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Critical success factors for ICT integration in agri-food sector: Pathways for decarbonization and sustainability

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ABSTRACT

A decarbonized agri-food sector may provide consumers with nutritious, secure, and reasonably priced food with a lower carbon impact. Decarbonizing the agri-food sector is intricate and necessitates a holistic strategy. Technological advancements, like Information and Communication Technologies (ICT), might be the solution. This study analyses the critical success factors (CSFs) for ICT integration in the agri-food sector in the Western and North Western States of India based on empirical data collected and analyzed. The study proposes a framework that determines and ranks the significant factors for ICT integration in the agri-food sector to achieve the decarbonization goals by utilizing the fuzzy evidential reasoning approach (FERA) and the evidential reasoning approach (EFA). The factors are examined based on the Technological, Organization, and Environmental (TOE) criteria. The results show that the most significant factors contributing to the effective implementation of ICT in the agri-food sector are continuous innovation and R&D, supportive policies and regulations, and cost-effectiveness. The results will assist managers and decision-makers in creating effective policies and making knowledgeable choices that will support sustainable growth in the agri-food industry by lowering carbon emissions through effective ICT integration.

1. Introduction

As per the estimates of the United Nations, the global population will grow to 8.5 billion by 2030 and 9.9 billion by 2050. (Mrabet, 2023). FAO (Food and Agriculture Organization) estimates that to feed the world's expanding population by 2050, it will be necessary to increase agricultural output by 70 % (Van Dijk et al., 2021). Feeding people is insufficient; providing them with nutrient-intensive food while avoiding environmental damage is essential. Climate change is the primary ecological hazard resulting from anthropogenic heating of the atmosphere and rising concentrations of greenhouse gases, mainly CO_2 (Shukla et al., 2019), a significant contributor to Greenhouse Gas (GHG) emissions in agriculture. Approximately one-third of the worldwide emissions of GHG originate from the food business (Wang et al., 2022). Of these emissions, 27 % are produced during the crop-production stage, and 18 % are generated throughout the supply chain's operations(Poore and Nemecek, 2018). Agriculture's high emissivity is starting to come up in social and political discourse. This relates to a more significant concern, such as the European Union (EU)'s goal of having zero net emissions by 2050 to achieve carbon neutrality (Prastiyo et al., 2020).

The global procurement, manufacturing, and distribution of food make decarbonization one of the most challenging supply chain activities. Decarbonization is removing carbon-based depositions, establishing carbon sinks for carbon, and minimizing energy-intensive transportation, output, and processing methods (Wimbadi and Djalante, 2020). Understanding that using clean and green energy technology is necessary to reduce highly energy-intensive practices. ICTs, with their disruptive potential, can help make agriculture more innovative and sustainable. The World Bank defines ICT as "any device, tool, or application that permits the exchange or collection of data through interaction or transmission" (El Bilali and Allahyari, 2018). The agriculture industry extensively uses ICTs across all operational sectors in the global economy. From 2017 to 2023, the global smart farming market grew at an annual rate of 19.3 %, reaching $23.14 billion in 2023 (Singh et al., 2020). This growth is being pushed by the greater adoption of ICT in the agri-food sector in industrialized and developing economies, along with

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an emphasis on climate-smart agriculture.

ICTs provide data that assists in various decisions at various phases of the agri supply chain. These modern technologies ensure that resources are used optimally to efficiently cut carbon emissions, resulting in a sustainable future (Kumar et al., 2023). ICTs enable accurate farming, decarbonized production techniques, and vendor evaluation during the processing and production phases. ICTs provide supply chain integration, which is vital for achieving decarbonization. It promotes circular economy initiatives, provides choices for origin monitoring, and enables effective trade and agro-e-commerce during consumption. It facilitates the exchange of knowledge and coordination within the Agri Supply Chain (ASC), which improves its decarbonization and resilience (Avşar and Mowla, 2022).

