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Bridging the digital gap: Empirical insights into agri-food supply chain transformation

Peiyun Yu [a,b], Roshayati Abdul Hamid [a,*], Lokhman Hakim Osman [a], Jing Liao [c]

[a] Faculty of Economics and Management, Universiti kebangsaan Malaysia, Bangi, Malaysia
[b] School of Management, Guangzhou College of Commerce, Guangzhou, China
[c] School of Modern Logistics, Guangzhou Panyu Polytechnic, Guangzhou, China

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ABSTRACT

The agri-food supply chain (AFSC) is undergoing transformation in the digital era. Despite growing interest in digital technologies, empirical studies examining the adoption of digital technology within AFSC are still scarce. This systematic literature review synthesizes state-of-the-art research from 2015 to 2024, identifying emerging trends and theoretical frameworks related to digital technology in AFSC. Utilizing the PRISMA process, this study reviewed 26 articles that employed Structural Equation Modeling (SEM). This review identified five main clusters: behavior intention, sustainability, operation, performance, and risk management. Results show a rising trend in empirical research on digital technologies in the AFSC, with blockchain emerging as the most frequently mentioned technology. Theories such as the Technology Acceptance Model (TAM), Unified Theory of Acceptance and Use of Technology (UTAUT), Resource-Based View (RBV), Natural Resource-Based View (NRBV), and Dynamic Capabilities View (DCV) are frequently applied. The review highlights the importance of integrating digital technologies to enhance efficiency, transparency, and sustainability in AFSCs. It underscores blockchain's potential for traceability and IoT's role in improving operational efficiency. Additionally, it stresses the need for managers to prioritize investment in digital infrastructure and training to effectively leverage these technologies. Future research should focus on exploring gaps, particularly in the context of emerging economies, to ensure that digital technologies can realize their potential for enhancing sustainability and performance in the AFSC.

1. Introduction

Agri-food supply chain (AFSC) is a complex network connecting farmers to customers. "From farm to fork" comprises multiple stakeholders, such as producers, manufacturers, logistics providers, retailers, and consumers [1]. The growing number of global populations is challenging AFSC. According to the report, the global population will get to the top at around 10.3 billion in the mid-2080s [2]. Nevertheless, there are still one third food produced for human daily consumption is wasted globally [3,4]. AFSC is under high pressure to deplete the rate of water and fossil fuels, the shrinking availability of arable land, and the increasing demand by consumers for more transparent and sustainable food chains. It is necessary for AFSC to improve efficiency and sustainability, so as to nourish the world's population [5].

Digital technology encompass a variety of tools, such as blockchain [6,7], Internet of things (IoT) [8], digital platforms [9,10], big data [11, 12], information system [13,14] information communication technology [15], and so on. Considering the terminology of technologies various differently, digital technology is used as an umbr1ella term to summarize those individual terms.

The digital transformation within the AFSC encompasses a range of technologies like blockchain, IoT, digital platforms, digital marketing, Industry 4.0, and AI, Blockchain applications in AFSC contribute to SDGs, such as SDG2(zero hunger), SDG3(health and wellbeing), SDG12 (consumption and production in AFSC), and it improves transparency, traceability, and food safety, food trade [16,17]. IoT is used for monitoring, while digital platforms facilitate the redistribution of food surplus in AFSC [8,18]. Digital marketing also has a direct positive impact on the sustainable food system [19]. Industry 4.0 positively affects sustainable supplier management, sustainable operations, and risk management [20–22]. AI makes a difference in agriculture, including soil management, pest and weed management, disease management, crop management, and water-use optimization [23].

However, digital technology in AFSC still faces many challenges,

* Corresponding author.
E-mail address: wanrose@ukm.edu.my (R. Abdul Hamid).

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such as technology adopting issue and low data transmission [24,25]. High implementation costs and a lack of expertise are among the most significant obstacles [26]. Specifically, digital agricultural technology may amplify the disparities within the food system, particularly affecting smaller farmers and agri-food enterprises [27]. Therefore, it is urgent to find a proper way to effectively adopt digital technology within AFSC.

Although digital technologies implication in AFSC has received extensive attention, most studies focused on qualitative analysis, such as case study [6,28], interview [29], as well as conceptual framework [30]. Life cycle assessment can analyze different scenario and catalyze circular economy transition [26], but unable to examine the relationship between digital technology and AFSC [31,32,26]. Previous reviews have combined quantitative and qualitative studies to provide insights into various aspects of the modern AFSC [33]. However, few scholars have systematically mapped the existing quantitative studies related to the AFSC [34].

Previous literature reviews have focused on specific digital technology along the AFSC, such as blockchain [16,35,36], AI [23], IoT [37,38], big data [37,39,40], Industry 4.0 [22,37,38] and so on. The topic varies from AFSC risk management [5,34], the benefits and challenges of digital technology adoption [35,36], to sustainability [33,39–42]. Klerkx et al., [43] identified five thematic clusters related to digital technology adoption in agriculture. There are some reviews that explores different aspects of digital technology in AFSC. However, there are comparatively few empirical studies based on Structural Equation Modeling (SEM), which limit quantitative analysis and in-depth understanding of the adoption of digital technologies. In addition, the integration of key variables and management theories in existing research is still imperfect [44], making it difficult to fully reveal the driving factors and influencing mechanisms of digital technology. Details are listed on Table 1.

To fill these gaps, a systematic literature review (SLR) of peer-reviewed journals over 10 years (2015–2024) was conducted to elucidate the role of digital technology using SEM. It aims to deeply understand the current management theory and future trends of the application of digital technology in AFSC. The study will address the following research questions (RQ): RQ1: What are the state-of-the-art studies of digital technology in AFSC? RQ2: What are the emerging management theories in relation to digital technology within AFSC? RQ3: What are the future trends of digital technology in AFSC?

The primary research objective (RO) of this paper is listed as follows: RO1: To understand the current studies of digital technology in AFSC. RO2: To provide the existing research landscape related to digital technology in AFSC, such as the main themes, constructs, and theories underlying current quantitative research on digital technology within AFSC. RO3: To explore future research directions through several theoretical lenses of digital technology in AFSC.

The paper is organized in this way: Section 2 outlines the proposed SLR methodology and material. Section 3 presents the main findings in detail. Section 4 engages in discussion, which includes thematic framework, practical implication, and potential future research directions. Section 5 provides an overarching conclusion on the study.

2. Methodology

SLR is used to determine the scope, covering a body of literature on a given topic. It gives a clear explanation of the volume of literature, available studies, and an overview of its interested area [45]. This methodology is useful for examining the extent, range, nature, and characteristics of the evidence on a topic [46]. This study identifies quantitative studies using SEM to measure the digital technology of the AFSC. This methodology is applied to identify articles related to the SLR process. It is applied below.

Stage 1: Identify studies related to digital technology in AFSC. Academic journals were retrieved from three main databases: Scopus, Web of Science (WoS), and Taylor & Francis. These databases include the top science and technology journals [47]. They offer access to a wide range of scientific papers from many different knowledge fields and with varied propositions [48]. Therefore, this study selected these three databases as original source. Table 2 shows comprehensive search strings of keywords that are related to digital technology.

Stage 2: Screen and to remove redundant articles. Only journal (research articles) are included. It serves as the main source of analytical evidence. Additionally, the study excluded the type of review articles, meta-analysis articles, meta-synthesis articles, book series, book chapters, and newspaper articles. All selected papers language are English. Articles published within the last decade (from Jan 2015 to Dec 2024) were included. Articles from other fields are excluded to avoid irrelevant articles or proceeding papers. Details are listed in Table 3.

Stage 3: Show the data. Using Microsoft Excel to assist with comparative analysis. Items like publication years, countries, main types of structural equation modeling, associated sectors and digital technologies were recorded in this form.

Stage 4: Collect, summarize, and report the results. The thematic framework, practical implications, and future research directions from the selected articles are compiled to understand the context of digital technology within AFSC.

