barbero, M. (2019). Exploring the adoption of precision agricultural technologies: A cross-regional study of EU farmers. *Land Use Policy*, 80, 163–174. <https://doi.org/10.1016/j.landusepol.2018.10.004>.
4. Bui, T., Nguyen, T. T. L., Nguyen, T. S., Kawarazuka, N., Schreinemachers, P., & Liu, Y. (2022). Introducing an agricultural app to urban vegetable farmers: A pilot study in Hanoi. *International Potato Center*.
5. Camacho, A., & Conover, E. (2019). The impact of receiving SMS price and weather information on small-scale farmers in Colombia. *World Development*, 123, 104596.
6. CGIAR Digital Innovation Initiative. (2022). Connect rural areas with digital innovations to unlock climate resilience for farmers. *CGIAR System News*. Accessed on 10 Oct 2026 at <https://www.cgiar.org/news-events/news/connect-rural-areas-with-digital-innovations-to-unlock-climate-resilience-for-hundreds-of-millions-of-farmers>.
7. Chandra, S., Ghadei, K., Chennamadhava, M., & Ali, W. (2024). Development and validation of a farmer's focused digital literacy scale: A new measurement tool. *Indian Journal of Extension Education*, 60(1), 111–115. <https://doi.org/10.48165/IJEE.2024.601RT1>.
8. Choruma, D. J., Dirwai, T. L., Mutenje, M. J., Mustafa, M., Chimonyo, V. G. P., Jacobs-Mata, I., & Mabhaudhi, T. (2024). Digitalisation in agriculture: A scoping review of technologies in practice, challenges, and opportunities for smallholder farmers in sub-Saharan Africa. *Journal of Agriculture and Food Research*, 18, Article101286. <https://doi.org/10.1016/j.jafr.2024.101286>.
9. Cole, S. A., & Fernando, A. N. (2021). 'Mobile'izing agricultural advice: Technology adoption, diffusion and sustainability. *The Economic Journal*, 131(633), 192–219. <https://doi.org/10.1093/ej/ueaa084>.
10. Dawson, G. E., Jr., Antunes, J. A. V., Jr., Wegner, D., & Adami, V. S. (2024). Creating a digital platform for the agricultural cooperative system through interorganizational collaboration. *Journal of Rural Studies*, 110, 103388. <https://doi.org/10.1016/j.jrurstud.2024.103388>.
11. Feng, X. (2024). Control, exploitation and exclusion: Experiences of small farmer e-tailers in agricultural e-commerce in China. *Journal of Agrarian Change*, 24(1), e12567. <https://doi.org/10.1111/joac.12567>.
12. Fountas, S., Carli, G., Sørensen, C. G., Tsiropoulos, Z., Cavalaris, C., Vatsanidou, A., Liakos, B., Canavari, M., Wiebensohn, J., & Tisserye, B. (2015). Farm management information systems: Current situation and future perspectives. *Computers and Electronics in Agriculture*, 115, 40–50. <https://doi.org/10.1016/j.compag.2015.05.011>.
13. Gabriel, A., & Gandorfer, M. (2023). Adoption of digital technologies in agriculture—An inventory in a European small-scale farming region. *Precision Agriculture*, 24, 68–91. <https://doi.org/10.1007/s11119-022-09931-1>.
14. Gonçalves, C., Fernandes, J., & Brites, C. (2025). Blockchain-enabled traceability in the rice supply chain: Insights from the TRACE-RICE project. *Foods*, 14(21), Article 3711. <https://doi.org/10.3390/foods14213711>.
15. Gray, B. (2018). Digital farmer profiles: Reimagining smallholder agriculture. *Grameen Foundation*. <https://grameenfoundation.org/partners/resources/digital-farmer-profiles-reimagining-smallholder-agriculture>.
16. Grossman, J., & Tarazi, M. (2014). Serving smallholder farmers: Recent developments in digital finance. *CGAP*.
17. Gumbi, N., Gumbi, L., & Twinomurinzi, H. (2023). Towards sustainable digital agriculture for smallholder farmers: A systematic literature review. *Sustainability*, 15(16), Article 12530. <https://doi.org/10.3390/su151612530>.
18. Hoang, H. G. (2020a). Determinants of the adoption of



- mobile phones for fruit marketing by Vietnamese farmers. *World Development Perspectives*, 17, 100178.
19. Hoang, H. G. (2020b). Exploring cereal smallholders' adoption of mobile phones for marketing in Quang Dien District of Vietnam. *Journal of Agricultural Extension*, 24(1), 106–117.
 20. Hoang, H. G., Nguyen, D. V., & Drysdale, D. (2022). Factors influencing the use of agricultural information by Vietnamese farmers. *IFLA Journal*, 48(4), 679–690. doi: [10.1177/03400352](https://doi.org/10.1177/03400352).
 21. Hui, J., Peng, Y., & Liu, B. (2026). Research on the current status, key challenges and optimization pathways of improving farmers' digital literacy: Evidence from an empirical investigation in Suqian, Jiangsu Province. *Critical Humanistic Social Theory*, 3(2). <https://doi.org/10.62177/chst.v3i2.1442>.
