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Systematic literature review and framework development of smallholder-inclusive Agri-FinTech ecosystem

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Joko Sustiyo
School of Agriculture and Food Sustainability, The University of Queensland, Gatton, Australia and
State Finance Polytechnic of STAN, Tangerang Selatan, Indonesia
Kodrad Winarno
School of Agriculture and Food Sustainability, The University of Queensland, Gatton, Australia
Suzanne Bonner
School of Economics, The University of Queensland, Brisbane, Australia, and
Ammar Abdul Aziz and Risti Permani
School of Agriculture and Food Sustainability, The University of Queensland, Gatton, Australia

Abstract

Purpose – Although the global financial technology (FinTech) market continues to grow, its potential role in agriculture remains underdeveloped, especially in developing countries. This study aims to examine the agricultural FinTech (Agri-FinTech) ecosystem, identify actors, drivers, and impacts of FinTech adoption in the agricultural sector and conceptualise a development framework.

Design/methodology/approach – A systematic literature review (SLR) was conducted following the Preferred Reporting Items for Systematic reviews and Meta-Analyses framework, analysing 107 studies published between 2013 and October 2023.

Findings – Synergy among actors in the Agri-FinTech ecosystem is key to driving inclusive innovation in the agricultural finance sector. Meanwhile, drivers of the use of Agri-FinTech are ease of use, perceived benefits, job relevance, habits and hedonic motivation. Agri-FinTech is associated with a wide range of positive impacts, including increased crop yields, improved farmer household income, enhanced village economic resilience, greater adoption of sustainable agricultural practices, digital transformation of the agribusiness sector and reduced carbon emissions. This study recommends further research to explore Agri-FinTech designs tailored to smallholder preferences, gender-responsive strategies, eco-friendly financing models and context-appropriate regulatory structures.

Originality/value – This study provides an important contribution to the development of Agri-FinTech by proposing a smallholder-inclusive Agri-FinTech development framework. The framework offers a conceptual roadmap for designing inclusive, sustainable and responsive technology-based financial services tailored to smallholder farmers' needs.

Keywords Agricultural finance, Financial technology, Agri-FinTech, Smallholder farmers, Systematic literature review

Paper type Research article

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1. Introduction

Financial technology, or FinTech, is revolutionising the finance industry. In 2023, there were 26,393 FinTech startups in the world with USD 186.87 billion in total revenue (Statista, 2025). The promise of FinTech lies in enabling customers to access financial services more safely, quickly, and cheaply than via conventional banks (Stulz, 2019; Taherdoost, 2023). In addition, FinTech has the potential to improve efficiency (Hua *et al.*, 2019; Ng *et al.*, 2017), accessibility (Im and Yoon, 2021; Nour, 2022), and ease of use (Ng *et al.*, 2017). More broadly, FinTech also offers opportunities to stimulate economic growth (Song and Appiah-Otoo, 2022), reduce carbon emissions (Wang *et al.*, 2024), and boost household consumption (Saraswati *et al.*, 2022).

FinTech's applications are expanding rapidly, including in the agriculture sector. Agri-FinTech, the convergence of financial technology and agriculture, directly addresses critical gaps in the agricultural financial system by providing inclusive digital financial services (Pothula, 2023). Agri-FinTech's positive impacts extend throughout agri-food supply chains. Empirical evidence suggests Agri-FinTech's potential to alleviate rural poverty (Kilombele *et al.*, 2023), enhance agricultural productivity (Wang and Fu, 2022), boost farm household income (Wang *et al.*, 2023), mitigate agricultural non-point source (NPS) pollution (Jiang *et al.*, 2019), reduce consumption inequality among farmers (Wang *et al.*, 2022b), accelerate the adoption of modern agricultural technologies (Batista and Vicente, 2020), and stimulate farmer investment (Xu *et al.*, 2022).

While many studies have highlighted the contribution of FinTech to agriculture, its global utilisation remains limited. In a rapidly growing FinTech ecosystem with 126,488 firms recorded globally in 2023, only 219 FinTech firms/platforms were dedicated to the agriculture sector (Tracxn, 2024). Although other general-purpose FinTech firms may also extend services to agricultural users, the small share of dedicated platforms still signals a substantial gap in tailored agri-financial services. This shortfall in dedicated platforms is compounded by a broader financing gap in agriculture: in 2019 alone, global agricultural financing needs reached USD 240 billion, yet conventional financial institutions could meet only about USD 70 billion of that demand (Shakhovskoy *et al.*, 2019). Taken together, the scarcity of dedicated Agri-FinTech providers and the substantial unmet demand in conventional agricultural finance reveal both untapped potential and underdeveloped infrastructure for FinTech-led solutions in this sector. A systematic synthesis of the existing literature is therefore warranted to clarify what Agri-FinTech has so far contributed, where its capabilities fall short, and how its role can be expanded.

A substantial body of literature sheds light on these challenges, including access to agricultural finance, such as mobile payment applications (Ong *et al.*, 2023) and crowdfunding (Fang, 2022). Other studies have adopted country-specific lenses, examining how Agri-FinTech development unfolds within particular national contexts, such as in China (Liu and Ren, 2023; Wang *et al.*, 2023), Indonesia (Pratiwi, 2023), and Kenya (Gichuki and Kamau, 2022; Omwansa *et al.*, 2013). However, a comprehensive and systematic synthesis of global Agri-FinTech research, particularly those studies focusing on the role of various stakeholders in the FinTech ecosystem, remains absent. Addressing this gap is crucial given the complex and evolving nature of FinTech, influenced by factors at multiple levels—from individual farmers to communities and the broader agriculture sector. Therefore, a systematic literature review is critical to understanding the determinants and impacts of Agri-FinTech development and to informing effective strategies for relevant chain actors.

This study offers three main contributions to the body of knowledge, specifically on the development of FinTech in agriculture. First, this study complements previous SLRs that are limited in scope, either to specific regions or countries or to particular actors, such as studies on the use of FinTech among smallholder farmers in Sub-Saharan Africa by Mapanje *et al.* (2023), FinTech applications in Indonesian agriculture (Rufaidah *et al.*, 2023), and FinTech adoption among smallholder farmers (Rayhan *et al.*, 2024). Second, this study explores the roles of and interactions among key stakeholders in the ecosystem, identifying approaches to support Agri-FinTech development, and broadening the geographical and thematic scope of

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the review through global studies. Third, this study develops a conceptual framework linking the dynamics of the Agri-FinTech ecosystem, technological innovations, adoption drivers, and multi-level impacts. The study's novel conceptual framework will steer the effective implementation and scaling of Agri-FinTech development. The following research questions guided the review:

(1) Who are the actors involved in the Agri-FinTech ecosystem?

(2) What are the drivers of Agri-FinTech development?

(3) What are the impacts of Agri-FinTech development at the farm, community and sectoral levels?