Following the above criteria, 1337 articles were identified from three databases. After reviewing the title and abstract, 778 articles were excluded because of types of review (systematic, meta-analysis etc.), not in English, not related to AFSC, and published year before 2015. Then, 172 articles were excluded because of duplication. From the remaining 387 articles, we excluded 326 articles after reading their titles, abstracts, and keywords. After going through a rigor process of assessing 61 full-text papers, a total of 26 articles that utilize Structural Equation Modeling (SEM) were identified that are aligned with the objectives of this systematic review, in accordance with Preferred Reporting Items for Systemic Review (Fig. 1 PRISMA) to conduct a SLR.

3. Main findings

3.1. Trend of publication year

Fig. 2 presents a comprehensive overview of the temporal

Table 2
Keywords with string.

Keywords with String	Database
TITLE-ABS-KEY (("Digital* technology" OR "technolog* adoption" OR "Industry 4.0″ OR "Blockchain" OR "RFID" OR "Big data" OR "IoT" OR "Information system") AND ("supply chain" OR "supply chain management" OR "logistics") AND ("perishable food " OR "agri* food" OR "agro* food"))	Scopus (603)
TS=(("Digital* technology" OR "technolog* adoption" OR "Industry 4.0″ OR "Blockchain" OR "RFID" OR "Big data" OR "IoT" OR "Information system") AND (“supply chain” OR “supply chain management” OR “logistics”) AND("perishable food " OR "agri* food" OR "agro* food"))	WoS (384)
[[All: title] OR [All: abstract]] AND [[All: "digital* technology"] OR [All: "technolog* adoption"] OR [All: "industry 4.0″] OR [All: "blockchain"] OR [All: "rfid"] OR [All: "big data"] OR [All: "iot"] OR [All: "information system"]] AND [[All: "supply chain"] OR [All: "supply chain management"] OR [All: "logistics"]] AND [[All: "perishable food "] OR [All: "agri* food"] OR [All: "agro* food"]]	Taylor & Francis (374)
Total	**1337**

Table 3
The inclusion and exclusion criteria.

Criterion	Eligibility	Exclusion
Literature type	Research articles published on Journals	Journals (review), conference paper, book series, book, chapter in book
Language	English	Non-English
Timeline	Between 2015 and 2024	<2015
Subject area	Business, Management and Accounting, Social sciences, Economics, Econometrics and Finance	Engineering electrical electronic, telecommunications, engineering industrial, and biology science, Psychology, Energy, Medicine, Chemical

distribution of empirical studies within the selected literature, spanning from 2015 to 2024. It is categorized by the development level of the countries involved: Developing, Developed, Underdeveloped, and Multiple (cross-country collaborations). Only two publications appeared in 2019. A modest decrease is observed in 2020 and 2021, with one study respectively. Three studies were published in 2022. The year 2023 marks a significant rise with six studies published, and 2024 witnesses the highest number of publications, totaling thirteen studies. The bar chart within each year further delineates the geographic origin of the studies. In 2019 and 2020, most studies originated from developing, underdeveloped and multiple regions. From 2021 onward, the proportion of studies from developing countries remains predominant, but there is increasing inclusion of research spanning multiple regions and collaborations involving different country groupings.

This trend suggests a steady annual increase in the number of articles published on this topic. However, compared to the broader field of AFSC, the number remains relatively small, indicating that the exploration of technology adoption in AFSC through empirical methodology is still in its nascent stages and warrants further investigation.

3.2. Country analysis

The countries of research contributions within the field of AFSC various differently. Fig. 3 categorizes 26 reviewed articles into four groups: Developing, Developed, Underdeveloped, and Multiple countries. A total of 17 studies were conducted in developing countries. India leads the distribution with seven studies. Followed by Thailand (3 studies) and China (2 studies), indicating a notable presence in the research landscape. Morocco, Peru, Brazil, Bangladesh, and Colombia each account for one study. Developed countries (UAE, UK, Australia, and Chile) contributes a total of four studies. Underdeveloped countries, represented by Ethiopia and Uganda, account for two studies. Additionally, the category labeled 'Multiple' reflects collaborative or multi-regional research efforts. These include studies encompassing a global study (Brazil, India, China, Kenya, Australia, and France), a European study (Italy, Germany, and the UK), and a partnership between France and Cameroon. These studies have engaged in comparative research, analyzing multiple countries and employing group analysis to draw insights. It is evident that most studies coincide with developing countries in Asia, where the economy largely depends on the agri-food industry.

3.3. Main types of Structural Equation Modeling

Fig. 4 illustrates the distribution of Structural Equation Modeling (SEM) methods employed across the reviewed studies. Partial Least Squares SEM (PLS-SEM) emerged as the dominant technique, utilized in 13 studies, representing 50 % of the total. Covariance-Based SEM (CB-SEM) was less frequent, applied in 3 studies (11.5 %). Several studies combined different analytical approaches: 5 studies (19.2 %) used both

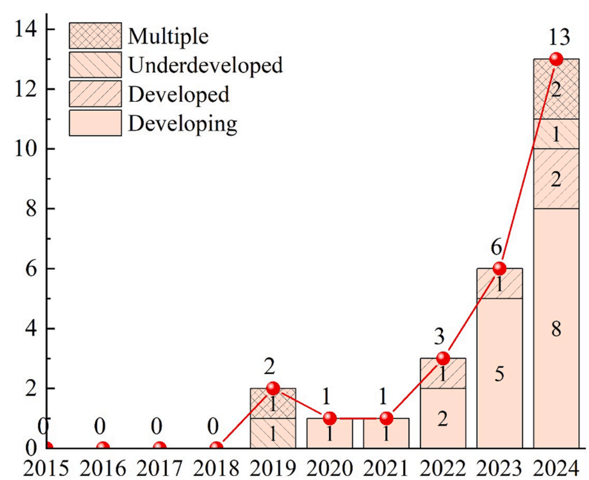

Fig. 2. Distribution of studies included in the review by year of publication.

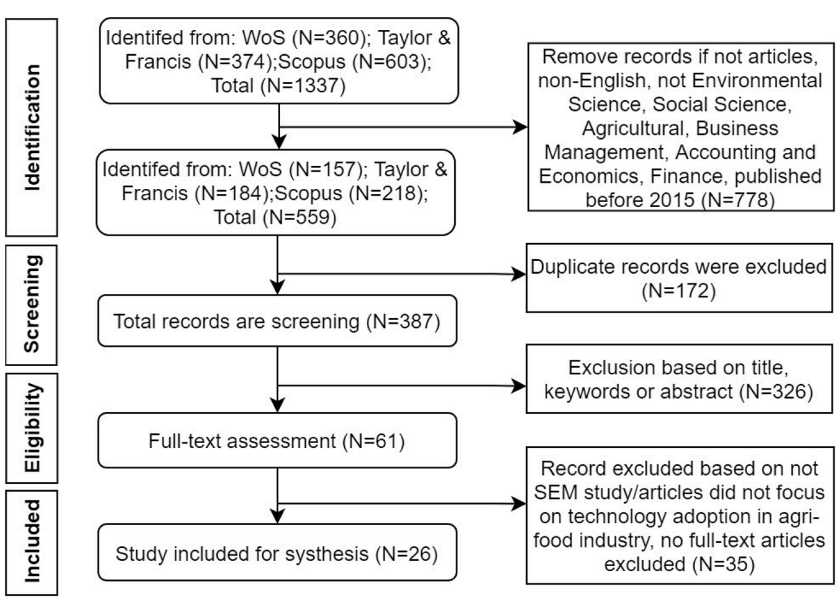

Fig. 1. Selection process using the PRISMA [45].