In light of this, it is essential to study the significant factors that can lead to the successful integration of ICT in the agri-food sector. The study is carried out in Western India, which has a robust agri-food sector and significantly contributes to India's agricultural economy. The region is renowned for producing diverse agri outputs and has a flourishing dairy and food processing sector (Tan et al., 2015). With robust infrastructure and widespread adoption of technology-driven solutions, this region presents a dynamic landscape for studying ICT integration in the agri-food sector. The study is based on empirical data collected and analyzed from June to Oct 2024. This study identifies and ranks several Critical Success Factors (CSFs) according to their significance, resulting in an extensive framework for decarbonization in the agri-food sector using ICT. Owing to the complexity of the agri-food industry and the multitude of factors that might lead to carbon emissions, an interdisciplinary study is necessary to bring together experts from several domains. By understanding and considering CSFs in their planning and implementation methods, organizations in the agri-food sector can increase their chances of minimizing carbon emissions in their processes.

Although the volume of research on ICT integration in the agri-food industry is expanding, a closer look at the decarbonization effect is an area of focus that needs further academic study. Few review studies have focussed on ICT applications to improve the ASC's efficiency in the past. The use of ICTs in ASCs has been the main focus of this research, with specific themes such as ASC risk management (Behzadi et al., 2018) or industry sectors (Lezoche et al., 2020; Moysiadis et al., 2023) being highlighted. There is a clear gap in the literature addressing the complete analysis of the critical success factors. Prior studies have not systematically analyzed CSFs for ICT integration in the agri-food sector for decarbonization. More precisely, there has been no systematic analysis in the academic literature of the technological, organizational, and environmental (TOE) factors that could lead to successful ICT integration in the agri-food sectors. Many studies focus solely on technological difficulties, neglecting crucial managerial aspects for successful ICT implementation. To fill this gap, the following research question will be examined in this study:

RQ1: What are the primary CSFs for ICT integration in the agri-food sector that enable a practical decarbonization effect

RQ2: How can these CSFs be appraised regarding their impact on successful implementation from a Technology, Organization, and Environment (TOE) standpoint?

A research framework built on the TOE framework was developed to answer the above research question. A well-tested empirical framework is essential for understanding the factors contributing to decarbonization through digitalization. When an organization wishes to achieve a radical paradigm shift, such as decarbonizing, all components of technology, organization, and environment must be in sync. This approach necessitates a knowledge of firms' technological and organizational preparedness to implement the latest technology or process enhancement. Understanding the external environment, including resource availability and infrastructural support, is crucial for successful adoption. By employing this framework, entities can methodically assess the critical success factors from all three angles, leading to a more thorough and nuanced comprehension of the factors in putting ICT into place for practical decarbonization effect.

From this viewpoint, the objectives of this research study are as follows:

- To identify CSFs for ICT integration in the agri-food sector for effective decarbonization effect
- To create a framework for analyzing CSFs built on Assessment values.
- To rank the CSFs for ICT integration in the agri-food sector for effective decarbonization effect

The paper is structured as follows. A thorough literature evaluation, which forms the basis of the study, is presented in Section 2. The third section explains our research methodology and strategic approach to attaining our objectives. Section 4 contains a detailed report and review of our research findings. The remaining two parts explore the implications of the findings and the study's conclusions.

2. Literature review

The literature on the TOE framework, the use of ICT in the agri-food sector, and ICT to achieve decarbonization goals is included in this section. This study centers on the existing literature regarding incorporating ICT in agricultural settings and its potential to improve decision-making and promote sustainable farming methods.

2.1. The TOE framework

DePietro and Byrd, 1990 proposed the technology, organization, and environment model (TOE) to investigate business choices in integrating technologies. The theoretical framework suggests that when a business decides to implement new technology, the three main contextual domains have an impact: technological, organizational, and environmental. In contrast to theories and frameworks like the Diffusion of Innovation (DOI), the theory of planned behavior, and the Technology Acceptance Model (TAM), which focuses on technological aspects, the TOE framework takes into account organizational and environmental factors along with the technological aspects, offering a deeper comprehension of the broader context (Morawiec and Sołtysik-Piorunkiewicz, 2023). According to(Gangwar et al., 2015; Senyo et al., 2016), this model effectively assesses value generation and innovation acceptability. The technological dimension assesses the organization's perceived utility, compatibility, intricacy, and usage of internal and external technology. The TOE framework's organizational perspective refers to the internal traits and assets of the businesses, including tangible and intangible resources such as the organization's size, organization, tradition, and assets. The environmental perspective relates to the external environment within which the business operates, including marketplace dynamics, regulatory necessities, and cultural and social values. The TOE framework was used by Wang et al. (2020) to determine the variables influencing blockchain technology adoption in Malaysian SMEs. Using the TOE framework, Sarkar et al. (2024) assessed the severity of traceability hurdles in Industry 5.0-enabled digitized food supply chains. The concept has also been widely applied with recent breakthroughs, such as cloud computing (Gui et al., 2020) and IoT (Solanki and Sarkar, 2022).