This chapter is organised as follows. Section 2 revisits the definitions of Agri-FinTech. Section 3 reviews the research methodology. Results are presented in Section 4, followed by a discussion of potential areas for future research in Section 5. Section 6 concludes the chapter.

2. The development of Agri-FinTech

The application of technology to financial services (FinTech) has a long history. Early examples include the telephone, and the automated teller machine (ATM), each of which significantly improved the efficiency of financial transactions (Arner *et al.*, 2016). FinTech's evolution can be broadly categorised into three stages, as shown in Figure 1.

FinTech 1.0 utilised the telegraph for financial transactions, enabled by the invention of transcontinental cable transmission. FinTech 2.0 was defined by the digitisation of financial services through electronic technology. FinTech 3.0, beginning around 2008, is marked by the rise of startups offering direct-to-consumer services, significantly expanding the accessibility and scope of financial services.

Given the rapid development of FinTech, it is crucial to understand what it is. While definitions extend from "financial technology combining bank services with computer science and management" (Bettinger, 1972) to encompass a wide array of activities such as contactless payments and digital processes (Walport, 2015), the common thread is the use of technology in the finance industry (Arner *et al.*, 2016). Following the definition of FinTech by Arner *et al.* (2016), this study adopts a definition of Agri-FinTech as "the use of FinTech in the agricultural sector" (Pothula, 2023), focusing specifically on FinTech 2.0 (digital finance offered by traditional institutions) and FinTech 3.0 (innovative services from non-traditional providers). This study focuses on technologies such as mobile banking, crowdfunding, and peer-to-peer lending within the agricultural context.

Agri-FinTech, encompassing FinTech 2.0 and 3.0, has the potential to increase financial inclusion for farmers by facilitating efficient credit disbursement (Pandey *et al.*, 2025). Additionally, the credit mechanisms and product market facilitation of Agri-FinTech platforms play an important role in promoting agricultural sustainability in developing countries by financing production (Rayhan *et al.*, 2024). Globally, Agri-FinTech startups that provide financial solutions continue to emerge year after year (Tracxn, 2025). One example, from Nigeria, is Thrive Agric, which connects farmers with lenders to provide agricultural

Figure 1. The three stages of FinTech (Arner *et al.*, 2016)

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inputs and digital loans. In Indonesia, Crowde has emerged as an alternative financing option for smallholder farmers using a crowdfunding model. Overall, these startups have the potential to increase access to capital and strengthen the resilience of the agricultural value chain (Gao and Gao, 2024; Lyu *et al.*, 2025).

3. Research methodology

Considering the accumulation of studies related to the use of FinTech in agriculture around the world, this study applied a systematic approach to reviewing the literature, which involved comprehensively identifying all relevant studies to answer the research questions (Petticrew and Roberts, 2008). The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) framework is used to guide the rigorous and transparent selection of literature relevant to Agri-FinTech developments in agricultural finance (Koutsos *et al.*, 2019; Page *et al.*, 2021). The PRISMA framework is comprised of five stages: (1) formulation of the research problem; (2) literature search; (3) evaluation of relevant literature; (4) data analysis, synthesis, and interpretation; and (5) reporting of the review results, each of which are discussed below.

3.1 Research problem formulation

This research addresses a critical gap in understanding of Agri-FinTech's impacts by systematically synthesising the main actors, development drivers, and multi-level impacts (farm, community, and sector) based on existing research. While the introduction established FinTech's potential and challenges in the agriculture sector, a comprehensive analysis of these aspects remains absent. Therefore, this study seeks to provide a nuanced understanding of Agri-FinTech's role in transforming agricultural finance.

3.2 Literature search

The literature search began by identifying bibliographic databases, keywords and article search strategies. The search used multidisciplinary databases including EBSCOhost, ProQuest, Science Direct, Scopus, Web of Science, and Google Scholar, which collectively cover agriculture, finance, and technology. The selected studies were drawn from grey literature and peer-reviewed journals. "Grey literature" refers to articles that are not easily identified by database indexes, such as conference proceedings and working papers (Rothstein and Hopewell, 2009). Peer-reviewed studies are included to ensure the quality of the literature in this systematic review (Denyer and Tranfield, 2009). During the literature search, the primary keywords ("financial technology") were paired with secondary keywords ("agriculture") to confine the scope to studies on Agri-FinTech. The set of keywords was searched on all chosen databases. The searches were finalised in October 2023. Appendix 1 details the Boolean operators used in this study.

3.3 Evaluation of the relevant literature

Before retrieving the articles, the inclusion and exclusion criteria were applied (see Table 1). These criteria were designed to ensure the inclusion of high-quality peer-reviewed evidence relevant to FinTech in agriculture. Furthermore, they filtered out ineligible papers (Koutsos *et al.*, 2019) and reduced bias and inconsistency in selecting relevant documents (Frampton *et al.*, 2017). After the screening process, a total of 107 articles relevant to FinTech in the agriculture sector were identified (see Figure 2).

3.4 Analysis, synthesis, and interpretation

The analysis of the 107 relevant studies was divided into two parts. The first part presented the descriptive statistics, including the publication year, publication type, publisher, Agri-FinTech

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Table 1. Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
The document discusses and focuses on the use of financial technology in agriculture	The document discusses factors and aspects other than the use of financial technology in agriculture
Peer-reviewed journal articles, conference papers, industry reports, book chapters	Books, commentaries, and projection studies
Full text available	Publication date before 2010 and after 21 October 2023
Written in English	
Published between 2010–October 2023	