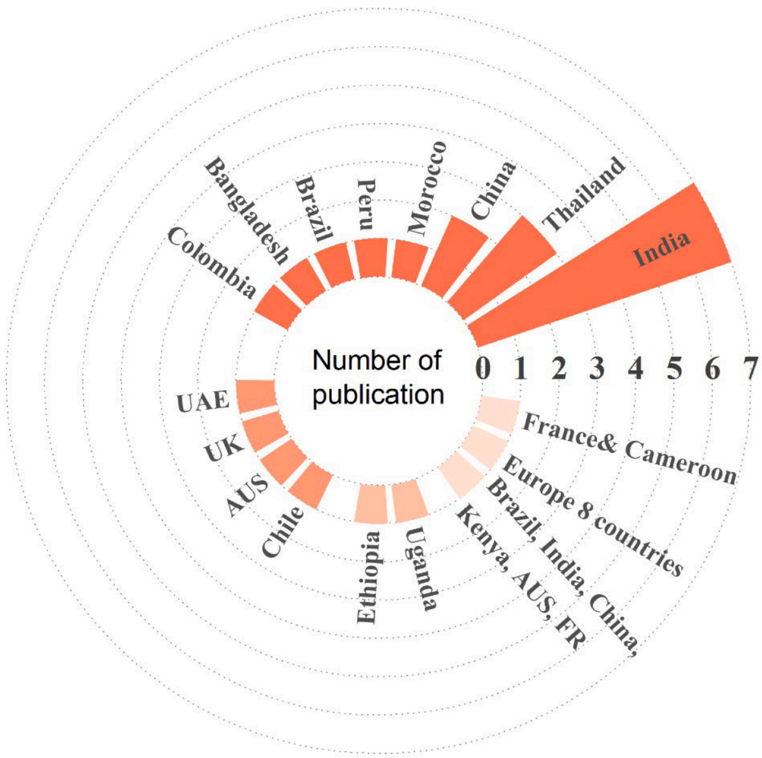

Fig. 3. Distribution of related studies by country of origin.

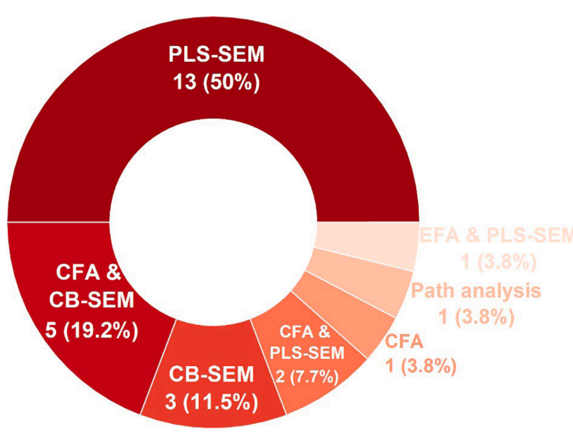

Fig. 4. Distribution of related SEM.

Confirmatory Factor Analysis (CFA) and CB-SEM, while 2 studies (7.7 %) combined CFA with PLS-SEM. Other methods included standalone CFA (1 study, 3.8 %), Path analysis (1 study, 3.8 %), and a combination of Exploratory Factor Analysis (EFA) and PLS-SEM (1 study, 3.8 %). This highlights the diverse application of SEM, with a clear preference for PLS-SEM among the included studies.

3.4. Associated sectors and digital technologies

Fig. 5 illustrates the distribution and prevalence of identified digital technologies and associated sectors discussed in the reviewed articles. The questionnaire respondents involved different stages of AFSC, including multiple producers, logistics, retailers, and customers. In the central theme, “From farm to fork” comprises the largest category (50 %), reflecting a holistic view of the AFSC. “Farmers & retailers” (19.23 %) are emphasized, alongside logistics providers and IT experts (each 7.69 %). With blockchain (19.23 %)section, information sharing (15.38

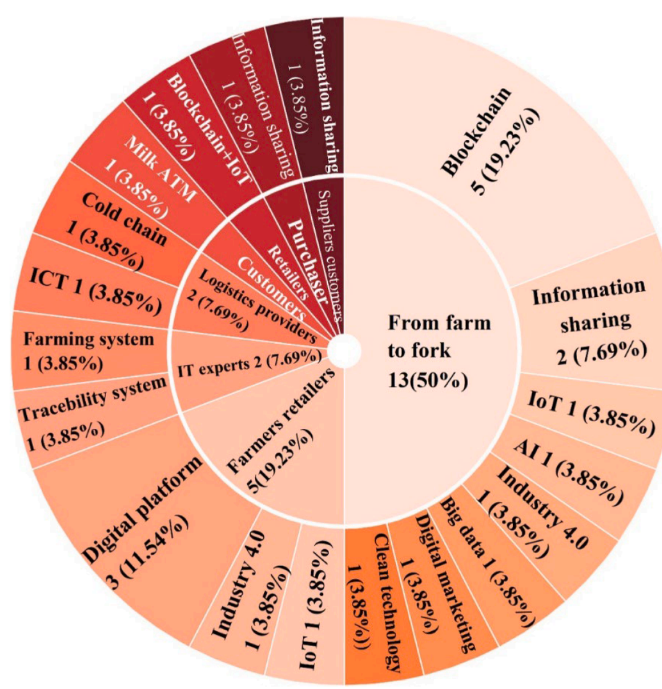

Fig. 5. Distribution of related studies by different stakeholders, technology, and research direction.

%), digital platform (11.54 %), farming system (3.85 %), traceability system (3.85 %) emerging as prominent solutions, highlighting their applicability across traceability and operational efficiency. Industry 4.0 (7.7 %) underscores the demand for transparency, while milk ATM (3.85 %) and AI (3.85 %) signify the adoption of advanced technologies. Notably, cold chain (3.85 %) and ICT (3.85 %) reflect sector-specific priorities.

Stakeholder collaboration (e.g., from farm to fork, farmers and retailers, suppliers and customers) and technological integration (e.g., big data, digital platforms) are pivotal for optimizing the AFSC. In the phase of food production, digital technologies can enhance food production efficiency, reduce waste, and improve food security. Take Nigeria for example, adopting Agriculture 4.0 requires collaboration among different stakeholders along the AFSC, and the Nigerian government needs to create a conducive environment for investment in this area [47]. Decision-makers perceive the technology as valuable and believe it enhances productivity AFSC [49]. The recurring emphasis on blockchain and IoT indicates their transformative potential in enhancing traceability and real-time monitoring, aligning with broader Industry 4.0 trends [17,50].

The framework demonstrates that successful digital transformation in the system depends on both technological deployment and theoretical alignment, ensuring operational efficiency, risk mitigation, and sustainability. This structured approach provides a foundation for future research on technology adoption in complex AFSC or agricultural systems.

4. Discussion

4.1. Thematic framework

Based on the review of selected articles, the identified studies are categorized into five primary themes concerning the intersection of digital technology and the AFSC: behavior intention, sustainability, operation, performance, and risk management. Fig. 6 provides a conceptual mapping of the reviewed literature, illustrating the interconnections between core research themes, digital technologies, and underlying theoretical perspectives. The analysis reveals five central themes: Operation, Performance, Risk management, Behavioral intention, and Sustainability. A diverse array of digital technologies is explored, with Blockchain, IoT, Information Sharing, and so on.

Table 4 Some scholars mentioned that the blockchain and IoT adoption serve as dependent variable through the lens of TAM [49]. Tseng et al. [14] found that the TAM model has a fair explanatory power of continuance intention, and system providers should raise users' confirmation level to reinforce their continuance intention of using digital technology. Saha et al. [49] underlined intention behind using blockchain in the AFSC with the help of TAM. UTAUT extends TAM by incorporating additional factors such as social influence, facilitating conditions, and effort expectancy in AFSC [51,52]. Moreover, Nayal et al. [7] explored the mediator role of blockchain technology that

