

# Harnessing Emerging Digital Technologies to Promote Equitable, Diverse and Inclusive Supply Chains: A Scoping Review

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## Systematic Review

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# Abstract

## Purpose

The impact of digital transformation in agriculture, including innovations in crop supply chains, is global. Despite that, the level of this technology practice varies across countries, regions, crop types, technologies, socio-economic statuses, and cultures. In the literature, there needs to be more evidence for digital technologies' role in the role of equity, diversity, and inclusion (EDI) to improve agricultural supply chains (ASC). Thus, this scoping study synthesizes extant research on the extent to which Emerging Digital Technologies (EDTs) promote EDI in the ASC.

## Methodology:

A scoping approach to systematic literature review (SLR) was applied to achieve the objective by deploying the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) extension for scoping reviews. The methodology guided the process of conducting the scoping review step by step.

## Findings:

Emerging technologies have been found to focus much on some parts of the ASC (such as transportation) where there are limited studies in other ASC parts. Most emerging technologies have been employed in the food supply chain where there is limited literature on the cash crops supply chain.

## Research limitations/implications:

The evidence gathered through this study informs innovation policies and prioritizes opportunities for future research and practices in the area. IoT, Blockchain, and Machine Learning are among the technologies worth detailed study for EDI in agricultural supply chain innovations. Each of these provides unique contributions but is subject to further evaluation, re-development, and deployment that considers the local context, nature of innovation, and other dynamics within the ecosystem.

## Originality/value:

This review provides insight into the current body of knowledge on the role of EDTs towards addressing EDI in ASC.

## 1 Background

### 1. 1. Introduction to ASC Innovations

Agricultural Supply Chain (ASC) is described as all activities from when the crops are on the farm up to the final consumer (Wilson & Clarke, 1998; Wang & You, 2022). Key activities include cultivating land for crop production, processing, packaging, distribution, and retailing (Aramyan & Van Gogh, 2014). The players in the ASCs are organizations and people responsible for producing, distributing, processing, and marketing agricultural products to the final consumers (Wang & You, 2022).

In the typical ASC, farmers produce agricultural raw products and sell them to processors. Processors in the ASC purchase raw crops from farmers' agriculture products, and processes and sell them to various retailers. In practice, processing and retailing are often conducted by the same organization, collectively called agricultural Small and Medium Enterprises (SMEs) (Jose & Shanmugam, 2020).

The management of ASC is complex and a high-risk process due to the diversity of actors involved (Zhai et al., 2022). As such, ASC suffers from challenges including post-harvest losses accounting for up to 30% of the produced food (Wicaksono & Illés, 2022), food safety issues, limited traceability, intensive manual work, and lack of transparency in agricultural finances (Jose & Shanmugam, 2020). Further, other challenges, such as the unpredictability of weather, pests, and diseases, are hard to control, making it even more challenging to keep up with the set targets.

Emerging Digital Technologies (EDTs) offer prospects for addressing the abovementioned challenges to enhance efficiency and productivity in the agricultural sector (Shao, Kombe & Saxena, 2022). These technologies include Artificial Intelligence (AI), Big data Analytics, the Internet of Things (IoT), and Blockchain Technology (BCT). The AI, for example, can be used to predict the weather changes and environmental impact on crop yields, helping farmers make informed decisions about expected harvests (Nosratabadi et al., 2020). The BCT in agriculture enables actors and consumers to track how the product has been handled from the farm to the shelf, which helps to minimize fraudulent activities and eliminate counterfeit products in the chain (Shao, Kombe & Stuti, 2021). Moreover, the BCT immutability attribute increases credibility in the ASC, which is necessary for promoting equitable financing (Panetto et al., 2020). Smart IoT devices can monitor crops on the farm and in storage. Moreover, the hybrid application of emerging technologies can reinforce the assurance of food safety, traceability, and transparency, which are vital to the ASC's success.

## **1.2 ASC and Equity, Diversity, and Inclusion (EDI)**

Equity, diversity, and inclusion are pillars of the ASC as they ensure fairness and inclusiveness for all stakeholders in the chain (Sangeetha & Vijayalakshmi, 2020). Equity considers differences to ensure a fair process and, ultimately, a fair outcome. Equity in the ASC increases diversity by ameliorating the conditions of disadvantaged actors, particularly farmers (Dadi et al., 2021). Diversity refers to the sum of how people are alike and different. In the ASC, diversity recognizes, values, and embraces each actor's uniqueness (Mukherjee et al., 2021). Inclusion refers to the fair and respectful treatment of all individuals concerning their unique skills, experiences, and perspectives. In the ASC context, it means all actors have

equal access to resources and opportunities; and can contribute fully to the ASC's success (Yakubu et al., 2022).

Having EDI is crucial for ASC operations, but the complex nature of the ASC poses challenges to its realization (Morella et al., 2021). For example, despite the critical role they play in the agricultural sector, women are sidelined from the benefits and opportunities of the ASC. This is because they are still poor (including having low access to capital) and uneducated, less skilled, and hence get less rewarded (FAO, 2010). As a result, men are highly placed in higher remunerative positions compared to women, who usually are household caretakers and labor in agro-industries (Amentae & Gebresenbet, 2021). This limits women's opportunities to acquire new technical and entrepreneurial skills, raising the risk of unemployment if their jobs are automated. To address the existing pattern of gender bias in the ASC and their potential costs, the equity should be promoted throughout the chain (Diem & Thuy, 2020).

The ASC is characterized by different scales; large, medium, and small-scale players (Saetta & Caldarelli, 2020). Small, medium and large operators are at each stage of the chain: production, processing, trade, or consumption. In such a situation, dealing with diversity and inclusion among these players is paramount. For example, compared to larger-scale players, most smaller players cannot access modern technologies for sustainable agriculture due to their financial constraints (Mushi et al., 2022; Saiz-Rubio et al., 2020; William & Kaserwa, 2015).