2.2. ICT integration in the agri-food sector

Agriculture 4.0, the fourth revolution in the agriculture industry, is merging ICTs to herald the transformative era of agriculture (Braun et al., 2018; Calafat-Marzal et al., 2023; Kazancoglu et al., 2024; Sonar et al., 2024). Successful implementation and ICT administration in the agri-food supply ensures reliability, effectiveness, and security (Miraz et al., 2020; Syed et al., 2022). Several novel technological combinations for innovative agrarian production have been thoroughly studied recently. ICT-based digital agriculture has improved access to information, decision-making assistance, and production Bhat et al. (2021); Saurabh and Dey (2021) suggest that advanced models incorporating ICTs can anticipate accurate weather forecasts and guide crop planting, harvesting, and water resource management decisions. Artificial intelligence and IoT can improve nitrogen management and crop production, decreasing costs and benefiting the environment (Ghag et al., 2024). ICT technology can minimize greenhouse gas emissions by focusing on location-specific temporal and spatial needs, which improve soil carbon sequestration (Roy and George K, 2020; Northrup et al. (2021) estimate a 25 % decrease in emissions of greenhouse gases by using precision agriculture in row crop settings. It can assist the supply chain in developing a risk-based management strategy. ICT and sensor-based applications can evaluate transport logistics and optimize procedures by tracking parameters like fuel consumption, speed, and position, increasing supply chain efficiency (Cuong and Tien, 2022). According to Spielman et al. (2021), implementing ICTs can transform farming into a profitable and attractive activity, re-engage farmers, and attract rural youth to agriculture.

2.3. ICT and decarbonization goals

ICTs can significantly improve economic results while preserving the environment and addressing sustainability challenges (Alromaizan et al., 2023). ICTs are crucial in developing smart agriculture (Sharma et al., 2023) because they allow for easier decision-making, selecting green processes and adaptive procedures, and efficient monitoring and regulation of emissions (Xu et al., 2023).emphasized that ICT is a significant driver in reducing carbon emissions. Among these technologies is the green Internet of Things, which has been proven effective in cutting carbon emissions by substituting energy-demanding operations with green tags and sensing. Green tags are intangible, marketable certifications that attest to the owner's use of renewable energy sources (Hansen et al., 2022). ICTs assist in achieving energy conservation through pooled environmentally conscious networking (Kumar et al., 2023). A low-carbon economy requires skill and leadership, which may be operationalized through assistance from top management. ICT-based irrigation solutions can cut greenhouse gas emissions and carbon footprint by using less electricity in addition to water use (Han et al., 2023). Through appropriate ICTs, post-harvest losses (PHL) can be decreased, and food safety can be enhanced, leading to more involved local economic growth and meeting client and market needs through improved social sustainability(Belaud et al., 2019). The application of AI to demand forecasting has increased customer satisfaction. Last-mile delivery enhances environmental and economic sustainability in a manner akin to how fleet management and optimized routing of vehicles increase fuel efficiency (Kumar et al., 2024; Sharma et al., 2020). Likewise, reverse logistics (RL), which handles returned goods, lowers carbon footprints using lean and green methods, guaranteeing the ecosystem becomes greener through improved processes and material consumption (Moreno-Camacho et al., 2023). Utilizing low-carbon resources and investing in energy-efficient technologies are two ways to help the supply chain become carbon-efficient (Lim et al., 2020). ICTs make it possible to track goods in real-time from farm to fork. According to (Rothe, 2020), developing ICT solutions without considering producers' and consumers' actual conditions and practices can hinder progress toward sustainable food system changes.