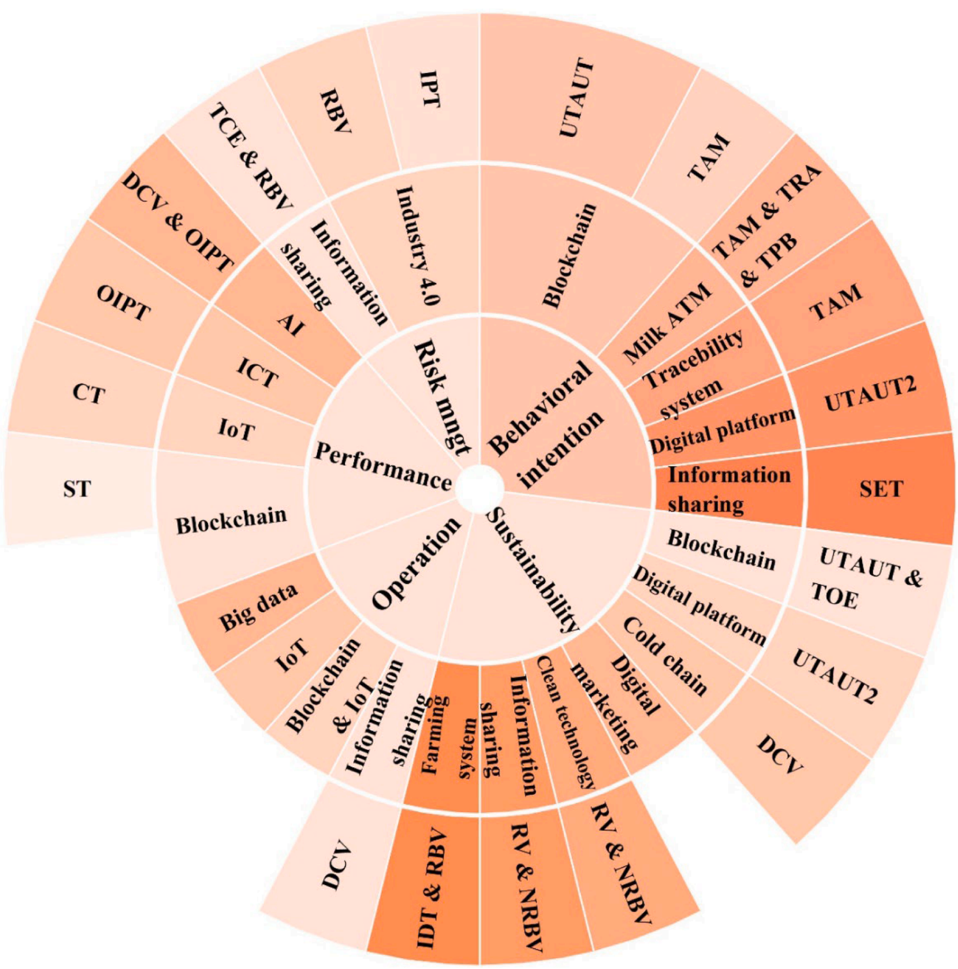

Fig. 6. Distribution of related studies by different stakeholders, technology, and research direction.

Notes: OIPT- Organizational information processing theory; TAM- Technology acceptance model; CT- Contingency theory; RV- Relational View; UTAUT- Unified Theory of Acceptance and Use of Technology; TOE- Technology, Organization, and Environment; IPT- Information processing theory; NRBV- Natural-resource Based View; SET-Social Exchange Theory; RBV- resource-based view; IDT- Innovation diffusion theory; TRA- Theory of reasoned action; TCE- Transaction cost economics theory positively influences sustainable AFSC performance within agri-food business underpinning the theory of UTAUT. Some factors like habits, expectancy, and motivation also stand for users' decision and intention [9,10].

RBV provides a framework for understanding how firms can gain competitive advantage through the strategic use of their resources [53]. R. Sharma et al. [13] and Zhang & Mohammad [18] used RBV to examine the role of digital technologies in improving supply chain resilience, risk management and sustainability. These studies highlight the importance of leveraging digital technologies to enhance the resource capabilities of AFSC stakeholders. NRBV extends the RBV, and it emphasizes the role of natural resources in achieving competitive advantage and sustainability [54]. It provides a valuable framework for understanding how the sustainable management of natural resources can enhance performance and sustainability in AFSC. Barbosa et al. [55] underpinned NBV to evaluate how environmental collaboration impacts sustainable performance in AFSC.

Less attention has been paid to explore the mediator and moderator role of digital technology [56,11]. These studies integrated these theories into SEM and provided a clearer understanding of the relationship between different variables. In short, technology adoption, as an independent variable, is widely deployed in firm level research frameworks, while it serves as dependent variable when studies focus on behavior intention.

This comprehensive overview demonstrates that research into digital technology applications in this domain is characterized by the application of various technologies to address a range of strategic and operational concerns. Research objectives and findings can be found on Table 5.

4.1.1. Digital technology and behavior intention

The effective adoption and utilization of digital technology within the AFSC are shaped by the behavioral intentions of various stakeholders. Foundational theories such as UTAUT, TAM, and TPB provide theoretical support to understand the behaviors of consumers, firms, and experts [57,58,52]. Research in this theme explores technology adoption intentions, purchasing intention, and the willingness to share information with other partners [10,49,14].

Empirical studies reveal various factors influencing the intention to adopt digital technologies, particularly blockchain. Key drivers include perceptions of food safety and security, traceability, transparency, and cost [49]. Stakeholder management is also recognized as potentially influential, although theoretical and empirical research specifically on its impact on blockchain adoption remains scarce [49]. Other factors like social influence, price value, and trust demonstrate varying levels of impact depending on demographic groups, with studies showing these are highly significant for older and higher-income users but less so for younger and lower-income users [10]. There is limited evidence of its broader impact across the consumer goods sector. Perceived trust, alongside performance expectancy and effort expectancy, significantly impacts adoption decisions, with AFSC partners often identified as a most influential factor [52], but few studies explore the perspectives of direct beneficiaries on innovative technologies.

Theories concerning technology acceptance (e.g., UTAUT, TAM) are predominantly linked to Behavioral intention [57,49,51,52,14]. The adoption and effective utilization of digital technologies in the agri-food sector are influenced by various factors, including behavioral intentions among stakeholders. Empirical studies have provided valuable insights into the factors influencing behavior intention in adopting digital technologies within the AFSC. Despite the development of technology adoption models aiming for theoretically and practically acceptable frameworks, factual evidence supporting blockchain benefits remains inconclusive [52]. Their research identified AFSC partners as the most influential factor in technology adoption, while performance expectancy, effort expectancy, and perceived trust also significantly impact adoption decisions [14,57].

In summary, digital technology adoption intention in the agri-food sector is influenced by a complex interplay of individual, social, technological, and economic factors, with influence varying across demographics and contexts. Different demographic groups may have varying motivations and barriers to technology adoption, emphasizing the need for tailored strategies.

4.1.2. Digital technology and sustainability

Sustainability in AFSC has become an increasingly significant area of research. A key focus within this domain is the mediating role of blockchain technology, and their impact on enhancing sustainable performance, particularly through improved supply chain traceability and waste reduction [55,18]. Industry 4.0 technologies, in general, are highlighted for their potential to enhance agri-food sustainability by improving efficiency and reducing environmental impact [37].

Sustainability in AFSC encompasses several critical sub-themes. Environmental performance is a well-developed construct within the agri-food industry [55]. Other significant dimensions include carbon footprint and waste management [55,18]. These elements are not merely abstract concepts but can serve as important performance indicators; for instance, carbon footprint and circular economy are increasingly used as dependent variables in research models [59]. Waste management, specifically, is recognized for its potential to have a deeper influence on overall AFSC performance, extending beyond being just a sub-construct of environmental performance [48,60].

Studies focusing on sustainability in AFSC often draw on various theoretical perspectives to explain the underlying mechanisms. Resource-based perspectives, including the Resource-Based View (RBV), Relational View (RV), and particularly the Natural Resource-Based View (NRBV) are prominent [60,55,13,18]. The NRBV, being widely used, provides a robust theoretical framework for understanding the role of natural resources in achieving environmental performance [54]. Efficiency theories, such as the Dynamic Capabilities View (DCV), are also relevant, particularly when examining performance enhancement [60].

Digital technologies play a crucial role in addressing specific sustainability challenges. They can significantly enhance data collection, analysis, and traceability, thereby supporting the transition to a circular economy within AFSC [26]. This transition involves identifying key challenges and opportunities, where digital technologies are central to enhancing sustainability [39]. Addressing food loss and waste, an increasingly important topic, particularly calls for digital technology adoption [40]. Specifically, IoT and digital platforms are frequently adopted for food loss and waste reduction; IoT is often used for monitoring, while digital platforms facilitate the redistribution of food surplus [8,18]. Furthermore, digital platforms are seen as innovative tools for managing agricultural waste, with farmers' and sellers' intentions regarding platform use being explored [10]. Companies are increasingly encouraged to leverage digital transformation among different stakeholders to create long-term value [37].