Many EDTs solutions have been proposed or implemented in ASCs worldwide, including artificial intelligence-based solutions, CCTV cameras with sensor networks, IoT systems, unmanned aerial vehicles, and robotic systems. (Pauschinger & Klauser, 2022). For example, in the Sub-Saharan context, in particular, some of the implemented solutions include the use of artificial intelligence in climate change adaptation in Africa (Rutenberg, Gwagwa, & Omino, 2021) and the use of unmanned ground vehicles (UGV) for farm management activities in Tanzania (Yonah et al., 2018). The role of these solutions in achieving EDI in ASCs is vital for national, regional, and even global agricultural innovation policies. In contrast, the systematic reviews and knowledge about the role of EDTs in achieving EDIs in ASC are scant. This research aims to bridge this knowledge gap by systematically exploring the synergy of EDTs and EDI in the ASC. The findings from this study may be helpful to policymakers, agricultural system leaders, SMEs, and EDT developers considering using EDI as a pillar for ASC success.

The organization of the paper is as follows. Section 2 describes the methods used in the scoping review. Section 3 presents the study findings and discussion. Section 4 discusses the implications to research and practice. Section 6 presents the study conclusions and the paper ends with recommendations in section 7.

## 2 Methods

This study conducted a scoping review, guided by the Preferred Reporting Items for Systematic Review and Meta-Analyses extension for Scoping Review (PRISMA-ScR) (Tricco et al., 2018). This review aimed to determine what research evidence is present on a particular subject and to depict that evidence by

mapping or charting the data and synthesizing the research by time, place, and source (Munn et al., 2018). The PRISMA-ScR checklist consists of the following steps: protocol and registration, eligibility criteria, information sources, search, selection of sources of evidence, data charting process, data items, critical appraisal of individual sources of evidence, and synthesis of results (Tricco et al., 2018).

### *Protocol and Registration*

This is a scoping evaluation of primary studies on how ASCs and emerging technologies work together. A literature search was conducted on March 15, 2022, per the protocol's parameters, and revealed several records on the chosen topics. An in-depth analysis was done to see if any other overviews or scoping studies addressed the same goals as ours.

### *Eligibility Criteria*

These criteria were used to evaluate the studies' validity, relevance, and comprehensiveness. The inclusion and exclusion criteria allowed the selection of the relevant studies. Table 1 describes the inclusion and exclusion criteria that were used.

Table 1  
The Inclusion and Exclusion Criteria Used

SN	Inclusion criteria	Exclusion criteria
1	Articles that have focused on EDI and ASC.	Articles that are not in English
2	Articles that have been published in a peer-reviewed journal.	Duplicate articles
3	Articles that have been published in English language.	Full texts of publications chosen for data coding are not available.
4	Articles that have been published between the year 2012 up to early 2022.	Grey literature, unpublished and non-peer reviewed articles
5	Full texts of publications chosen for data coding are available.	

### *Information Sources*

The database search was carried out on the five academic electronic databases: IEEE Xplore, ScienceDirect, Emerald Insight, Science Direct, and Google Scholar. These were intended to provide a comprehensive and detailed account of findings related to the study topic. Forward and backward citations were examined on the found articles to ensure that any additional relevant literature was included.

### *Selection of Source of Evidence*

The following keywords were used to ensure that all relevant articles were identified: ("Agricultural Supply Chain Innovation" OR "ASC Innovation") AND ("Emerging Technolog\*" OR "Emerging Digital Technolog\*" OR "Industry 4.0" OR "Agriculture 4.0"). The key terms were chosen after a preliminary examination of previous research related to the study's goal.

### *Data Charting Process*

At this stage, all researchers perused the list of articles potentially eligible (after analyzing abstracts), and those chosen for review were openly discussed and approved. An Excel spreadsheet was prepared for data extraction with a row for each included study and columns for extracting relevant information and concepts. All researchers took data from the protocols and entered it into an Excel spreadsheet. A standardized data extraction form was used to document each article's features.

Discrepancies were settled through discussion, whereby duplicate and irrelevant articles were eliminated. Data from article discussions were included because they frequently featured additional insights from the authors, which provided valuable insights and enriched the findings.

Figure 1 illustrates the flow chart of the study selection process

### *Data Items*

The following data items were extracted from the literature: Article title, publication year, publisher, publication type, country of first author's first affiliation, synthetic of paper, keywords, ASC innovation, whether the article focuses on ASC and EDT, and if the authors reported on EDI.

### *Critical appraisal of individual sources of evidence*

The quality of the evidence gained from the studies were evaluated to ensure that the study design was adequate for the study objective, that bias was eliminated, and that the research was well documented.

### *Synthesis of Results*

The dispersion of studies and thematic areas were depicted using tables and charts mapping. The significance of the findings was reviewed and weighed in relation to the overall study goal, as well as the implications for future research, practice, and recommendations. The following processes were involved for results synthesis as guided by (Dhlamini et al., 2019).

1. Coding data from the included articles
2. Categorizing the coding into major themes
3. Build themes
4. Displaying the data
5. Identifying key patterns in the data and identify sub-themes
6. Summarizing the findings

## 3 Findings and Discussion

### 3.1 Descriptive Analysis

The papers were arranged by year, revealing an upward trend in the number of papers published on this topic (refer to Fig. 2). The first paper was published in 2012, and the number of publications has steadily increased over time. This demonstrates the growing interest in this field among researchers, industry, and policymakers.

The type of publication refers to the method by which the paper was made public. The selected papers were published in various settings and forms, including conferences, journals, technical Reports, and books (See Fig. 3 distribution of the papers per avenue). The study findings reveal that most papers were published in journals (55), accounting for 73.33 percent. Papers published in book chapters were 11, conference papers were 6, and white papers and technical reports made up the remainder of 3.