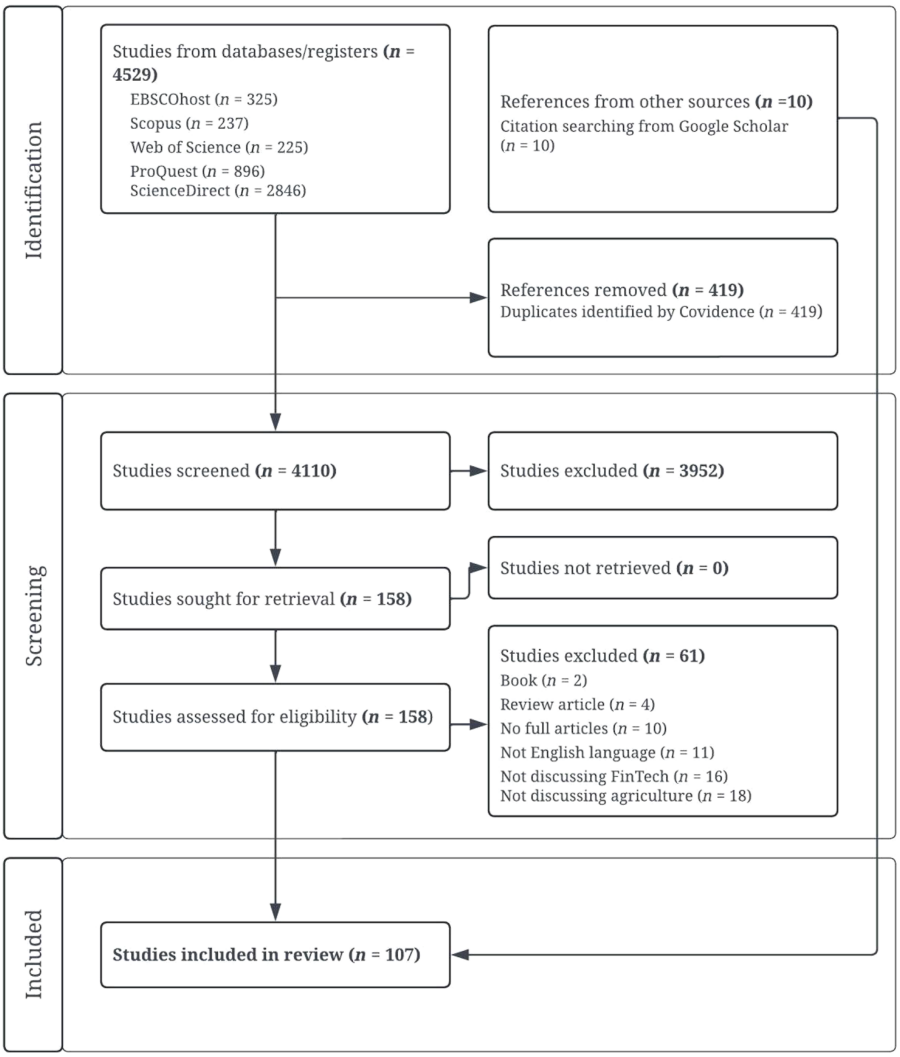

Figure 2. Flowchart of literature selection results following the PRISMA approach

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type, and region. The second part focused on synthesising the reviewed literature, including the actors involved in the Agri-FinTech ecosystem, drivers, and the impacts of Agri-FinTech development.

4. Results

This section presents the results of the systematic literature review in two main parts. The first part offers a descriptive analysis of the 107 reviewed studies, summarising their distribution by year of publication, type of publication, geographical focus, and Agri-FinTech type. The second part synthesises the substantive findings of the review along three lines of inquiry: the actors in the Agri-FinTech ecosystem, the drivers of Agri-FinTech development, and the impacts of Agri-FinTech at the farm, community, and sector levels. Building on these findings, the section concludes with the proposed smallholder-inclusive Agri-FinTech development framework.

4.1 Descriptive analysis

Figure 3 presents the distribution of the selected documents based on the year of publication, the type of publication, the location of the research (i.e. by continent), and the type of

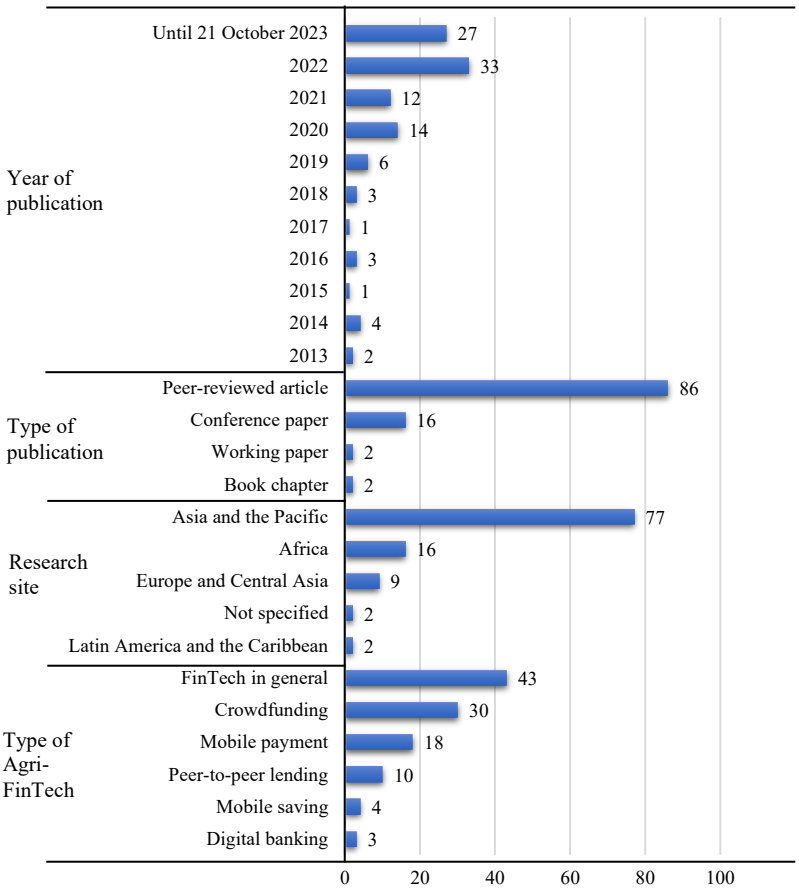

Figure 3. Selected document distribution based on four categories (n = 107)

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Agri-FinTech analysed. The reviewed studies are published between 2013 and 2023, with the majority (approximately 80%) published between 2020 and 2023, reflecting a recent surge in academic interest in Agri-FinTech.

By publication type, 87 articles were published in peer-reviewed journals, while 16 were conference papers. By geographical distribution, 93 articles (88%) described studies in developing countries, particularly in Asia and Africa. This concentration highlights a strong interest in Agri-FinTech in the context of the agriculture sector, where there is limited access to formal financial services and high participation among smallholder farmers. China was the focus of nearly half of the reviewed studies (49 articles), followed by Indonesia (13 articles), India (6 articles), and other countries (see Appendix 3). In Africa, Kenya (6 articles) was the leading focus of research related to Agri-FinTech.

Regarding the Agri-FinTech type, more than a quarter of the selected papers discussed crowdfunding (28%), followed by mobile payments (18%). Figure 4 shows the distribution of Agri-FinTech type studies by year. Because many studies examined FinTech in general rather than specific types, the only clear trends are an increase in research on crowdfunding since 2018, and a growing interest in mobile payments since 2021.

4.2 Actors in the Agri-FinTech ecosystem

This review identified the roles of various actors in the development of Agri-FinTech. To visualise the linkages between actors and elements of the FinTech ecosystem that stimulate innovation in financial services for smallholder farmers, this study examines the Agri-FinTech ecosystem based on previous studies. In Figure 5, the yellow circles show the six elements of the ecosystem, while the pink circles are the actors. The actors in the "providers" element are Agri-FinTech companies, which act as providers of technology-based financial services; smallholder farmers are the users of FinTech. The government has several roles, including as policy maker and provider of FinTech infrastructure. Furthermore, investors provide capital that enables farmers to fund production.