In the AFSC context, particularly in emerging economies, there is a gap in understanding the relationship between environmental collaboration and environmental performance [60]. The existing literature lacks empirical evidence on the relationship between sustainability innovation, supply chain resilience, and sustainability performance, especially in the context of China's cold chain logistics industry [18,33].

Despite the recognized potential, the existing literature highlights several areas requiring further exploration. A key gap lies in the comprehensive understanding and quantitative measurement of the sustainability impacts of technologies like IoT and digital platforms from a complete AFSC perspective [40]. While agri-waste management platforms are considered innovative, their development remains a novel area, indicating a research gap, particularly in contexts like Thailand [10]. More broadly, the direct relationship between digital technology and sustainability outcomes remains underexplored empirically.

Specifically, there is a gap in understanding how blockchain, particularly when integrated with green product platform strategies, contributes to mitigating the carbon footprint of AFSC [59,61]. Furthermore, niche applications like the use of technology-based urban farming approaches for food demand in specific regions (e.g., UAE) are limited in studies [13]. Beyond technology, environmental collaboration among companies as a developing strategy has been less explored, and a supply chain-wide perspective for assessing sustainable performance is seldom studied [55].

4.1.3. Digital technology and performance

Digital technologies enhanced performance, improved supply chain management, and reduced cost [15,44]. Camel et al. [59] proposed a conceptual framework illustrating the mediator of blockchain technology in the link between supply chain management practices and their performance. The application of digital technology, particularly AI in the agricultural sector holds significant potential for enhancing economic, social, and environmental performance [23]. AI can improve productivity, sustainability, and efficiency. However, these challenges highlight the need for an interdisciplinary approach to develop robust, economically viable, and socially acceptable AI solutions [23].

Empirical evidence from various studies highlights the positive impact of digital technologies on different dimensions of performance. For instance, sustainability innovation has been shown to positively affect economic performance, environmental performance, and social performance [18]. In the context of logistics, research indicates that logistics outsourcing risk management does not have a significant direct impact on trade performance [62]. However, perceived supplier performance significantly increases buyer trust, and trust partially mediates the relationship between perceived supplier performance and information sharing [58]. This suggests that behavioral intentions are also related to performance outcomes.

Digital technologies hold significant potential for enhancing performance in the agri-food sector. However, their successful implementation hinges on overcoming substantial barriers. Performance improvement through digital technologies is closely linked to various themes and specific contexts within the AFSC. An interdisciplinary approach, integrating technological, economic, and social considerations, is essential for developing effective and sustainable solutions.

4.1.4. Digital technology and operation

Operation connects strongly with technologies like Blockchain and IoT. Organizational theories such as RBV and DCV frequently combined to provide a comprehensive analytical lens [53,63]. Digital technologies are increasingly being adopted within AFSC to enhance operation, improve efficiency, collaboration, and innovation.

Among these technologies, Hasan et al. [8] investigated how IoT can improve transparency and operational efficiency in Bangladesh's AFSC. blockchain technology holds promise for enhancing transparency, traceability, and resilience within the AFSC, but practical implementations are still limited, and the technology is in its infancy [50]. Various digital technologies were used in the domain of AFSC operation, while only digital value chain were introduced to explore the mediating role of AFSC agility between AFSC integration, flexibility, and AFSC operational performance [63]. Egwuonwu et al. [64] examined how the integration of blockchain and the IoT impacts the global value chain in the UK agri-food retail sector. Valencia-Cárdenas et al. [12] explored the impact of Big Data Analytics on collaboration, optimization, and inventory management in the agribusiness supply chain. Treaceability system improves inventory management, logistics, and overall operational efficiency. By minimizing waste, boosting productivity, and enhancing market access, traceability systems play a vital role in ensuring the future profitability of dairy operations [28,44].

This oversight results in limited technological support for executives to handle data and make effective decisions in the AFSC. Additionally, theoretical and empirical research on blockchain technology adoption remains scarce, highlighting the need for further investigation for empirical and theoretical inquiry [63].

4.1.5. Digital technology and risk management

Risk Management represents a significant theme in the literature on digital technology adoption in AFSC. Research in this area addresses various risks, including logistics outsourcing, overall supply chain risks, resilience building, and risks associated with technology adoption itself [56,62,20]. These investigations are frequently guided by RBV, TCE, and IPT.

Industry 4.0 technologies and IoT are explored for mitigating operational risks and the challenges of IoT adoption [56,62]. These perspectives highlight the potential benefits of integrating digital technologies for risk mitigation, although practical deployment remains limited. However, empirical research on how the exploitation of Industry 4.0 generates capabilities (automation, data analytics, and connectivity) that help mitigate supply chain risks is still limited [21].

Industry 4.0 technologies have demonstrated positive effects on sustainable supplier management, operations, and risk management. There is a lack of studies using SEM on how these technologies mitigate risks or disruptions specifically within the agri-food sector [20]. Although risks can significantly undermine firm performance, their negative impact appears to be less pronounced for firms that adopt Industry 4.0 compared to those that do not [21]. In addition, there is lack of empirical evidence on the relationship between outsourcing risks management and trade performance [62]. This gap highlights the need for further research to understand how digital technologies can effectively manage and mitigate risks in the agri-food supply chain.

Consistent with broader systematic reviews on digital technology in AFSCs [43], this review confirms the significant role and potential of digital solutions in enhancing AFSC capabilities, including risk management. In summary, although digital technologies like blockchain and Industry 4.0 offer significant potential for improving risk management in the AFSC, practical implementations and empirical evidence remain limited.

4.2. Practical implications

The application of digital technologies is becoming increasingly instrumental in enhancing the functionality and performance of AFSC. Key technologies explored in the literature include Blockchain, IoT, Big Data Analytics, and Digital Platforms, alongside foundational elements such as Information and Communication Technology and concepts like Industry 4.0 and advanced Traceability Systems [64,8,12]. These technologies collectively offer potential benefits spanning improved transparency, security, operational efficiency, waste reduction, enhanced decision-making, and ultimately, increased consumer trust [51,52].

Specific technologies offer distinct yet often complementary capabilities within the AFSC. Blockchain technology is frequently highlighted for its capacity to address security and trust challenges within the AFSC by providing a decentralized, immutable ledger for data integrity [64]. Managers and technology solution providers can leverage the capabilities of blockchain technology to achieve sustainability in supply chain operations. By utilizing these features, they can reduce food waste, food recall costs, food poisoning incidents, and contamination [7]. Studies elucidate its potential for enhancing transparency, enabling robust stakeholder engagement, ensuring regulatory compliance, and supporting initiatives such as green product platforms [59, 51].

Furthermore, blockchain implementation is posited to reduce risks and fraudulent activities, bolster food quality and safety, and facilitate rapid detection of contamination or safety issues within warehouses [51]. Research has also begun to identify the primary determinants influencing the adoption of blockchain, emphasizing the need for organizations to understand strategies to amplify its transformative potential and navigate integration challenges, including judicious resource allocation and acknowledging the significance of supply chain partners [52]. Understanding behavioral intention and actual usage of drivers is crucial for companies seeking competitive advantage through such innovations [49,52].

IoT plays an integral role by embedding sensors and smart devices throughout the supply chain. This enables real-time data collection and exchange, significantly enhancing supply chain visibility and interoperability. Such capabilities support improved decision-making and optimize the flow of both physical goods and information [8]. The integration of IoT with technologies like blockchain can further enhance system security and trustworthiness by leveraging blockchain's data integrity features [64]. IoT-based technologies enhance supply chain traceability by providing consumers about the journey of products, using pictures or scannable QR codes on packaging [50]. This enables precise resource allocation, minimizes waste, and optimizes quality control. Additionally, the integration of AI-driven machinery reduces dependence on human labor for processing and harvesting, offering a strategic solution to labor shortages and disruptions [11].