In addition, the publications were clustered by country, with India at the top, followed by China, the United States of America (USA), the United Kingdom (UK), Hungary, and Canada (refer to Fig. 4). The cross-country classification was based on the study's geographic location. However, there were few papers where the first author's affiliation location was used as a country classification criterion. The distribution shows a global interest in the topic under study, as evidenced by where the primary papers selected for this review were published (Table 2).

Table 2  
Summary of country-wise related research

<b>Continent</b>	<b>Country</b>	<b>Number of articles</b>	<b>Percentage</b>
Africa	Tanzania	1	1.3
	Ethiopia	1	1.3
Asia	Taiwan	1	1.3
	Malaysia	2	2.7
	Pakistan	1	1.3
	Cambodia	1	1.3
	China	12	16.0
	Vietnam	1	1.3
	India	19	25.3
	Indonesia	2	2.7
	Turkey	1	1.3
	Australasia	Papua New Guinea	1
Europe	Spain	2	2.7
	Netherlands	1	1.3
	Serbia	1	1.3
	France	2	2.7
	Germany	1	1.3
	Hungary	4	5.3
	Italy	3	4.0
	Greece	2	2.7
	UK	4	5.3
North America	USA	7	9.3
	Canada	3	4.0
South America	Brazil	1	1.3
	Peru	1	1.3
Total		75	100.0
<i>.1.2 Thematic Classification of the Selected Literature</i>			

The papers were classified according to 14 themes related to EDTs and ASC. Figure 4 depicts the word-cloud of the theme classification while Table 3 describes a summary of the concepts ac

Table 3  
Summary of Papers concepts distributions across EDI aspects

Thematic Area	Authors	Technology	E	D	I
Security	(Abideen et al., 2021; Amentae & Gebresenbet, 2021; Bhat et al., 2021; Brewster et al., 2017; Caro et al., 2018; Cui, 2018; Dadi et al., 2021; Despoudi et al., 2021; Diem & Thuy, 2020; Dutta et al., 2020; Hu et al., 2021; Kumar et al., 2022; Liu et al., 2021; Luthra et al., 2018; Morella et al., 2021; Mukherjee et al., 2021; Panetto et al., 2020; Saetta & Caldarelli, 2020; Sangeetha & Vijayalakshmi, 2020; Sharma et al., 2020; Tao et al., 2018)	AI, IOT, Big Data, Blockchain, Agri-food 4.0, Smart Agri-Food	Ö	Ö	Ö
Traceability	(Abideen et al., 2021; Amentae & Gebresenbet, 2021; Bhat et al., 2021; Biagio Di Terlizzi, Robert Van Otterdijk, 2016; Brewster et al., 2017; Caro et al., 2018; Chen et al., 2020; Cui, 2018; Dadi et al., 2021; Despoudi et al., 2021; Diem & Thuy, 2020; Dutta et al., 2020; Hu et al., 2021; Kumar et al., 2022; Liu et al., 2021; Luthra et al., 2018; Morella et al., 2021; Mukherjee et al., 2021; Panetto et al., 2020; Rejeb et al., 2022; Saetta & Caldarelli, 2020; Sharma et al., 2020; Tao et al., 2018)	AI, IOT, Big Data, Blockchain, Smart packaging, Agri-food 4.0, Smart Agri-Food	Ö		
Decentralization	(Abideen et al., 2021; Amentae & Gebresenbet, 2021; Bhat et al., 2021; Caro et al., 2018; Dadi et al., 2021; Dutta et al., 2020; Liu et al., 2021; Morella et al., 2021; Mukherjee et al., 2021; Panetto et al., 2020)	AI, IOT, Big Data, Blockchain, Agri-food 4.0, Smart Agri-Food	Ö		
Transparency	(Abideen et al., 2021; Amentae & Gebresenbet, 2021; Bhat et al., 2021; Caro et al., 2018; Cui, 2018; Dadi et al., 2021; Devaux et al., 2018; Diem & Thuy, 2020; Dutta et al., 2020; Hu et al., 2021; Kumar et al., 2022; Liu et al., 2021; Luthra et al., 2018; Morella et al., 2021; Mukherjee et al., 2021; Nosratabadi et al., 2020; Panetto et al., 2020; Rejeb et al., 2022; Saetta & Caldarelli, 2020; Sharma et al., 2020)	AI, IOT, Big Data, Blockchain, Agri-food 4.0, Smart Agri-Food, E-commerce, ML	Ö	Ö	Ö
Consensus	(Amentae & Gebresenbet, 2021; Dadi et al., 2021; Devaux et al., 2018; Diem & Thuy, 2020; Dutta et al., 2020; Liu et al., 2021; Morella et al., 2021; Mukherjee et al., 2021; Panetto et al., 2020; Saetta & Caldarelli, 2020)	AI, IOT, Big Data, Blockchain, Agri-food 4.0, Smart Agri-Food	Ö	Ö	
Task Automation	(Abideen et al., 2021; Amentae & Gebresenbet, 2021; Cui, 2018; Dadi et al., 2021; Diem & Thuy, 2020; Liu et al., 2021; Morella et al., 2021; Nayal et al., 2021; Panetto et al., 2020)	AI, IOT, Big Data, Blockchain	Ö		
Site search and selection	(Panetto et al., 2020)	AI, IOT, Big Data, Blockchain	Ö		