2.4. Insights from literature review and research gaps

The literature illustrates that technologies significantly influence the modern agri-food business in light of the growing environmental concerns. Incorporating digital technologies and circular economy principles is essential to ensure safe and sustainable food products for global customers. The literature shows that decarbonizing agri-food is crucial for attaining low-carbon growth and sustainability. Some studies have discussed the pathways to achieving decarbonization goals in developed countries like the USA (Bataille et al., 2020; Sroufe and Watts, 2022). Although some research has looked into how technology might help achieve sustainable development (Khan et al., 2021; Shariff et al., 2022), energy has been the focus of the majority of studies in this area (Arshad et al., 2020; Lange et al., 2020). The agricultural and food industries can benefit significantly from ICT integration, but several obstacles must be removed to ensure a seamless integration process, particularly in developing countries(Getahun, 2020). These include disconnected and small-scale software development, societal and regional variations, a focus on specific regions, challenges integrating diverse systems at the farmer's or supply chain level, and complex handling and integration of enormous volumes of data. These critical findings open the door to understanding the crucial success elements for ICT integration in the agri-food sector to achieve successful decarbonization goals.

Despite extensive study, significant gaps exist in understanding the crucial success factors for integrating ICT in the agri-food sector for decarbonization. More precisely, there has been no systematic analysis in the academic literature of the technological, organizational, and environmental (TOE) factors that could lead to successful ICT being implemented in the agri-food sectors. Many studies focus solely on technological difficulties, neglecting crucial managerial aspects for successful ICT implementation. To effectively decarbonize and promote sustainable development, this study adopts a larger perspective to uncover the critical success factors that impact ICT integration in the agri-food sector. Future studies should explore how ICT solutions can be tailored to various agricultural contexts like smallholder farmers, resource-constraint regions, and large agribusinesses while ensuring suitability across different geographical areas and terrains. For small-scale farmers or resource-constrained regions, the studies should focus on developing cost-effective solutions that integrate their cultural wisdom. At the same time, scalable technological frameworks that improve data accessibility are necessary for large-scale agribusinesses. Future research should also assess how ICT-driven decarbonization techniques can influence environmental sustainability over the long run. Even though digital solutions offer optimized production with decreased emissions, scarce knowledge exists about their sustainability impacts, like energy consumption, e-waste handling, and life cycle assessments of ICT instruments.

3. Methodology

This study employs a mixed-method approach to explore the Critical Success Factors (CSFs) for ICT integration in the agri-food sector in the Western and North Western States of India, focusing on decarbonization. The fuzzy evidential reasoning approach (FERA) uses qualitative and quantitative data to rank the CSFs under the TOE framework. FERA, which integrates fuzzy set theory and evidential reasoning, is selected for its ability to handle uncertainties, vagueness, and incomplete data. This makes it ideal for complex decision-making scenarios like ICT integration in the agri-food sector, where factors involve quantitative and qualitative elements. While other multi-criteria decision-making (MCDM) techniques like AHP, TOPSIS, MAUT, and DEMATEL were considered, they were deemed less suitable due to their limitations in addressing uncertainty and imprecision (Choudhary et al., 2020). FERA, however, enables the synthesis of expert opinions and belief structures, providing a comprehensive evaluation of the CSFs. Additionally, the study ensures methodological rigor by systematically collecting and analyzing empirical data from key stakeholders in the agri-food sector in the Western and North Western States of India, based on data collected between June and October 2024. This approach enhances the reliability of findings and provides a robust foundation for policy recommendations and strategic decision-making. The study's systematic research structure is shown in Fig. 1.