Big Data Analytics technology involves data capture, storage, and predictive analytical models. These technologies are used to enhance decision-making processes in the agribusiness supply chain, particularly for perishable products. The study also examines the use of software for inventory control, forecasting, and optimization [12]. Digital platforms are emerging for specific applications, such as facilitating circular economy initiatives by enabling the trade of agricultural waste. Adoption of such platforms is contingent upon meeting users' specific needs, addressing concerns, and enhancing awareness of social impacts through community influencers [9]. Effective traceability systems, often built upon IoT and blockchain, are critical for ensuring product authenticity and safety [17]. Maintaining user confidence and positive confirmation levels requires system providers to ensure high service quality, system availability, and seamless integration with logistical processes to ensure timely information delivery upon consumer inquiry [14]. Information sharing, facilitated by various digital means, is recognized as a fundamental enabler of overall AFSC digitalization [62, 58,15,63].

The implications of digital technology adoption and its associated challenges vary significantly across different stakeholder groups within the AFSC. Industry managers, raw material suppliers, warehouse operators, and related organizations can leverage the findings on technology potential and adoption determinants to allocate resources effectively and prioritize investments in integrating technologies like blockchain and IoT to enhance operational efficiency and trust technologies [64, 52]. Policymakers play a crucial role in creating an enabling environment for digital transformation. They should consider consumer preferences and factor price and value information into policies aimed at monitoring sustainable purchasing behaviors [57]. It is imperative that policymakers prioritize the development of user-friendly and accessible digital tools specifically tailored for farmers and provide comprehensive education and training programs to equip them with the necessary skills for effective technology utilization [9]. Advocating supportive policies and financial incentives, such as subsidies or tax breaks for adopting sustainable digital practices, is also essential. Policies and actions in digital agriculture should prioritize reducing food loss and waste as a core strategy to achieve environmental sustainability, enhance food system efficiency, and promote social equity [3,4,9,27]. To sum up, AFSC practitioners should leverage digital intelligence thinking to deepen the digital transformation of the cross-border AFSC and establish a digital intelligence-driven supply chain for cross-border agri-food [42].

4.3. Future research directions

To advance understanding of digital technologies in the AFSC, future research should address critical gaps across five interconnected themes: behavioral intention, sustainability, operations, performance, and risk management. Understanding behavioral intention towards adoption of technology remains crucial. Future research should explore the impact of stakeholder management on digital technology adoption, considering the economic, social, and environmental impacts. Developing comprehensive measurement systems that integrate these impacts can provide deeper insights into how stakeholders' behaviors influence technology uptake and sustainability outcomes. Additionally, Future research should employ both qualitative and quantitative methods to investigate the behaviors of actors within the agri-food industry. Additionally, emphasis is placed on enhancing user experiences through functional applications and software, which is crucial for facilitating the widespread adoption of these technologies [29]. Industry-specific validations are needed to generate conclusive evidence of the benefits realized through digital technology integration in the AFSC [52].

Addressing sustainability challenges requires a holistic perspective of the AFSC. Future studies should adopt a comprehensive sustainability framework to better understand the role of digital technologies in reducing food loss and waste [40]. Exploring how blockchain integration with green product platform strategies can mitigate the carbon footprint of the AFSC [59] is another promising avenue. Moreover, investigating environmental collaboration among companies and evaluating sustainable performance from a supply chain perspective could provide valuable insights into collective sustainability efforts [55,39]. More specifically, future studies suggest stakeholders, academics, and practitioners in the AFSC implement digital methods to minimize and prevent food loss and waste [48].

Operational advancements driven by digital technologies are central to enhancing performance in the AFSC [22,28]. Theoretically, OIPT emphasizes the alignment between business needs for information processing and a company's capabilities to fulfill those needs. Building on this foundation, future research could explore the theory of OIPT, DCV and transaction cost theory to provide a more comprehensive understanding of how to enhance the efficiency of business operations and decrease information asymmetry [6,11].

With increasing uncertainties, it is vital to examine how digital technologies contribute to risk mitigation within the AFSC. Future studies should investigate how these technologies generate capabilities to address various supply chain risks, improve trade performance, and enforce overall resilience and sustainability [62]. It is important to understand how digital innovations can help mitigate disruptions and enhance the robustness of the AFSC, especially in emerging economies where such impacts can be profound. Previous studies have examined the influence of Industry 4.0 Technologies on risks that are currently deemed critical to the performance of firms in the AFSC, and future research should delve deeper by testing the impact of each individual technology as a continuous moderator [56]. The existing literature on the intersection of AFSC risks and food waste is not up-to-date or well-developed [5]. This gap should be addressed in future research.

For the methodology of SEM, future research directions should focus on several key areas to enhance the understanding of behavioral intentions in adopting digital technologies. First, testing and refining the proposed models across different countries could provide valuable insights and improve the generalizability of the findings. Researchers are encouraged to explore the factors influencing the adoption of this innovative technology [52]. Moderating effects (age, gender, and experience on the drivers of blockchain adoption and business intelligence) need to be explored [51]. Furthermore, incorporating additional factors like technical knowledge, government intervention, regulatory frameworks, and policy implementation practices could offer a more comprehensive understanding of the adoption dynamics [49].

For specific applications like Milk ATMs, future research should evaluate the perspectives of various stakeholders in the dairy value chain [57]. Similarly, future research should investigate the manufacturer's side of traceability systems, focusing on factors like quality control to understand the impact of human error and bias [14,17]. In the context of agricultural waste management, studies should focus on the long-term factors influencing technological adoption and sustained use, enriching the current research findings [9]. Policymakers should develop targeted marketing campaigns leveraging social influence to boost platform adoption among retailers. Improving platform usability, security, and incentives for habitual use is crucial [9].

4.4. Contribution

This review contributes to a better understanding of the digital technologies in AFSC and provides a foundation for future research and industry practice. This SLR contributes to the development of a comprehensive framework for understanding digital technology in AFSC. It provides insights into both theoretical development and practical application in the agri-food supply chain. By highlighting key themes and future study, the review offers valuable guidance for future research and industry practice. The implications of this review are twofold. For practitioners, it underscores the significance of integrating digital technologies to enhance AFSC efficiency and sustainability. For policymakers and researchers, it highlights the need for further investigation into the specific benefits and challenges of digital technology in different AFSC contexts.

5. Conclusion

This SLR synthesized 26 empirical studies focusing on the adoption and impact of digital technologies within the AFSC. The analysis revealed a growing academic interest in understanding how digital technologies enhance the efficiency, transparency, and sustainability of AFSCs. The review identified five primary thematic clusters examined in the literature: behavioral intention, sustainability, technology capability, AFSC performance, and risk management, each underpinned by various theoretical frameworks such as the RBV, TAM, and TPB.

This study only examined a limited number of articles from the Web of Science, Scopus, and Taylor & Francis databases. Future studies can explore more potential databases, such as PubMed, IEEE Xplore, Sage, Springer, Science Direct, and so on. Secondly, this study only reviewed empirical articles using the method of SEM. Future research can focus on multi-method approaches, such as Multiple-criteria decision analysis, simulation, or mathematical model. Thirdly, this study categorized four main clusters of digital technology in AFSC. Future studies may focus on in-depth investigation of technology adoption in the context of AFSC. Food loss and waste affect sustainable AFSC, but how it influences them is still unclear. Further studies can explore the technology capability to prevent food waste and loss in AFSC. Finally, current empirical studies examine the role of digital technology as an antecedent. Future studies can examine the mediating or moderating role of digital technology in AFSC to achieve sustainability, improve firm performance, decrease risk, and improve behavior intention.

CRediT authorship contribution statement

Peiyun Yu: Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Roshayati Abdul Hamid:** Writing – review & editing, Supervision, Methodology. **Lokhman Hakim Osman:** Writing – review & editing, Supervision, Methodology. **Jing Liao:** Writing – review & editing, Supervision, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix

Table 1
Existing review articles of DTA in AFSC.