Thematic Area	Authors	Technology	E	D	I
Prediction in ASC	(Amentae & Gebresenbet, 2021; Dadi et al., 2021; Morella et al., 2021; Nayal et al., 2021; Panetto et al., 2020)	AI, IOT, Big Data, Blockchain	Ö		
Decision Making	(Abideen et al., 2021; Dadi et al., 2021; Liu et al., 2021; Morella et al., 2021; Nayal et al., 2021; Panetto et al., 2020; Rejeb et al., 2021; Sangeetha & Vijayalakshmi, 2020; Sharma et al., 2020)	AI, IOT, Big Data, Blockchain, Agri-food 4.0, Smart Agri-Food, ML	Ö		Ö
Data Analytics	(Abideen et al., 2021; Dadi et al., 2021; Diem & Thuy, 2020; Liu et al., 2021; Morella et al., 2021; Panetto et al., 2020; Rejeb et al., 2021; Sangeetha & Vijayalakshmi, 2020; Sharma et al., 2020; Tao et al., 2018)	AI, IOT, Big Data, Blockchain, Agri-food 4.0, Smart Agri-Food	Ö	Ö	
Access to Information	(Abideen et al., 2021; Caro et al., 2018; Cui, 2018; Dadi et al., 2021; Devaux et al., 2018; Morella et al., 2021; Mukherjee et al., 2021; Nayal et al., 2021; Nosratabadi et al., 2020; Saetta & Caldarelli, 2020)	IOT, Agri-food 4.0, Smart Agri-Food, E-commerce		Ö	Ö
Immutability	(Amentae & Gebresenbet, 2021; Bhat et al., 2021; Caro et al., 2018; Dutta et al., 2020; Morella et al., 2021; Mukherjee et al., 2021; Panetto et al., 2020; Rejeb et al., 2022)	AI, IOT, Big Data, Blockchain		Ö	Ö
Communication	(Abideen et al., 2021; Bhat et al., 2021; Caro et al., 2018; Cui, 2018; Diem & Thuy, 2020; Liu et al., 2021; Nosratabadi et al., 2020; Panetto et al., 2020; Saetta & Caldarelli, 2020).	AI, IOT, Big Data, Blockchain, E-commerce	Ö		Ö
Rapid Response	(Abideen et al., 2021; Caro et al., 2018; Cui, 2018; Dadi et al., 2021; Nosratabadi et al., 2020; Panetto et al., 2020; Saetta & Caldarelli, 2020)	AI, IOT, Big Data, Blockchain, Agri-food 4.0, Smart Agri-Food, E-commerce			Ö

## 3.2 Discussion

### 3.2.1 EDI Considerations in ASC related Emerging Digital Technologies

#### 3.2.1.1 Equity

Agriculture is the backbone of most economies in developing countries, sustaining their food security, export incomes, and rural development (FAO, 2022). One of the prevailing tools is to end extreme poverty and feed a projected 9.7 billion people by 2050 (World Bank, 2018). In the developing world, smallholder farmers account for roughly two-thirds of the rural population (Nosratabadi et al., 2020). Many farmers cannot earn a living wage due to limited market access and specialized services (Wang & Yu, 2022). As a result, farmers bear the risks associated with nearly the entire supply chain. Managing external suppliers, vendors, logistics, and transportation risks throughout the supply chain is critical to achieving actors' equity (Sharma et al., 2020). Emerging digital technologies are being heralded as a way to mitigate inherent risks. Specifically, emerging technologies such as the IoT, BCT, AI, and big data offer the possibility of transforming the ASC in ways that promote sustainability and equity among ASC participants.

The ASC, in particular, is plagued by a severe lack of transparency and trust (Kumari et al., 2022). One of the significant challenges is the proliferation of fake Agri-inputs, which costs farmers and consumers time and money. Sharma et al. (2020) proposed the 'Farm-2-Home' artifact, which uses a well-organized and feedback-oriented supply-demand chain and predictive insights from machine learning to bridge the gap between farmers and end consumers, ensuring product authenticity and increase consumer confidence. To maintain consumer confidence and trust in agricultural products, data security is ensured through data encoding in a way that only the applications that are part of the system can access it; the rest of the data is kept private. As a result, their system provides all stakeholders with unprecedented transparency. The farmer, in particular, is protected from the wrath of a poor yield and tampering and increased consumer confidence and loyalty. Consequently, an equitable environment is created among ASC actors through the capabilities offered by the EDTs.

Brewster et al. (2017) provide an overview of the potential role of IoT in the agricultural sector from the standpoint of designing and specifying IoT-based Large-Scale-Pilots (LSP), allowing readers to understand the associated opportunities, constraints, and requirements of the sector that IoT can address. The technologies associated with the IoT have much potential for use in agriculture. Besides, there are several challenges, such as a lack of transparency and, by nature, security threats, including availability, data lock-in, confidentiality, audibility, data privacy, and solutions for data governance and ownership. However, these challenges can be mitigated when other technologies, such as BCT, complement the IoT and BDA capabilities by offering data security, anonymity, trust, and decentralization. As such, that combination can offer an equitable environment to bolster the ASC.

Traceability entails providing accurate information about the product's geolocation at any time and point along the supply chain. Often, traceability can be delineated into backward traceability (or tracing) and forward traceability (or "tracking"), depending upon the intended trajectory of the product (Wang & Yu, 2022). EDTs are becoming increasingly important at these levels, as they are frequently the operational component used to improve product traceability within an integrated FSC. Thus, EDTs, particularly BCT (Hu et al., 2021), expose all the required properties for decentralizing food traceability systems while

making traceable data available at every supply chain step. Thus, traceability is a function of equity as it allows equitable access to information across different levels of the ASC.

The Internet of Things (IoT) allows for ASC traceability, which enhances the ASC operation process, and fosters equity among ASC stakeholders (Jinbo et al., 2019). Moreover, adopting IoT can boost the effectiveness of ASC in domestic and global markets by achieving inclusiveness and accessibility of agricultural product supply chains by all stakeholders (Yakubu et al., 2022).