The remaining actors operate across multiple elements of the ecosystem rather than within a single category. Traditional financial institutions function as both "providers" and "talent", directly delivering FinTech services while also contributing financial services expertise, for instance, in innovative credit scoring. Technology developers contribute primarily to the "technology and infrastructure" element by designing and deploying the underlying enabling technologies (e.g. blockchain). Academia also operates across three elements of the

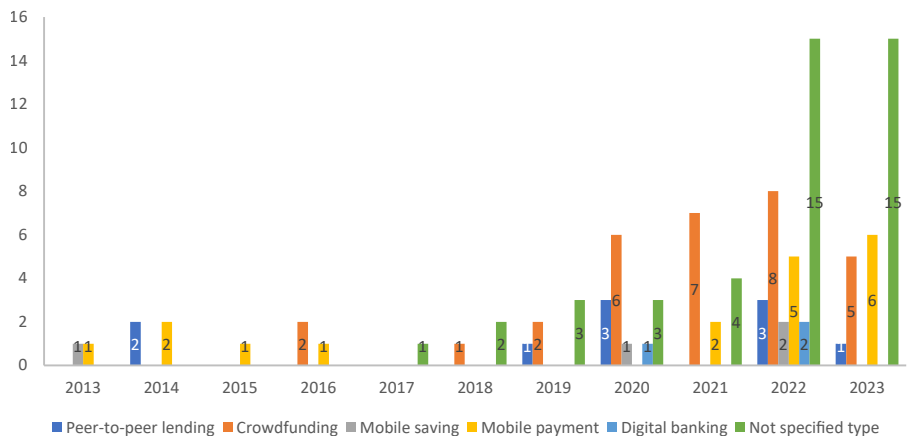

Figure 4. Distribution of Agri-FinTech types over time

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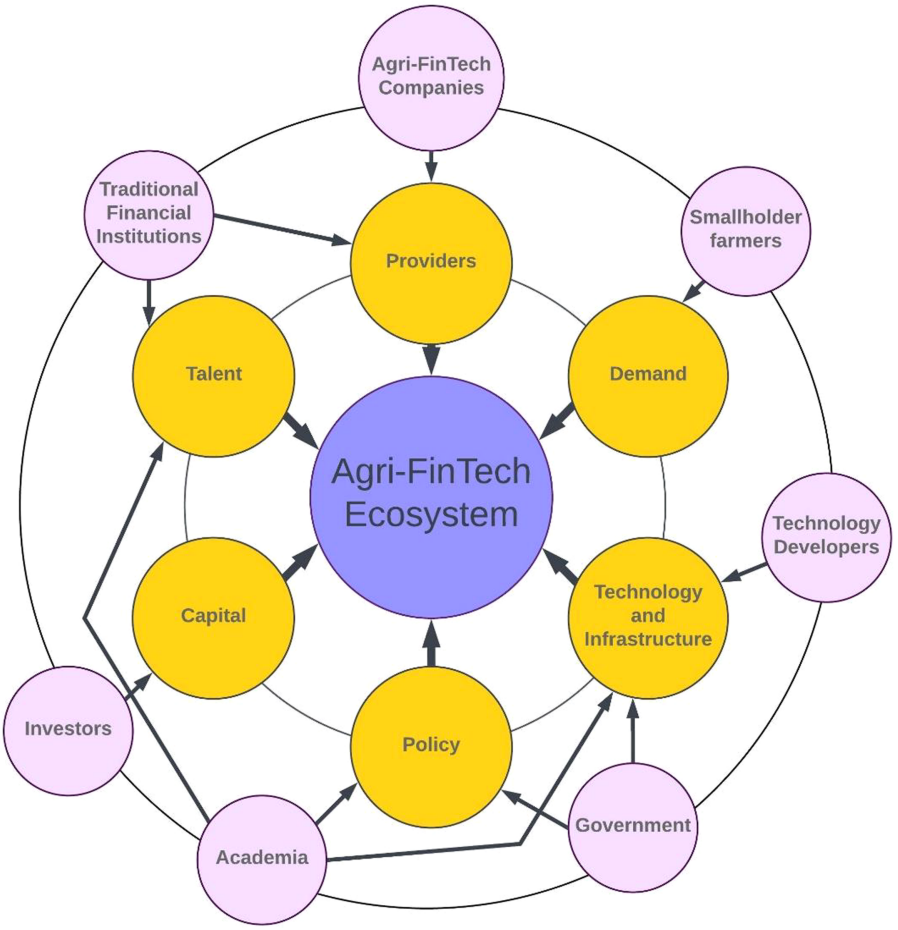

Figure 5. Agri-FinTech ecosystem. Source: Authors' illustration adapted from Diemers *et al.* (2015), Hudaefi *et al.* (2023), Lee and Shin (2018), Senyo *et al.* (2022) and Siddiqui and Rivera (2022)

ecosystem. Academia's contribution to the "technology and infrastructure" element lies in producing the scholarly and applied research that underpins these enabling technologies. Its role in the "talent" element, in turn, is to train the skilled human capital who staff Agri-FinTech firms and supporting institutions. Within the "policy" element, academia supports evidence-based policymaking by generating the empirical evidence on which effective Agri-FinTech regulation and public programmes can be designed. The synthesis described in the following sub-sections is organised around these identified actors.

4.2.1 Agri-FinTech companies. Agri-FinTech companies are key financial intermediaries in the agricultural financial landscape, particularly in providing technology-enabled innovative financing models, including crowdfunding and peer-to-peer lending (Afandi *et al.*, 2021; Azganin *et al.*, 2021a, b; Jaenudin and Hendratmi, 2023; Omwansa *et al.*, 2013; Saiti *et al.*, 2018; Sylla, 2023; Thaker *et al.*, 2020; Yuzaria *et al.*, 2020). These models are designed to bridge the credit gap in agriculture by offering alternative sources of capital outside traditional banking. These include those based on Islamic principles, such as waqf

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crowdfunding (WCM) (Azganin *et al.*, 2021a), Islamic peer-to-peer crowdfunding (IP2PC) in Malaysia (Azganin *et al.*, 2021b), muzara'ah-based crowdfunding in Mali (Sylla, 2023), and salam-based crowdfunding in Afghanistan (Saiti *et al.*, 2018). These Islamic crowdfunding models aim to expand Agri-FinTech adoption—particularly crowdfunding—in predominantly Muslim countries. Another crowdfunding model is the Integrated Agricultural Land Fundraising Model (IALCM) in Indonesia (Thaker *et al.*, 2020), in which the government participates through the selection and shortlisting of farmers' work plans to obtain funding from crowdfunders.