No	DT	Number of articles	Main themes	Review method	Main Findings	Source
1	Big data, IoT, AR, robotics, sensors, etc.	Not mentioned	Precision agriculture, Smart farming & agriculture 4.0	Snowball methods	Five thematic clusters: (1) Adoption, adaptation and uses of digital technologies on farm; (2) The impact of digitalization on farmer identity, skills, and work; (3) Authority, control, privacy and ethical consideration in the digital agricultural production systems; (4) Digitalization and agricultural knowledge and innovation systems; and (5) The economic and managerial aspects of digitalization	[43]
2	Blockchain	45 (2016 –2022)	Food safety and quality; sustainability, etc.	SLR	Blockchain applications in AFSC contribute to SDGs, such as SDG2(zero hunger), SDG3(health and wellbeing), SDG12 (consumption and production in AFSC); technologies improve transparency, traceability, food safety, food trade.	[16]
3	IoT, Big Data, Cloud Computing, Blockchain, AI, etc.	91 (2015 –2020)	Agriculture 4.0 and Precision Agriculture	SLR	Digital technologies can enhance food production efficiency, reduce waste, and improve food security. Nigeria's Adoption of Agriculture 4.0 requires collaboration among different stakeholders along the AFSC. The Nigerian government needs to create a conducive environment for investment in Agriculture 4.0	[47]
4	AI	20	Eco, env, soc, ethical, and technological of AI	Narrative desk study	AI in agriculture has significant potential for improving productivity, sustainability, and efficiency but faces challenges related to cost, data quality, ethical concerns, and accessibility. An interdisciplinary approach is crucial for developing robust, economically viable, and socially acceptable AI solutions.	[23]
5	IoT, Digital Platforms, Big Data, Blockchain	136 (2012 - 2021)	Consumer behavior, AFSC coordination, Business models, etc.	SLR	Key challenges and opportunities for transitioning to circular food systems include the role of digital technologies in enhancing sustainability. It highlights the need for coordinated	[39]

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Table 1 (*continued*)

No	DT	Number of articles	Main themes	Review method	Main Findings	Source
					efforts among stakeholders. Future research directions to fill the gap in circular economic practices in the food sector.	
6	IoT, Big Data Analytics, Blockchain, AI, etc.	48 (2016 - 2023)	Prevent food loss and waste, governance, sustainability,	SLR	IoT and digital platforms are most frequently adopted for FLW reduction, with IoT used for monitoring and digital platforms for food surplus redistribution. However, literature lacks a comprehensive AFSC perspective and quantitative measurement of sustainability impacts.	[40]
7	Industry 4.0, IoT, Big Data, Blockchain, etc.	109 (2011 - 2021)	Digitalization, sustainability, circular economy	SLR	Identify 10 main research clusters. Industry 4.0 technologies can enhance agri-food sustainability by improving efficiency and reducing environmental impact. Companies should focus on long-term value creation through digital transformation.	[37]
8	AI, ML, and industry 4.0	Not mentioned	Digital transformation of using industry 4.0 technology in dairy sectors	SLR and Bibliometric Analysis	It examines the role of Industry 4.0 technologies, such as Artificial Intelligence (AI), Machine Learning (ML), and the Internet of Things (IoT), in transforming the dairy sector. It identifies key areas of technological intervention, including traceability, data management, and environmental impacts, and highlights the need for further research on these topics.	[38]

Notes: DT- digital technology, eco- economic, env- environmental, soc- social.

Table 4
The main themes, DT, Theories and DT related structures in identified study.

Theme	DT	Theories and DT Related Structure	Source
Behavioral intention	Blockchain	Theory: UTAUT; Med: Drivers of blockchain adoption	[51]
	Blockchain	Theory: UTAUT; IV: organizational blockchain readiness; Med: Behavioral intention	[52]
	Blockchain	Theory: TAM; IV: Transparency and traceability	[49]
	Information sharing	Theory: SET; DV: Information sharing	[58]
	Milk ATM	Theory: TAM&TRA&TPB; IV: attitude; DV: purchasing intentions	[57]
	Digital platform	Theory: UTAUT2; DV: Behavioral intention to digital innovations	[9]
	Traceability system	Theory: TAM; IV: System quality, information quality	[14]
Sustainability	Blockchain	Theory: UTAUT&TOE; Med: Blockchain technology	[7]
	Digital platform	Theory: UTAUT2; DV: Behavioral intention to use mobile technology for agri-waste valorization	[10]
	Information sharing	Theory: RV&NRBV; IV: Internationalization orientation	[55]
	Cold chain	Theory: DCV; IV: Sustainability innovation	[18]
	Digital marketing	Theory: /; IV: Digital marketing	[19]
	Farming system	Theory: RBV&IDT; IV: Innovative urban farming systems	[13]
	Clean technology	Theory: RV&NRBV; IV: Environmental collaboration	[60]
Operation	Information sharing	Theory: DCV; Med: Supply chain agility, flexibility	[63]
	IoT	Theory: /;IV: IoT; DV: Transparency in AFSC	[8]
	Blockchain + IoT	Theory: /; IV: Blockchain technology; DV: IoT system	[64]
	Big data	Theory: /; IV: Big data analytics; Med: big data	[12]
Performance	Blockchain	Theory:/; IV: Traceability and transparency, smart contract	[65]
	Blockchain	Theory: ST; Med: Blockchain-enabled product platforming	[59]
	IoT	Theory: CT&RV; IV: Internet of things, Med: information sharing with AFSC	[66]
	ICT	Theory: OIPT; IV: Information & communication technology	[15]
	AI	Theory: DCV&OIPT; IV: AI; Mod: AI adoption impediments	[11]
Risk mngt	Industry 4.0	Theory: IPT; IV: Industry 4.0 technology	[20]
	Industry 4.0	Theory: RBV; Med: Industry 4.0 adoption	[56]
	Information sharing	Theory: RBV&TCE; Logistics capability of provider	[62]

Notes: DT-digital technology; OIPT- Organizational information processing theory; TAM- Technology acceptance model; CT- Contingency theory; RV- Relational View; UTAUT- Unified Theory of Acceptance and Use of Technology; TOE- Technology, organization, and environment; IPT- Information processing theory; NRBV- Natural-resource based view; SET-Social Exchange Theory; RBV- Resource-based view; IDT- Innovation diffusion theory; TRA- Theory of reasoned action; TCE- Transaction cost economics theory.

Table 5
Description of thematical findings within the reviewed articles.

Theme	Research objective	Findings	Source
Behavioral intention	To identify key factors (facilitating conditions, interfirm trust, transparency, etc.) that drive blockchain adoption and its influence on behavioral intention of AFSC.	There is a strong positive correlation between the factors driving the adoption of blockchain technology and behavioral intention.	[51]
	(1) To identify factors influencing the adoption and the use of blockchain based on the UTAUT framework; (2) To investigate the relationship between organizational blockchain readiness and the expected Usage Behavior of blockchain-based AFSC platforms.	(1) AFSC partner preparedness is the most influential factor; performance expectancy, effort expectancy, and perceived trust also significantly impact the adoption of blockchain; (2) blockchain readiness positively affects expected Usage Behavior.	[52]
	(1) To measure the effect of blockchain-certified information on consumers' perception of product flavor and health; (2) To examine the user intention to adopt BLCT in AFSC.	(1) Food safety, security, traceability, transparency, and cost are key factors that significantly influence the intention to adopt blockchain technology. (2) Decision-makers view technology as highly valuable and believe it can enhance productivity.	[49]

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Table 5 (*continued*)