Mahalik & Kim (2016) stipulate that traceability is becoming increasingly important to ensure proper documentation of processed food for financial, regulatory, and safety purposes. Radio Frequency Identification (RFID) and barcode technologies have been used in the agri-food industry supply chain to facilitate the security and traceability of food products (Costa et al., 2013). RFID enables locating commodities and food products and following their history in the supply chain (from source to consumer or vice versa) (Trace, 2007; Amentae & Gebresenbet, 2021). Moreover, the application of nanotechnology in food processing and packaging can complement traceability approaches while gathering information such as food temperature, acidity, salinity, and restricted pathogen content (Diem et al., 2020). At the endpoint, stakeholders of the ASC have access to reliable and equitable information on how food is produced and transacted (Xiong et al., 2020). Decentralization, transparency, traceability, data immutability, and data privacy, along with a consensus, improve the production processes and make the existing supply chains agile, resilient and responsive in the long term (Terry et al., 2020).

In the ASC, the stored records must be tamper-proof to maintain trust and reliability along the whole chain. The best case would be if each actor issuing transactions could do that without relying on any centralized third-party intermediary. A potential solution to alleviate such issues and concerns is the BCT, a peer-to-peer digital ledger that does not rely on centralized servers (Santhi & Muthuswamy, 2022). Since all the records stored in a blockchain are based on a consensus reached at least by the absolute majority of peers of the network itself, this distributed ledger is immutable by design and offers an auditable and transparent source of information as such equity is ensured among players of the ASC.

The EDTs, such as BCT, have the potential to combat corruption in the ASC by ensuring transparency in the ASC activities, hence boosting equity, diversity, and inclusion (Kamilaris et al., 2019; Madumidha1 et al., 2019). Existing issues in the developed world, such as unfair bidding and the dominance of large corporations, have traditionally hindered the economic viability of smaller farms. Thus, the transparency in the BCT modus operand can aid the creation of reputation-based trading systems, which can reduce bias and corruption while also increasing equity and inclusion in the ASC (Sachin et al., 2020). Moreover, smart contracts and AI can eliminate unethical contract-breaking and bribe solicitation by ensuring parity among stakeholders, for instance, between a cooperative of farmers (producers) and distributors/retailers (Kamilaris et al., 2019).

### **3.2.1.2 Diversity**

Key technologies such as GIS, GPS, sensors, and computer-controlled equipment can be employed to boost ASC production (Sharma et al., 2018). When the government employs these technologies to support farmers, especially in unprivileged poor regions, they assist the diversity and inclusiveness of farmers in the ASC, especially in rural areas and underprivileged regions.

The EDTs, such as AI, ML, and BDAs, contribute to the knowledge management and decision-making processes to support ASC operations. For instance, ML and other analytic methods can improve predictive and prescriptive capabilities, providing diverse options to all ASC stakeholders. Furthermore, these technologies could facilitate practical farm-related analysis of crucial variables such as water consumption, nutrients, moisture, and soil temperature data (Despoudi et al., 2021). Moreover, the advent of IoT, AI, and DBAs are transformative and impactful tools that could empower small and marginalized farmers to enrich their livelihoods and provide varied opportunities (Dutta & Mitra, 2021).

In addition, the role of BCT features like self-executing smart contracts in improving traceability, preventing fraud incidents, and providing insurance in agricultural supply chains has the potential to enhance diversity in the ASC. Moreover, the prospects of robotic aerial farming technologies such as drones for farming land surveillance, crop data generation, spatial data analysis, field mapping, aerial spraying, and aerial planting (Despoudi et al., 2021).

Farmers can use big data to get detailed information on weather patterns, water cycles, fertilizer demands, and more. This allows them to make informed judgments about which crops to sow for maximum profit and when to harvest. Thus, in ASC decision-making, the role of data is compelling. Data reveals and addresses inequities and needs within the ASC and farming communities, paving the way for innovation and change (Misra et al., 2020). As the amount of data collected grows, so does the level of diversity and inclusion among ASC stakeholders. Big data analytics plays a crucial role in addressing diversity and inclusion, allowing for identifying gaps, prioritizing action areas, and continual performance monitoring.

Access to information is fundamental for the effectiveness of ASC operations. It is argued that IoT enhances equal access to information and decision-making among ASC stakeholders (Sanjeev et al., 2020). Thus, IoT can be used by farmers, agricultural officers, managers, and other stakeholders to collect data at different levels of the ASC (Jellason et al., 2021). The agricultural agencies can use the collected data for agricultural implementations (such as agricultural aid and education) and policymaking, eventually promoting diversity and inclusiveness among the ASC stakeholders.

Moreover, emerging digital technologies can capture a wide range of data and generate predictive models that can alleviate several problems and promote diversity in the ASC, as evidenced by (Mike & Ahmed, 2021). For instance, ML-based chatbots could be used by farmers who can assist in the diversity of knowledge of agriculture and its supply chain process across ASC actors, as some farmers have less knowledge of ASC than others.

### **3.2.1.3 Inclusion**

An inclusive agricultural supply chain requires equitable access and participation by all actors. It includes access to resources, gender representation in the agricultural supply chain, access to information, control over labor allocations, and social norms. However, consideration of inclusion aspects in the current ASC innovations has not been given the attention it deserves. In this context, inclusion is discussed in several dimensions, including but not limited to immutability, transparency, communication, consensus, sustainability, and rapid response.

Emerging technologies such as Blockchain have immutability aspects where each block has a digital signature and a connection to the previous one, necessitating the participation of each player in the network (Amentae & Gebresenbet, 2021; Bhat et al., 2021; Caro et al., 2018; Morella et al., 2021; Mukherjee et al., 2021; Panetto et al., 2020; Rejeb et al., 2022). Henceforth, the records and underlying operations in a Blockchain-based system rely on a consensus reached at least by the absolute majority of peers in the network itself and offer an auditable and transparent source of information.