Studies on Agri-FinTech companies have also adopted a case study approach, including of TernAkses (Afandi *et al.*, 2021), i-Ternak (Yuzaria *et al.*, 2020), and Ternaknesia (Jaenudin and Hendratmi, 2023) in Indonesia, and M-Pesa in Kenya (Omwansa *et al.*, 2013). The TernAkses platform offers two investment options: livestock capital investment and livestock-raising services. Investors share in the profits from livestock sales based on the type of investment. During the investment period, investors can monitor the progress and prospects of the livestock farm via the web and email. Overall, the relationship between the two parties creates an ecosystem in which investors provide capital while farmers gain access to funding. Meanwhile, i-Ternak and Ternakesia only provide funding investment options and do not offer livestock-raising services. However, the three platforms share similar business characteristics. In contrast, the M-Pesa case study concluded that sustainable mobile money savings products are essential to improve farmers' welfare.

4.2.2 Smallholder farmers. The selected studies address smallholder farmers' demand for Agri-FinTech services. A study in Madagascar found that female farmers differed from male farmers in terms of instalment payments, distance travelled to service providers' offices, and FinTech service transaction costs (Wahbi *et al.*, 2023). Meanwhile, a case in Southern Nigeria found that female smallholder farmers who accessed FinTech earned higher incomes and had more savings than those without access to FinTech (Chinelo and Ayodeji, 2023). In Ghana, mobile phone-based saving appeared to benefit female farmers in particular, in contrast to male farmers (Possner *et al.*, 2022).

Based on the findings of the systematic literature review, there are challenges in developing Agri-FinTech for smallholder farmers. Parlasca *et al.* (2022) found limited usage of FinTech for agricultural purposes among farmers, such as mobile payments and mobile banking loans. This pattern of limited usage reflects farmers' unfamiliarity with FinTech and their sense of insecurity when using digital financial platforms (Jaiswal *et al.*, 2022; Suasih *et al.*, 2022). Low financial and digital literacy is another contributing factor, partly because information about FinTech, especially through the internet, reaches farmers unevenly due to the rural–urban digital divide (Suasih *et al.*, 2022). Farmers' uptake of FinTech is also constrained by their access to ICT infrastructure, including the internet (Filimonova *et al.*, 2019).

4.2.3 Government. The systematic review found very limited existing research on Agri-FinTech policy. One of these studies discussed the impact of FinTech policy support on the development of agricultural industrialisation (Wang *et al.*, 2021). The authors highlighted the need for policies to increase support for e-commerce financing, expand the scope of mobile financing, and supervise the agriculture industrialisation system (Wang *et al.*, 2021). Another study discussed the need for policies to expand the role of non-bank financial intermediaries to foster ICT-based financial innovation, especially FinTech for farmers (Nkala, 2023). Therefore, regulators should focus on creating an enabling environment for digital financing of agriculture while closely supervising the delivery of financial services.

4.2.4 Traditional financial institutions. Traditional financial institutions (e.g. banks) play a part in the Agri-FinTech ecosystem. Since individuals with access to bank services are more likely to use financial technology, farmers, who often lack such access, remain the least likely group to adopt FinTech (Song *et al.*, 2023). To improve financial service accessibility for borrowers with limited credit documentation, several studies have considered linking FinTech to alternative banking services. One study argued that a potential solution is FinTech-based Islamic banking to provide interest-free loans (Maryam and Ahamad, 2021). However, others

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positioned FinTech as an alternative to conventional banking services. For instance, farmers without bank accounts can use a simple P2P mobile payment for money transfers (Szopinski and Staniewski, 2014).

4.2.5 Investors. Investors play an integral part in the Agri-FinTech ecosystem by providing capital. Studies have found that investors prefer low-risk projects (Du, 2022; Mardhiyyah *et al.*, 2020), short-term loans (Du, 2022; Mardhiyyah *et al.*, 2020; Tong and Xiao, 2019), low interest rates (Tong and Xiao, 2019), and small investment amounts (Du, 2022). Further, a study found that investors tend to prefer female farmers over male farmers as women are perceived to be more competent in managing finances (Tong and Xiao, 2019). Furthermore, early-stage crowdfunding supporters are positively influenced by people, product, and convenience dimensions, whereas cost discourages contribution (Du, 2023). Investors' decision speed in crowdfunding is shortened by good product reputation, publicity, reasonable returns, low investment threshold, and additional benefits (Li *et al.*, 2020). The crowdfunding platform's website interface and responsiveness also influence investor satisfaction (Portus and Flores, 2017).

4.2.6 Technology developers. Existing research on technology developers has discussed blockchain, Internet of Things (IoT), and near-field communication (NFC) technologies. Blockchain-based crowdfunding has the potential to increase investor trust and to help identify which project investments are most beneficial (Rashmitha *et al.*, 2022). Blockchain technology can also strengthen credit systems, reduce information asymmetry, smooth information channels, improve transaction reliability and efficiency, and lower financing costs (Zhang, 2020). For IoT, a FinTech-based approach to designing and assessing IoT systems (FINDEAS) has been developed to identify IoT-based smart agricultural systems that are efficient, safe, affordable, and responsive to farmers' needs (Polymeni *et al.*, 2022). Improving transaction security through blockchain technology and IoT is expected to increase farmers' trust in using FinTech. NFC has been developed to overcome poor internet connectivity and the absence of conventional banks in rural areas, supporting applications such as online payment (Imbachi *et al.*, 2015). Integrating technologies is expected to improve the efficiency and accessibility of FinTech.

4.2.7 Academia. Most of the studies selected in this systematic review were conducted by university researchers from various academic disciplines. Many articles were written by researchers affiliated with economics schools (Fang, 2022; Jaiswal *et al.*, 2022; Lian *et al.*, 2023; Song *et al.*, 2023), business schools (Amin and Li, 2014; Septiani *et al.*, 2020; Thaker *et al.*, 2020), finance schools (Aisaiti *et al.*, 2019; Liu *et al.*, 2022), and management schools (He and He, 2022; Li *et al.*, 2020; Xue and Li, 2022). Others were from agriculture schools (Filimonova *et al.*, 2019; Lin *et al.*, 2022; Wang *et al.*, 2022a). In addition, researchers from information technology schools have also conducted studies (Desabathina *et al.*, 2022; Omwansa *et al.*, 2013; Ong *et al.*, 2023). This indicates that Agri-FinTech as a research field has drawn scholars from various backgrounds.

4.3 Drivers of Agri-FinTech development

The systematic literature review found three studies that used the Technology Acceptance Model (TAM) (Davis, 1989) to determine the drivers of Agri-FinTech adoption. In Bangladesh, job relevance was a determinant of perceived benefits, and self-efficacy served as a determinant of ease of use, which influenced the intention to adopt Agri-FinTech (Amin and Li, 2014). In China, job relevance was also found to be a determinant of perceived benefits, while product innovation and self-efficacy were determinants of relative advantage and Agri-FinTech's ease of use, respectively (Amin and Li, 2014). In a Brazilian context, Malaquias and Silva (2020) found that ease of use, perceived benefits and trust were each significantly and positively associated with FinTech adoption among farmers. Social influence, in contrast, exhibited a negative association with FinTech use, diverging from the positive relationship reported by Amin *et al.* (2014).