Theme	Research objective	Findings	Source
	To examine the relationship between perceived supplier performance and trust. To investigate the relationship between trust and information sharing. To test the mediating role of trust between perceived supplier performance and information sharing.	A high level of perceived supplier performance significantly increases buyer trust; Trust positively influences information sharing; Trust partially mediates the relationship between perceived supplier performance and information sharing	[58]
	To evaluate consumer attitudes as a crucial factor influencing preferences and purchase intentions for milk dispensed through milk ATMs in Uganda.	Male purchasers are more likely to be driven by new food technologies than females.	[57]
	To investigate the factors (performance expectation, effort expectancy, social influence, etc.) derived from the extended theory of UTAUT2, including trust and privacy on FASC	Social influence had a greater impact on retailers than on farmers. Facilitating conditions, habits, and privacy were important for both groups. Unlike retailers, farmers were also motivated by the hedonic motivation they derived from using the platform. Overall, retailers' behavioral intentions were influenced by a greater number of factors compared to those of farmers.	[9]
	To examine how the intention to continue using traceability systems during the COVID-19 pandemic varies by comparing three models: TAM, TAM-IS Success, and TAM-ECM Integrated models.	(1) The TAM model explains 62.2 % of continuance intention and is valued for its simplicity; (2) The TAM-IS success integrated model has the highest predictive power at 78.3 %; (3) System providers should enhance users' confirmation levels to strengthen their continuance intention of using traceability system through perceived value and satisfaction.	[14]
Sustainability	To study the mediating role of blockchain technology in sustainable AFSC.	Green and lean practices, supply chain integration, supply chain risks, internal and external conditions, regulatory support, innovation capability, and cost positively influence BLCT adoption. Moreover, BLCT positively influences sustainable agriculture supply chain performance.	[7]
	To investigate user segments and factors influencing behavioral intentions to use mobile technology for agri-waste valorization.	1.multigroup Structural Equation Modeling showed two types of users: (1) older users with various income ranges, and (2) younger users with a low-income range; 2. The results also revealed that social influence, price value, and trust highly affected the behavioral intentions of older and various-income users, but did not influence younger and low-income users.	[10]
	To assess the effects of environmental collaboration on sustainable performance in internationally oriented companies	Environmental collaboration positively impacts sustainable performance, with internationalization orientation strengthening this effect. All dimensions of sustainability (environmental, social, economic) are positively affected.	[55]
	To examine the impact of sustainability innovation and supply chain resilience on economic, environmental, and social performance. Investigate the interrelationships among economic, environmental, and social performance in the context of China's cold chain logistics industry.	Sustainability Innovation (SI) positively affects Economic Performance (ECP), Environmental Performance (ENP), and social performance. Supply Chain Resilience (SCRI) positively affects ECP, ENP, and social performance. ECP positively affects ENP and social performance. ENP has no significant effect on social performance.	[18]
	To examine the role of digital marketing in enabling a sustainable food system. Test the mediating role of relationship marketing between digital marketing and sustainable food systems. Provide practical insights for policymakers and practitioners in the agri-food sector.	Digital marketing significantly enhances relationship marketing capabilities; Relationship marketing positively impacts the sustainable food system; Relationship marketing fully mediates the positive effect of digital marketing on the sustainable food system; Digital marketing also has a direct positive impact on the sustainable food system.	[19]
	To develop and validate a framework for technology-driven urban farming systems to enhance food security.	Crop production practice is positively associated with resource efficiency; and resource conservation practice is positively associated with sustainable urban farming performance. Furthermore, the study highlighted that digital technologies do not moderate the relationship between innovative urban farming systems and sustainable urban farming performance.	[13]
Operation	To utilize the DCV theory to analyze how three key supply chain capabilities – organizational flexibility, integration and agility – should be combined to obtain the desired supply chain performance.	Organizational flexibility (OF), supply chain integration (SCI), and supply chain agility (SCA) are key drivers of supply chain performance. SCA is necessary but not sufficient without integration and flexibility.	[63]
	To investigate the impact of IoT integration on transparency and efficiency	The findings validate both hypotheses, demonstrating a significant and positive impact of IoT technologies on PHF and, subsequently, on TASC. The results highlight the crucial role of IoT in enhancing supply chain transparency and operational efficiency.	[8]
	To examine the impact of blockchain combined with IoT on global value chain and value creation.	Blockchain enhances IoT scalability, security, and traceability, leading to improved global value chain performance and value creation.	[64]
	To analyze the relationship between Big Data Analytics and collaboration in inventory management	Available Technologies associated with Big Data, generate improvement of Collaboration Strategies, improving also Forecasting and Optimization; besides, Inventory Planning and Collaboration are related to Available Technologies associated with Big Data.	[12]
Performance	T bridge this knowledge gap identified in the literature by understanding and examining blockchain's value to the Indian AFSC. The primary objective of this study is to validate the benefits of BCT and its influence on AFSC performance.	BCT positively impacts AFSC performance by improving traceability, transparency, food safety and quality, immutability, and trust. Additionally, BCT adoption enhances stakeholder collaboration, provides a decentralised network, improves data accessibility, and yields a better return on investment, resulting in the overall improvement in AFSC performance and socio-economic sustainability.	[65]
	To dissect the interplay between BCT and GPP, exploring their potential to catalyze a shift towards more sustainable, low-carbon agri-food systems.	1. quantitative results indicate a positive relationship between BCT and GPP in the agri-food supply chain. This is evidenced by improved supply chain transparency and efficiency, aligning with existing literature highlighting BCT's role in enhancing this aspect; 2. BCT enables enhanced transparency, stakeholders' engagement, and regulatory compliance of GPP initiatives in the agrifood sector. 2. BCT enables enhanced transparency, stakeholders' engagement, and regulatory compliance of GPP initiatives in the agrifood sector.	[59]
	(1) To propose the theoretical backgrounds to support the relationship between IoT technologies and agri-food SC practices at different stages.	IoT-based digital technologies and supply chain processes organization integration (OI), information sharing and customer integration (CI) have a	[66]

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Table 5 (*continued*)

Theme	Research objective	Findings	Source
	(2) To propose a hypothetical framework to analyse and uncover the previous inconclusive results. (3) To analyze the proposed conceptual model to measure the IoT impact on SC performance and firm performance	significant positive correlation. Furthermore, supply chain practices are positively associated with SCP. Finally, it has been found that FP is positively impacted by SCP.	
	To investigate the role of information and communication technology (ICT) in agri-food supply chain and determine the impact of supply chain management practices on firm performance.	The results indicate that ICT and SCM practices (logistics integration and supplier relationships) have a significant relationship. Furthermore, SCM practices (information sharing, supplier relationship and logistics integration) have a significant and positive impact on performance of the organization.	[15]
	To examine the effect of AI based technologies on reducing waste and minimizing agrifood supply chain costs, hence increasing organization profitability.	AI positively affects distribution network efficiency and agri-food supply chain efficiency. Distribution network efficiency mediates the relationship between AI and supply chain efficiency.	[11]
Risk mngt	To determine the effect of Industry 4.0 on S-AFSC to enhance survivability post-COVID-19. To evaluate the moderating effect of organization flexibility on ITe and S-AFSC. To enhance resiliency for managing global food security issues post-COVID-19.	Industry 4.0 positively affects sustainable supplier management, sustainable operations & risk management, and pressure & incentive management. Organizational flexibility moderates the relationship between Industry 4.0 and sustainable agri-food supply chains.	[20]
	To explore the impact of Industry 4.0 technologies on mitigating operational risks in agri-food supply chains	Risks can significantly undermine firm performance; their negative effect is non-significant for the firms that adopt I4Ts compared to those that do not adopt.	[56]
	Investigate the impact of logistics outsourcing risk management on trade performance. Examine the mediating role of customer service in this relationship. Compare the findings between developed (France) and developing (Cameroon) countries.	Direct Relationship: Logistics outsourcing risk management does not have a significant direct impact on trade performance. Mediating Role of Customer Service: Customer service significantly mediates the relationship between logistics outsourcing risk management and trade performance. Country Differences: In Cameroon, logistics outsourcing risk management significantly influences customer service, while in France, the logistics capabilities of providers are more critical. Customer Service Impact: Customer service positively impacts trade performance in both countries.	[62]

Notes: DT- digital technology; Stakeholders – more than three respondents, such as farmers, production, transportation, and retailing of agricultural products; Producer – farmers, food manufacturers, food producers; Logistics – storage holder, distributors, transportation providers, handling and processing.

Data availability

Data will be made available on request.

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