Blockchain technology in ASC has the potential to promote transparency and solve problems in scenarios where resource distribution involves numerous untrusted actors. It also supports automatically matching real-time data, avoiding manual checks and duplication, and reducing documentation work by 20%. (Abideen et al., 2021; Amentae & Gebresenbet, 2021; Bhat et al., 2021; Caro et al., 2018; Cui, 2018; Dadi et al., 2021; Devaux et al., 2018; Diem & Thuy, 2020; Dutta et al., 2020; Hu et al., 2021; Kumar et al., 2022; Liu et al., 2021; Luthra et al., 2018; Morella et al., 2021; Mukherjee et al., 2021; Nosratabadi et al., 2020; Panetto et al., 2020; Rejeb et al., 2022; Saetta & Caldarelli, 2020; Sharma et al., 2020). Traceability tags in BCT can efficiently attain tag source verification, information, and ownership, which are fundamental aspects of transparency. As such, in the ASC context, the application of BCT could bolster transparency among actors efficiently. Moreover, a combination of IoT and BCT in the ASC can provide more transparency, robustness, and stability of information access by actors.

The use of IoT can enhance communication in the ASC. Moreover, this technology allows the collection of data that can improve the quality and traceability of agricultural products along the chain. It can also help to increase productivity, efficiency, and performance and provide machine data and information to improve operational processes (Abideen et al., 2021; Bhat et al., 2021; Caro et al., 2018; Cui, 2018; Diem & Thuy, 2020; Liu et al., 2021; Nosratabadi et al., 2020; Panetto et al., 2020; Saetta & Caldarelli, 2020). In an environment where there is a lack of information and concerns about pandemics such as COVID-19, IoT can provide better information management, thereby enhancing traceability.

One of the advantages of emerging technologies such as Blockchain is its consensus mechanism, whereby data cannot be altered without the consent of a majority of the participants (Malaya et al., 2020; Geneci et al., 2021). As a result, the Blockchain ledger in BCT can be shared but not changed. If someone tries to change data, all participants will be notified, and the perpetrator will be identified. This promotes inclusivity among ASC stakeholders because all participants must agree on the ASC records in the Blockchain. Application of BCT can address bride soliciting and data tampering challenges, which are likely to be implicated by corrupt farmers, producers, distributors, and merchants.

The sustainability of ASC is critical to ensuring food and income security for the world's ever-growing population. Before the final product reaches the end-users, the ASC includes several pre-productions, production, storage, processing, trading, and distribution operations. However, sustainable ASCs are knowledge-intensive and rely on the supply chain actors' information, skills, technologies, and attitudes.

Big Data Analytics (BDA) can potentially drive long-term agri-food supply chains (Rejeb et al., 2021). BDA can revamp potential ASC areas such as soil, water, crop, and plant management, animal management, waste management, and traceability management. Furthermore, ML-driven technologies are transformative and impactful in improving the overall efficiency of ASC and addressing the various challenges associated with data management in the agricultural sector (Sharma & Rohit, 2020; Hernández Jorge et al., 2018).

In agriculture, there has always been a need for timely and accurate information on input (for instance, seeds and fertilizers), digitized soil maps, remote sensing, and global positioning system (GPS) guidance, as well as data for precision agriculture, in order to yield higher returns. A comprehensive application of Blockchain, Internet of Things (IoT), and Big Data Analytics (BDA) in the agricultural supply chain can undeniably improve the welfare of all stakeholders, including farmers' welfare, which is a significant concern in the industry. According to Kumar et al. (2022), a Blockchain framework can eliminate the entire agricultural supply chain's moral hazards while contributing to the stakeholders' sustainable welfare. Specifically, Blockchain technology is more relevant in financial transactions and may thus be the primary technology for future sustainable agricultural supply chain development. For example, Blockchain can reduce the risks of agreements between players in the supply chain, particularly in contract farming schemes.

## **4 Implications to Research and Practice**

### **4.1 Research**

The study indicates the increasing interest in empirical and desk research on EDT with practical application and value addition in ASC. The implications call for the need of research-informed enabling environment towards the promotion of EDI within ASC as follows:

- i. The trends geographically (more in developed and emerging countries but limited in low- and middle-income countries) and thematically (silos of thematic with equity, diversity and inclusion dimensions).
- ii. Technological convergence where possible integration of more than one technology is possible (For example: Decentralized applications and Blockchain, Blockchain and Machine Learning, AI and Blockchain and GIS-enabled sensor systems, IoT and GIS). The readiness for such a combination among SMEs in ASC is an interesting area for ICT4D researchers in developing countries.
- iii. Research on possible innovation convergence for example of Warehouse Receipt System (WRS) and Contract Farming (CF) for efficient, effective and trusted ASC.

- iv. The EDI's value proposition in technologies supporting ASC innovations at different levels of decision making and its potential to inform agricultural development, poverty reduction and contribution to SDGs is an interesting area for future research.
- v. Research on disrupting poorly performing ASCs through the use of EDTs.

## 4.2 Practice

The existing and future research will inform the practice on the following:

- i. Inform the existing innovation policies on the role of EDTs in refining the ASCs and EDI objectives.
- ii. Provision of conducive policies and legal frameworks such as food and cash crop policy, ICT policy, data management and sharing policy, laws and by-laws, regulations such as electronic communication regulations and guidelines to enhance EDI practices.
- iii. Improving good governance through participation, accountability, and transparency for ASC innovation prosperity.
- iv. Enhancing the capacity of institutions implementing the innovations in terms of coordination, infrastructure, human resources, and financial resources for positively disrupting and adopting the ASC innovations and technologies.