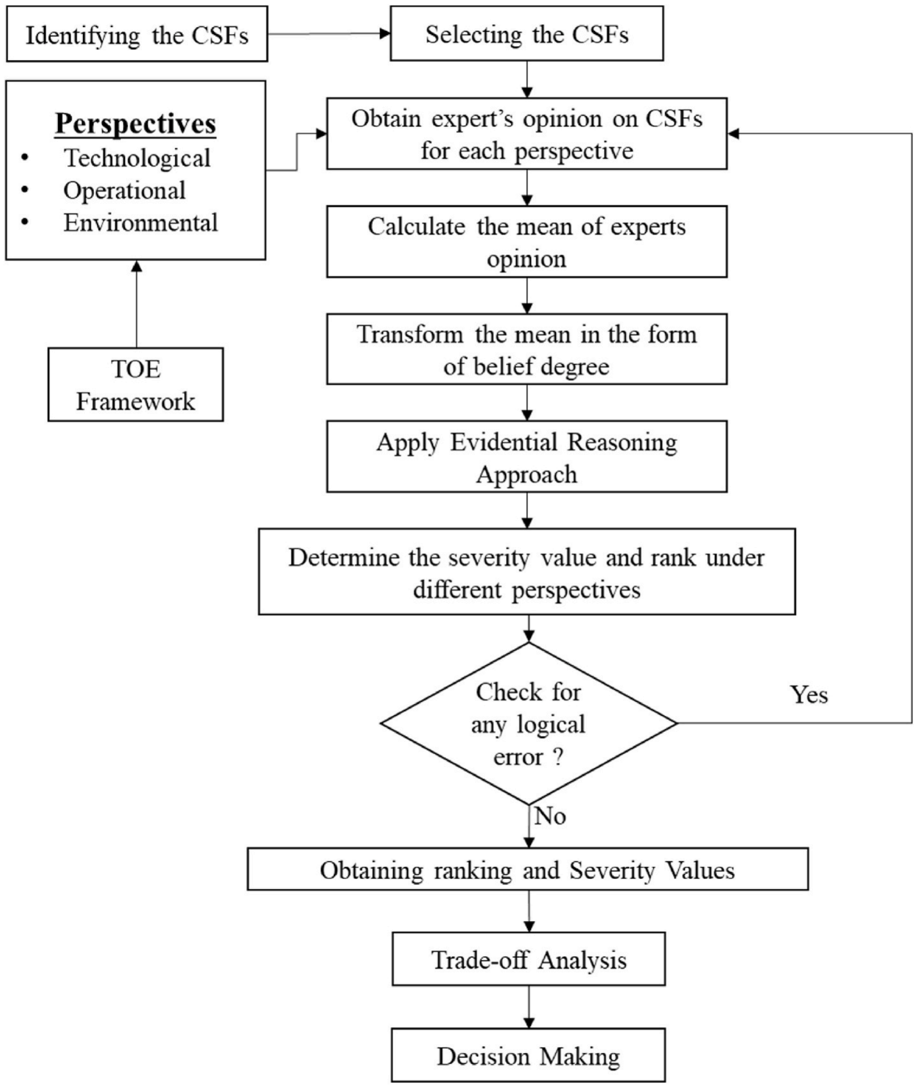

Fig. 1. Research framework.

3.1. *Identifying the CSFs*

After thoroughly examining the literature, a CSF for ICT integration in the agri-food industry was determined. Most of the reviewed articles were downloaded from the Scopus database. The literature review identified 14 CSFs. The researchers initially interviewed the experts. The experts were provided with a list of CSFs that were selected from the existing literature. Then, the researchers explained to the experts what each CSF means. The experts used their expertise and knowledge in practice to establish the significance of sampling those CSFs. Finally, they mutually discussed and agreed upon a final list of CSFs, presented in Table 1. Based on data collected between June and October 2024, Table 2 presents the detailed list of experts considered for the study, along with their geographical area and years of work experience. By concentrating on these aspects, the study aimed to formulate strategic recommendations and solutions that would facilitate the removal of obstacles and facilitate the easier integration of ICTs in the agri-food sector that will achieve the decarbonization targets.

3.2. *Applying fuzzy-evidential reasoning approach*

Fuzzy-evidential reasoning (FERA) addresses decision-making difficulties that involve two uncertainties: vagueness and incompleteness. It combines fuzzy logic, which handles imprecise information with fuzzy sets, and evidential reasoning, which deals with missing knowledge by assigning belief degrees. FERA allows for modeling factors with fuzzy sets, assigning evidence-based belief levels, and developing fuzzy rules to conclude. This approach offers flexibility for various data types, reflects real-world uncertainties, and provides a transparent reasoning process.