 22. Kandulu, J. M., Wheeler, S. A., Zuo, A., & Connor, J. D. (2025). Mobile technology and gender: A pathway to increased yield and farm profit for smallholder farmers in Bangladesh. *Australian Journal of Agricultural and Resource Economics*, 69(3), 674–686.
 23. Kirui, O. K., Okello, J. J., Nyikal, R. A., & Njiraini, G. W. (2013). Impact of mobile phone-based money transfer services in agriculture: Evidence from Kenya. *Quarterly Journal of International Agriculture*, 52(2), 1–22. <https://doi.org/10.22004/ag.econ.173644>.
 24. Liu, M., Liu, T., Ren, Y., & Wu, L. (2025). How does the adoption of e-commerce impact the selling prices of agricultural products? Empirical evidence from apple farmers in China. *Review of Development Economics*, 29(3), 1464–1485. <https://doi.org/10.1111/rode.13168>.
 25. Lowenberg-DeBoer, J., & Erickson, B. (2019). Setting the record straight on precision agriculture adoption. *Agronomy Journal*, 111(4), 1552–1569.
 26. Magesa, M., Jonathan, J., & Urassa, J. (2023). Digital literacy of smallholder farmers in Tanzania. *Sustainability*, 15(17), 13149. <https://doi.org/10.3390/su151713149>.
 27. Mattern, M. W., & Ramirez, R. M. (2017). Digitizing value chain finance for smallholder farmers (CGAP Focus Note No. 106). CGAP. <http://documents.worldbank.org/curated/en/685021505111787704>.
 28. Mittal, S., Gandhi, S., & Tripathi, G. (2010). Socio-economic impact of mobile phones on Indian agriculture. ICRIR Working Paper No. 246.
 29. Mwalupaso, G. E., Wang, S., Rahman, S., Alavo, E. J.-P., & Tian, X. (2019). Agricultural informatization and technical efficiency in maize production in Zambia. *Sustainability*, 11(8), 2451. <https://doi.org/10.3390/su11082451>.
 30. Ngissah, E., Leeuwis, C., Cieslik, K., & Freeman, C. (2025). Uberisation of mechanisation: Exploring the features and establishment of matchmaker digital tractor-hire platforms in Ghana through the lens of actor network theory. *NJAS: Impact in Agricultural and Life Sciences*, 97(1), Article 2531122. <https://doi.org/10.1080/27685241.2025.2531122>.
 31. Reissig, L., Stoinescu, A., & Mack, G. (2022). Why farmers perceive the use of e-government services as an administrative burden: A conceptual framework on influencing factors. *Journal of Rural Studies*, 89, 387–396. <https://doi.org/10.1016/j.jrurstud.2022.01.002>.
 32. Schulze Schwering, D., Bergmann, L., & Sonntag, W. I. (2022). How to encourage farmers to digitize? A study on user typologies and motivations of farm management information systems. *Computers and Electronics in Agriculture*, 107133. <https://doi.org/10.1016/j.compag.2022.107133>.
 33. Singh, R., Slotznick, W., & Stein, D. (2023). Digital tools for rural agriculture extension: Impacts of mobile-based advisories on agricultural practices in Southern India. *Journal of the Agricultural and Applied Economics Association*, 2(1), 4–19. <https://doi.org/10.1002/jaa2.42>.
 34. Tummers, J., Kassahun, A., & Tekinerdogan, B. (2019). Obstacles and features of farm management information systems: A systematic literature review. *Computers and Electronics in Agriculture*, 157, 189–204.
 35. Uy, T. C., Ha, H. D., Truyen, N. N., Chung, N. V., Phuoc, D. N., Nam, L. V., Phuong, L. T. H., & Thuyet, C. T. (2023). Mobile phone use for farm-related activities by ethnic minority farmers during the COVID-19 pandemic in Quang Tri Province, Central Vietnam. *Information Services & Use*.
 36. Uy, T. C., Limnirankul, B., Kramol, P., Hoang Gia, H., & Nguyen Thi, D. T. (2025). Digital technology adoption among smallholder farmers in Vietnam: Implications for digital agricultural extension strategies. *Journal of International Development*, 37(2), 351–370. doi: 10.1002/jid.3904.
 37. Yang, L., Yu, S., & Liu, B. (2025). The impact of digital literacy on farmland scale operations: Exploring the mediating and moderation roles of land transfer and land dependence. *Frontiers in Sustainable Food Systems*, 9, Article 1546024. <https://doi.org/10.3389/fsufs.2025.1546024>.
 38. Zarco-Tejada, P. J., Hubbard, N., & Loudjani, P. (2014). Precision agriculture: An opportunity for EU farmers - Potential support with the CAP 2014-2020. European Parliament. <https://doi.org/10.2861/58758>.
 39. Vuorikari, R., Kluzer, S., & Punie, Y. (2022). DigComp 2.2: The digital competence framework for citizens—With new examples of knowledge, skills and attitudes. Publications Office of the European Union. <https://doi.org/10.2760/115376>