## 5 Conclusions

This paper has systematically explored the synergy of Emerging Digital Technologies (EDTs) and Equity, Diversity, and Inclusion (EDI) in the Agricultural Supply Chain (ASC). The review revealed that the emerging technologies with the potential to enhance EDI aspects in ASC included BCT, AI, IoT, GIS, and BDA. Moreover, these EDTs can address the EDI challenges in the ASC in several ways. Blockchain (BCT) has shown the potential to address most of these challenges, including the ASC's lack of security, trust, transparency, traceability, and sustainability. The varied features of Blockchain, like smart contracts, decentralization, transparency, traceability, data immutability, and data privacy, along with a consensus mechanism, make it suitable to be utilized in the complex and multi-echelon supply chains of today. These factors improve the production processes and make the existing supply chains agile, resilient, and responsive in the long term. Blockchain also adds an aspect of sustainability that correlates with the phenomenon of the circular economy in today's world. Nevertheless, the integration of multiple EDTs is pertinent. Furthermore, the study indicated a potential implication of EDTs and EDI for ASC policy and practice.

## 6 Recommendations

EDTs offer various potentials for supporting EDI aspects in ASC. Moreover, each EDT has its strengths and weaknesses in assisting EDI. In order to comprehensively ensure EDI in the ASC, it is recommended for governments, researchers, and practitioners to use a combination of EDTs, including BCT, IoT, AI, and BDA, since these technologies complement each other. Some weaknesses of these digital technologies

appear as strengths in others. For instance, IoT and BDA can benefit from blockchain by providing and enhancing data security, anonymity, trust, and decentralization. Since BCT exchanges information in a distributed network, researchers and developers should create innovative IoT applications for distributed environments.

On the other hand, the valuable data generated from the IoT could enrich transaction details that are registered on the BCT. In turn, the accurate data provided by BCT can be used as input for ASC-based AI applications and to record their outputs. Besides, AI can enhance the IoT by developing innovative ASC applications to analyze data captured by sensors in real-time using machine learning algorithms. Machine learning and other analytic methods can also improve BDA's predictive and prescriptive capabilities (decision-making) in ASC. This enables intuiting the appropriateness of using them as complements to the others. Thus, combining the different technologies will enhance the ASC and make it more innovative, informed, efficient, secure, sustainable, and resilient. In general, EDTs will lead the ASC to evolve into a data-driven, intelligent, agile, and autonomous, connected system of systems.

## Declarations

### Data Availability

The data generated during or analyzed during the current study are available from the corresponding author upon reasonable request.

### Funding Declaration

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### Conflict of Interest Declaration

I do not have any competing interest in relation to the publication of this paper.

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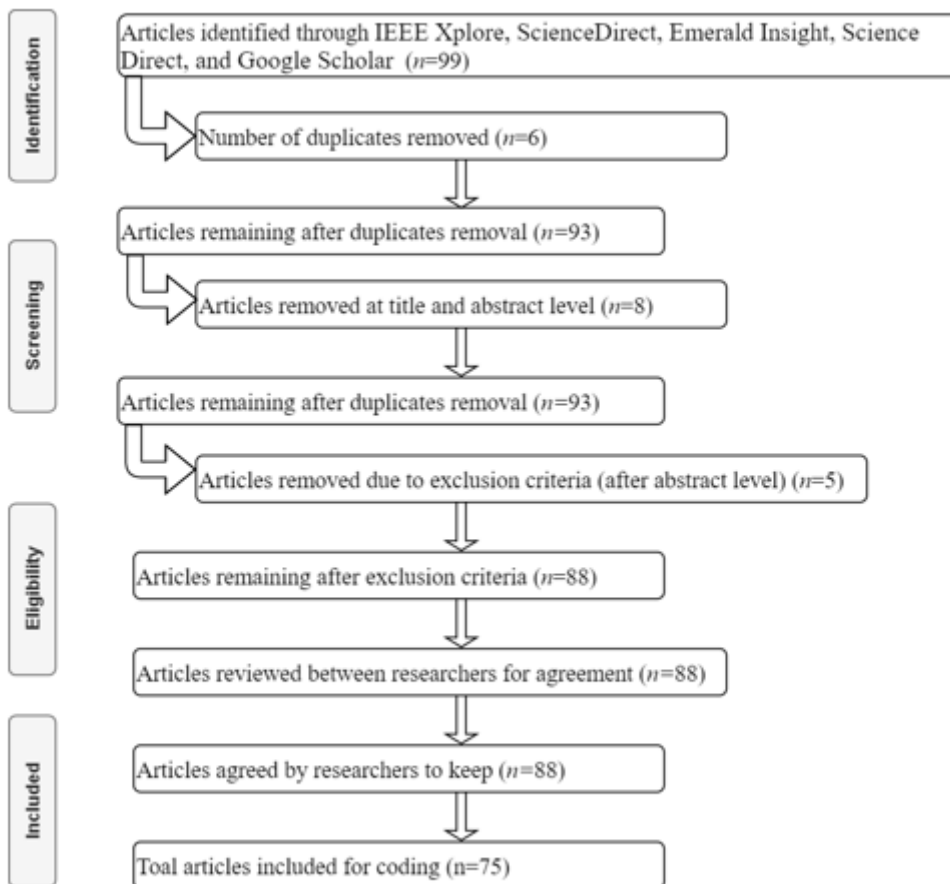
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## Figures