3.2.1. *Data collection*

The TOE framework is well-suited for selecting perspectives in the agri-food supply chain when identifying CSFs for ICT integration, especially for decarbonization and sustainability. These three dimensions provide a holistic approach to understanding the complex factors influencing ICT integration in the agri-food sector. This makes the TOE framework ideal for identifying and ranking CSFs to promote decarbonization and sustainability. Therefore, according to the TOE framework, 168 opinions were collected from four expert groups, with three experts each from various technological, operational, and environmental perspectives. Snowball sampling was used to identify a few organizations. Experts from these companies were contacted by phone and email. Twelve experts eventually consented to participate in the study, despite others declining. Experts were chosen based on their domain expertise, work history, academic interest, and acquaintance with the subject of the study. A sample size of 5–15 experts was recommended by (Murry Jr and Hammons, 1995; Sarkar et al., 2025)

Table 1
List of CSFs used for the study.

S. NO	CSFs	Description	References
1	Data Integration and Interoperability (F1)	Compatibility of various ICT systems and platforms used in intelligent farming.	(López-Morales et al., 2020; Roussaki et al., 2023)
2	Reliability and Accuracy of ICT Tools (F2)	The ability of sensors, Internet of Things devices, and data analytics software to offer information that can be implemented with great accuracy and reliability.	(Giua et al., 2022; Omar et al., 2020)
3	User-Friendly Interfaces (F3)	Designing user-friendly interfaces for farmers and agricultural managers.	(Mössinger et al., 2022; Sawant et al., 2019)
4	Cost-Effectiveness (F4)	Initial expenditures and continuous maintenance for modern ICT technology should be priced reasonably	Aker et al. (2016)
5	Access to Funding and Subsidies (F5)	Provision of financial assistance, subsidies, or grants from governments or agricultural organizations.	(Balkrishna et al., 2020; Mapiye et al., 2021)
6	Stakeholder Engagement and Collaboration (F6)	Participation of all relevant stakeholders, such as producers, agricultural scientists, researchers, and technology suppliers	Fieldsend et al. (2021)
7	Training and Education (F7)	Training programs aimed to educate farmers and other stakeholders in agribusiness on utilizing advanced ICT technologies.	Gow et al. (2020)
8	Energy consumption and efficiency (F8)	Using minimum energy-requiring ICT technologies that harness renewable energy sources to lower total carbon footprints and precision agricultural operating costs.	(Alharbi and Aldossary, 2021; Fu and Niu, 2023)
9	Supportive Policies and Regulations (F9)	Government policies and regulations promote adopting low-carbon products and sustainable practices.	(Acharya et al., 2020; Balkrishna et al., 2020)
10	Management Commitment and Support (F10)	Strong leadership and commitment from farm management to invest in and support ICT initiatives.	(Bolfe et al., 2020; Gouvea et al., 2022)
11	Continuous Innovation and R&D (F11)	Ongoing R&D is needed to enhance current technology and create new solutions.	(Blakeney, 2022; Steinke et al., 2022)
12	Adaptability and Scalability (F12)	Technologies adaptable to different farm sizes, types, and geographic locations.	(Abbasi et al., 2022; Dayıoğlu and Turker, 2021)
13	Market Demand and Consumer Awareness (F13)	Increasing market demand for sustainably produced food and transparency in agricultural practices.	Liu et al. (2021)
14	Robust Infrastructure and Connectivity (F14)	It involves having reliable network systems and internet access to ensure smooth operation and integration of ICT tools in the agri-food industry.	Rijswijk et al. (2021)

Table 2
Profile of the experts involved in the research.