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Other studies on Agri-FinTech adoption factors used the Unified Theory of Technology and Acceptance (UTAUT) (Venkatesh *et al.*, 2003, 2012). Maryam *et al.* (2023) concluded that benefit expectations, effort expectations, perceived credibility, anxiety, and consumer innovation influenced the adoption of FinTech in the agriculture sector. Another study revealed that social influence, facilitating conditions, habits, effort expectations, and epistemic value affected farmers' intention to use FinTech (Ong *et al.*, 2023). Septiani *et al.* (2020) concluded that effort expectation, social influence, hedonic motivation, price value, habit, perceived risk, basic values, and trust influenced farmers' willingness to adopt Agri-FinTech.

Agri-FinTech development can also be influenced by project characteristics. For crowdfunding, its success is shaped by the funding rationale (Du, 2022), fund usage plan (Du, 2022), funding target (Chang, 2018; Du, 2022; Ljumović *et al.*, 2021), the product qualification certificate (Du, 2023) and the number of investors (Chang, 2018). Collaboration, organisational leadership capabilities, and assurance of quantity and quality of agricultural products also influence the success of Agri-FinTech projects (Xue and Li, 2022). Knowledge management capabilities have also been identified as critical (Cillo *et al.*, 2019). Shared responsibility through self-selected farmer groups can therefore help mitigate the risk of project failure (Pratiwi, 2023). Equally important to increasing the uptake of Agri-FinTech is ensuring access to an internet connection (Filimonova *et al.*, 2019).

Innovation in credit scoring is another potential driver of Agri-FinTech development. The review found two studies on designing online credit risk evaluation for farmers (Rao *et al.*, 2020a, b). The credit scoring models proposed in the two studies used an indexing approach related to smallholder farmers' financial history, such as their annual income, annual expenditure, land contract, and planting scale.

4.4 Impacts of Agri-FinTech development

The review identified that Agri-FinTech produces effects related to smallholder farmers at multiple levels, including at the farming household level, the community level and the general agriculture sector level (see Appendix 2). At the household level, Agri-FinTech has proven to have the potential to increase income, consumption, economic resilience, and women's access to financial services. For example, research in China by Wang *et al.* (2023) shows that P2P lending platforms significantly increased farmers' income. At the community level, FinTech contributes to poverty alleviation and the reduction of income inequality, as demonstrated by research in Tanzania (Kilombele *et al.*, 2023) and China (Wang *et al.*, 2022b; Wang and Fu, 2022). At the agriculture sector level, the impacts have been more widespread, including improvements in agricultural productivity (Musa *et al.*, 2023; Shen *et al.*, 2023), agribusiness digitalisation (Liu *et al.*, 2023), and decarbonisation (Liu and Ren, 2023). Some studies also indicate the potential of FinTech to reduce dependence on conventional financial institutions (Azcárate *et al.*, 2023) and to promote agricultural export growth (Kere and Zongo, 2023). Through this categorisation, it is evident that Agri-FinTech provides economic, social, and environmental benefits.

Furthermore, a growing body of research has examined FinTech adoption's environmental benefits. FinTech can help reduce carbon emissions by enabling entrepreneurship and agricultural technology innovation (Chang, 2022; Liu and Ren, 2023). A more nuanced finding emerges from Jiang *et al.* (2019), who posited an inverted "U"-shaped relationship between FinTech use and agricultural pollution, meaning that FinTech development after crossing a particular "threshold value" would curb pollution in underdeveloped areas. However, the authors also argued that this is not the case in countries where agriculture is already developed (Jiang *et al.*, 2019). Lin *et al.* (2022), in contrast, contended instead that pollution reduction increases alongside Agri-FinTech development. Regarding sustainable agricultural practices (SAP), empirical research has concluded that the use of Agri-FinTech significantly increased SAP adoption by reducing credit constraints. This encouraged investment in SAP implementation, provided production and marketing information, reduced

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information search costs, and promoted social interaction among farmers, thereby facilitating the dissemination of production information (Zhao *et al.*, 2022b).

Regarding the gender dimension, Gichuki and Kamau (2022) concluded that female farmers produce smaller harvests because limited land ownership restricts their access to credit, and identified FinTech as one potential solution. Wahbi *et al.* (2023) confirmed the lack of financial inclusion of women and stated that FinTech could improve this situation, given its ease of use and affordability. Further, Chinelo and Ayodeji (2023) found that female farmers who accessed FinTech products had higher incomes and savings than those who did not. These studies suggest that female smallholder farmers' access to credit differed from that of males, resulting in lower production and income levels.

4.5 Smallholder-inclusive Agri-FinTech development framework

Having synthesising the current research on Agri-FinTech, a conceptual framework is proposed, as shown in Figure 6. This framework is specifically developed to explain the adoption and sustainable use of digital financial technology in the agricultural sector (Agri-FinTech), particularly among smallholder farmers.

The Agri-FinTech framework in Figure 6 illustrates a systemic approach to the development of financial technology in the agriculture sector. This framework emphasises the importance of multi-dimensional integration to create sustainable agricultural system transformation (High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security (HLPE), 2017). In this framework, Agri-FinTech serves as an instrument that can enhance farmers' access to finance and contribute to the transformation of the food system towards greater agricultural productivity and sustainability.

The framework structure uses causal pathway logic and emphasises that change occurs through a series of measurable and traceable outcomes following the theory of change (TOC) (Connell and Kubisch, 1998; Fullbright-Anderson *et al.*, 1998; Taplin *et al.*, 2013). Individual factors, innovation ecosystems, and regulatory project factors are "drivers" that serve as preconditions for initiating change and determining the success of Agri-FinTech implementation. Beyond individual-level factors, project characteristics, credit-scoring innovation, and adequate regulatory certainty also significantly shape technology adoption (Chang, 2018; Du, 2022; Rao *et al.*, 2020a). The project-related factors are considered important because they influence investors' and farmers' decisions to use Agri-FinTech platforms, particularly in crowdfunding and peer-to-peer lending, both of which are rapidly growing in various countries.