**Figure 1**

Flow diagram of the study selection process

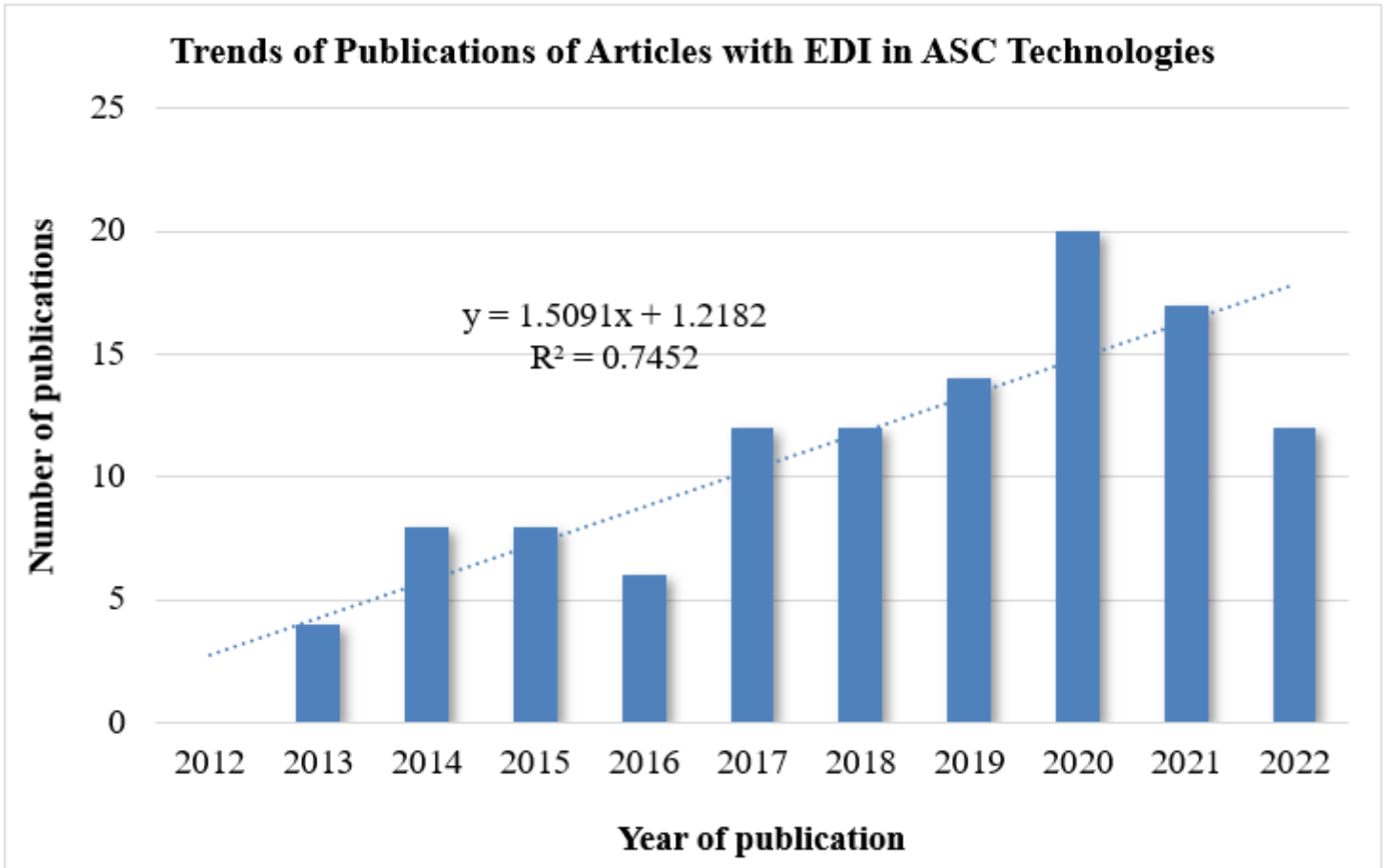


Figure 2

Summary of year-wise related research

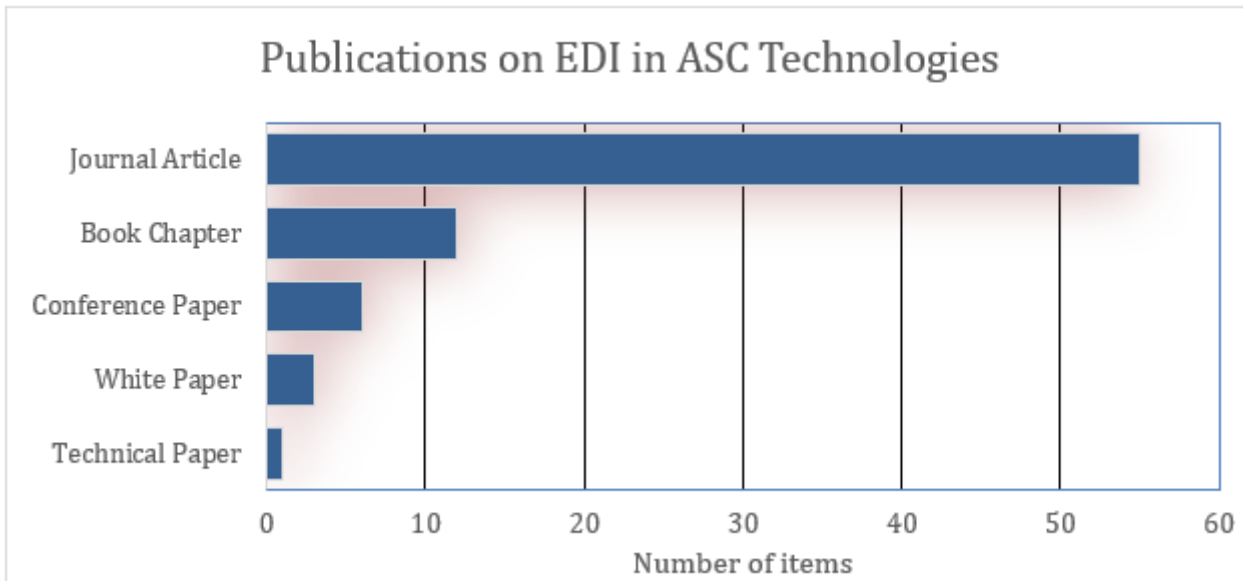


Figure 3

Summary of the various types of publications



Figure 4

Word Cloud of the frequent keywords