The innovation ecosystem—comprising farmer platforms, Agri-FinTech companies, academia, technology developers, traditional financial institutions, investors, and the government—consists of actors that collaborate to implement FinTech in the agricultural sector in line with the High Level Panel of Experts on Food Security and Nutrition of the

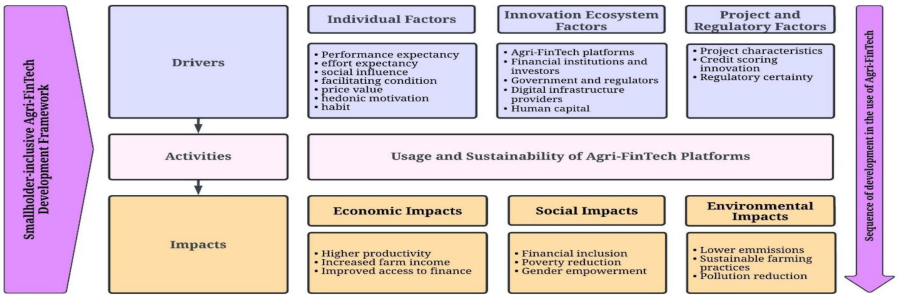

Figure 6. Smallholder-inclusive Agri-FinTech development framework

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Committee on World Food Security (High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security (HLPE), 2017) framework. These elements create conditions that support the use of financial technology in agriculture. Furthermore, "activities" that focus on the use and sustainability of Agri-FinTech platforms represent the implementation stage of the TOC.

The impacts of this framework, spanning economic, social, and environmental dimensions, demonstrate a commitment to multi-dimensional results (High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security (HLPE), 2017). In addition, the implementation of activities based on drivers is expected to encourage the use of FinTech technologies not only at the outset but also sustainably. This sustainable adoption will generate various positive impacts in three main sustainability dimensions, namely economic impacts (increased agricultural productivity, increased farmer income, and easier access to capital), social impacts (increased financial inclusion especially for women, reduced poverty, and reduced socio-economic inequality), and environmental impacts (reduced carbon emissions, increased adoption of sustainable agricultural practices, and decreased pollution due to agricultural activities) (Jiang *et al.*, 2019; Kilombele *et al.*, 2023; Liu and Ren, 2023; Wang *et al.*, 2023). Assumptions across these various levels of impact must be continuously monitored to ensure that the use of Agri-FinTech achieves the expected results (Taplin *et al.*, 2013). Thus, this Agri-FinTech framework offers an operational roadmap for achieving sustainable agriculture through financial technology innovation, mapping how initial conditions (drivers) are translated into actions (activities) that ultimately deliver financial access, agricultural productivity, and environmental sustainability.

5. Future research directions

The results of the systematic review suggest five priority topics for further research. First, only six of the reviewed studies addressed Agri-FinTech adoption factors, indicating a notable research gap. Therefore, future studies should more comprehensively examine the factors influencing smallholder farmers to utilise FinTech, drawing on other theories or methodologies. A gender focus is also critical, given the differences in access to assets, technology, and training opportunities between male and female farmers, which contribute to gendered differences in FinTech adoption.

Second, a topic not addressed in any of the reviewed articles is how to introduce FinTech to smallholder farmers for the first time. Many developing countries' farmers are older and less educated, and unfamiliar technologies pose a particular challenge for these farmers. Future research must therefore critically examine effective strategies for communicating FinTech benefits to this group.

Third, farmers' perceptions of the reasons for using, not using or discontinuing use of FinTech have not been thoroughly scrutinised. Such research is critical to ensuring inclusive, demand-led FinTech development in agriculture. Farmers' willingness to use FinTech, and their views on FinTech product attributes that influence their adoption decision, their understanding of the investments required to acquire FinTech technology, and the expected benefits they will gain from FinTech use compared to alternative financing services remain understudied. Accordingly, future studies should explore approaches such as discrete choice experiments to identify FinTech attributes that matter most to smallholder farmers. Research on the costs involved in using FinTech is also important. Therefore, ex-ante cost-benefit analyses (CBA) are relevant to determining the net benefits of FinTech to farmers.

Fourth, none of the 107 primary studies reviewed provided details on FinTech regulations in the agriculture sector. To ensure inclusivity, future studies should evaluate whether there is a rational basis for public policy intervention in FinTech development. To inform appropriate policy design, ex-ante CBA can complement this work by identifying unintended consequences and the distribution of benefits and costs.

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Fifth, there is limited research on green Agri-FinTech articles among the articles selected for this review. Some of these articles concluded that FinTech has the potential to reduce carbon emissions and increase the adoption of SAP. No study, however, included findings about the latest technologies (such as IoT, NFC, and blockchain), Agri-FinTech services, and environmental considerations (e.g. the impact of agricultural waste). Future research is also needed on how Agri-FinTech companies can offer services oriented toward environmental projects for investors.

6. Conclusions and recommendations

This study makes an important contribution to the literature on Agri-FinTech development. Using the PRISMA framework, the study systematically reviewed the international literature on Agri-FinTech and analysed 107 articles published between 2013 and October 2023. The findings reveal that although FinTech has revolutionised the global financial sector, its application in the agriculture sector is not yet mature, especially in developing countries. In addition, this study proposes a new framework that provides an operational roadmap for achieving sustainable agriculture through financial technology innovation.

The synthesis of the systematic literature review highlighted the following key findings. First, nearly a third of the studies discuss crowdfunding, and nearly half of these were conducted in China. Second, collaboration among actors in the Agri-FinTech ecosystem is key to driving inclusive innovation in the agricultural finance sector. Third, important drivers influencing the use of Agri-FinTech include the characteristics of funded projects, adequate infrastructure, technologies, and innovations in credit scoring. Fourth, the results demonstrate the positive impact of FinTech on farmer households, communities, and the agricultural sector. Fifth, this study proposes a smallholder-inclusive Agri-FinTech development framework to explain the adoption and sustainable use of Agri-FinTech. This framework describes a collaborative ecosystem among farmers, Agri-FinTech companies, traditional financial institutions, technology developers, academia, investors, and governments to achieve financial inclusivity. The framework also outlines strategic steps to scale up Agri-FinTech adoption. Overall, this framework encompasses the provision of digital financial services, the promotion of sustainable use, and improved financial access for smallholder farmers.

This systematic review research identifies several avenues for future research. Research on the adoption of FinTech by smallholder farmers remains limited, necessitating the expansion of theoretical and methodological approaches, including the integration of gender perspectives. Future work should also formulate effective strategies for introducing FinTech to older or less educated farmers and examine smallholder preferences for Agri-FinTech characteristics that may encourage adoption, using methods such as discrete choice experiments (DCE) and cost-benefit analysis (CBA). At the regulatory level, contextual Agri-FinTech policy studies are important to ensuring inclusiveness. The research agenda also needs to integrate the latest technological findings, Agri-FinTech services, and environmental considerations.

Several caveats apply when interpreting these results. First, the literature search was conducted in October 2023, excluding more recent research. Given the rapidly evolving nature of the FinTech industry, the relevance of this study's findings to the latest FinTech context must be considered. Second, most of the documents reviewed were peer-reviewed articles while many privately published paid consultancy reports were not accessible. Therefore, insights from the private sector are limited. Nevertheless, this study contributes to the limited body of literature reviewing FinTech development in the agricultural sector. This contribution is timely, given the growing global interest in FinTech and digital transformation across the agriculture sector.

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Appendix 1

Table A1. Search terms and number of studies found

Enquiry date	Database	Terms	Results
21 October 2023	EBSCOhost	AB (“financial technology” OR “digital finance” OR “fintech” OR “mobile payment” OR “digital payment” OR “crowdfunding” OR “p2p lending” OR “peer to peer lending” OR “online lending” OR “digital lending” OR “smart financ*”) AND AB (“farm*” OR “agri*” OR “e-agri*”)	325
21 October 2023	ProQuest	noft (“financial technology” OR “digital finance” OR “fintech” OR “mobile payment” OR “digital payment” OR “crowdfunding” OR “p2p lending” OR “peer to peer lending” OR “online lending” OR “digital lending” OR “smart financ*”) AND noft(“farm*” OR “agri*” OR “e-agri*”)	896
21 October 2023	Science Direct	(“financial technology” OR “digital finance” OR “fintech”) AND (“farm” OR “farmer” OR “farming” OR “agriculture” OR “agricultural”)	1,192
		(“mobile payment” OR “digital payment” OR “crowdfunding” OR “p2p lending”) AND (“farm” OR “farmer” OR “farming” OR “agriculture” OR “agricultural”)	1,451
		(“peer to peer lending” OR “online lending” OR “digital lending” OR “smart finance”) AND (“farm” OR “farmer” OR “farming” OR “agriculture” OR “agricultural”)	203
21 October 2023	Scopus	(TITLE-ABS-KEY (“financial technology” OR “digital finance” OR “fintech” OR “mobile payment” OR “digital payment” OR “crowdfunding” OR “p2p lending” OR “peer to peer lending” OR “online lending” OR “digital lending” OR “smart financ*”) AND TITLE-ABS-KEY (“farm*” OR “agri*” OR “e-agri*”))	237
21 October 2023	Web of Science	“financial technology” OR “digital finance” OR “fintech” OR “mobile payment” OR “digital payment” OR “crowdfunding” OR “p2p lending” OR “peer to peer lending” OR “online lending” OR “digital lending” OR “smart financ*” (Topic) AND “farm*” OR “agri*” OR “e-agri*” (Topic)	225

Appendix 2

Table A2. The impacts of Agri-FinTech

No.	Impacts of Agri-FinTech at each level	Author(s), year
1	*The farming household level*	
	a. Household income growth	Guo *et al.* (2023), Kikulwe *et al.* (2013), Lian *et al.* (2023), Song *et al.* (2022), Wang *et al.* (2022a), Wang *et al.* (2023), Yi *et al.* (2023)
	b. Increased household consumption	Zhang *et al.* (2022), Zhao *et al.* (2022a)
	c. Household resilience	Wu *et al.* (2023)
	d. Increased farmer investment	Xu *et al.* (2022)

(*continued*)

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Table A2. Continued

No.	Impacts of Agri-FinTech at each level	Author(s), year
2	*The community's level*	
	a. Carbon emission reduction	Chang (2022), Farstad and Hårstad (2022), Jiang *et al.* (2019), Li and Fang (2025), Lin *et al.* (2022), Liu and Ren (2023), Yu *et al.* (2020)
	b. Poverty reduction	Kilombele *et al.* (2023), Wang and Fu (2022), Zhang *et al.* (2021)
	c. Income inequality reduction	Wang *et al.* (2022b)
	d. Reducing reliance on financial intermediaries	Desabathina *et al.* (2022)
	e. Credit risk control	Wu *et al.* (2022)
	f. Rural economic growth	Mei *et al.* (2022)
3	*The agriculture sector level*	
	a. Increased financial resources	Aisaiti *et al.* (2019), Anjani and Waluyati (2022), Azcárate *et al.* (2023), Chen and Ren (2022), He and He (2022), Li *et al.* (2023a), Manta (2018), Ningrat and Nurzaman (2019), Szopinski and Staniewski (2014), Yao *et al.* (2022)
	b. Increased agricultural production	Dannenberg and Lakes (2014), Kanagavalli *et al.* (2021), Kilombele *et al.* (2023), Liu and Ren (2023), Musa *et al.* (2023), Shen *et al.* (2023)
	c. Adoption of agricultural technology	Batista and Vicente (2020), Li *et al.* (2023a, b)
	d. Increased proportion of agricultural land	Lei and Su (2023)
	e. Adoption of sustainable agricultural practices (SAP)	Zhao *et al.* (2022b)
	f. Stimulating exports	Kere and Zongo (2023)
	g. Digital transformation of agribusiness	Liu *et al.* (2023)
	h. Financial deepening	Turyatemba *et al.* (2023)
	i. Sustainability-oriented innovation	Troise *et al.* (2021)
	j. Alternative financing during the Covid pandemic	Liu *et al.* (2022)

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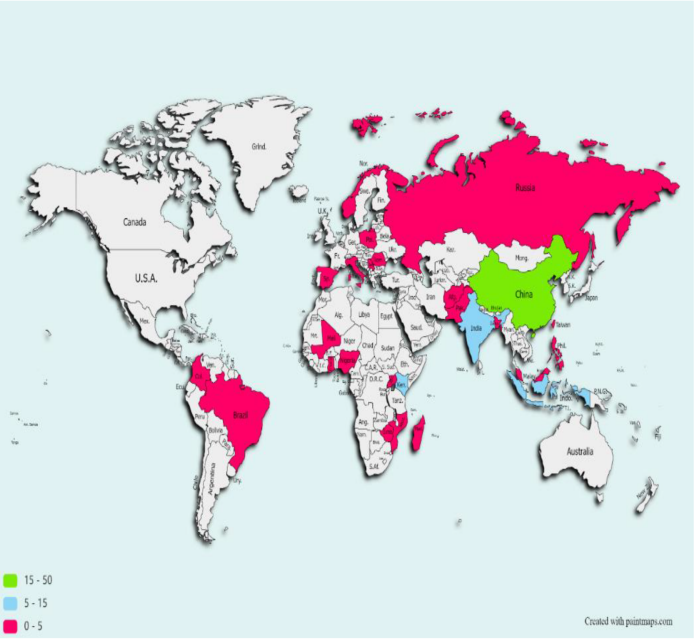
Appendix 3



No	Country	Total
1	China	49
2	Indonesia	13
3	India	6
4	Kenya	6
5	Malaysia	2
6	Norway	2
7	Pakistan	2
8	Other countries	27

Figure A1. Geography of countries studied

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Corresponding author
Joko Sustiyo can be contacted at: j.sustiyo@uq.edu.au

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