	Experts	Designation Title	Area of expertise	Geographical Area	Work Ex (in years)
Industry	Expert 1	Director	Agri Exports and Imports	Western India	30+
	Expert 2	Senior-Vice President	Supply chain Management		27+
	Expert 3	Value Chain Manager	Agri and Food Value Chain		15+
	Expert 4	Director	Agro Chemical		12+
	Expert 5	Co-founder	Agri-Business Operations		12+
	Expert 6	Senior-Manager	Sustainable Agriculture		15+
	Expert 7	Deputy Vice President	Supply Chain and Risk Management		15+
	Expert 8	Head	Agri Operations Management	Northwestern India	10+
	Expert 9	Business Lead	Sustainable Agriculture		25+
Academia	Expert 10	Professor	Faculty of Agriculture	Northwestern India	20+
	Expert 11	Assistant Professor	Supply Chain Management	Western India	5+
	Expert 12	Assistant Professor	Supply Chain Management		5+

because of the high heterogeneity of the panel of experts. Therefore, the sample size of experts in this research is adequate to meet the study's objectives. The panel comprised 75 % experts from industry and 25 % from academia, all of whom have at least five years of experience in their respective domains and are located in the Western region of India. Industry experts represented diverse profiles from the agri-food sector, including Directors, Presidents, Vice Presidents, and others. The objective of selecting diverse experts is to reduce the possibility of biased outcomes and incorporate diverse viewpoints. These experts provided their insights to finalize the barriers. The expert judgments were combined using the consensus approach. Each expert made independent judgments, which were then compared for consistency. To reduce bias, comments were evaluated collectively rather than assigning different weights to individual experts. The linguistic responses help register the vague and ambiguous reactions of the stakeholders (Sarkar et al., 2023). The linguistic terms are taken from (Pathak et al., 2021; Sarkar et al., 2024) and converted into fuzzy membership functions. The experts and their responses in terms of linguistic terms were recorded on five-point membership functions of Very High (VHI), High (HI), Medium (), Low (LW), and Very Low (VLW) and presented in Table 3.

3.2.2. Application of fuzzy set theory (FST)

This study applies the triangular fuzzy membership values provided by (Sarkar et al., 2022) to convert the linguistic terms into their corresponding TFNs. 126 TFNs were generated. Table 4 presents the mean of the triangular fuzzy membership values.

3.2.3. Application of belief degree

A belief degree is an assessment of the value of the opinion that is believed to be accurate. The values obtained in the form of TFNs cannot be used for the ERA analysis (Fulzele and Shankar, 2021). These TFNs are assigned to the corresponding member functions to determine the belief degrees. Obtained belief degrees are non-normalized values. These non-normalized values are now being transformed into normalized ones. Thus, the TFNs are converted into the five belief degree values, as presented in Table 5.

Table 3
Expert's perspectives for ICT integration in Agri-Food Sector.

		EXPERT GROUP 1			EXPERT GROUP 2			EXPERT GROUP 3			EXPERT GROUP 4		
	CSFs	T	O	E	T	O	E	T	O	E	T	O	E
1	Data Integration and Interoperability (F1)	VHI	M	LW	HI	LW	LW	HI	VLW	VLW	HI	M	LW
2	Reliability and Accuracy of ICT Tools (F2)	HI	VLW	VLW	VHI	VLW	VLW	VHI	LW	LW	VHI	VLW	LW
3	User-Friendly Interfaces (F3)	HI	M	HI	VHI	LW	LW	VHI	LW	VLW	HI	LW	LW
4	Cost-Effectiveness (F4)	M	VHI	HI	HI	VHI	M	LW	VHI	M	LW	HI	M
5	Access to Funding and Subsidies (F5)	M	VHI	M	LW	HI	LW	HI	VHI	LW	HI	VHI	LW
6	Stakeholder Engagement and Collaboration (F6)	LW	HI	LW	M	VHI	LW	LW	HI	M	LW	VHI	M
7	Training and Education (F7)	M	HI	LW	M	HI	LW	M	HI	VLW	HI	VHI	VLW
8	Energy consumption and efficiency (F8)	LW	LW	VHI	VLW	VLW	VHI	VLW	VLW	VHI	VLW	M	HI
9	Supportive Policies and Regulations (F9)	LW	M	VHI	M	HI	VHI	LW	HI	VHI	LW	HI	HI
10	Management Commitment and Support (F10)	LW	VHI	HI	LW	M	HI	VLW	LW	HI	VLW	M	VHI
11	Continuous Innovation and R&D (F11)	M	HI	M	HI	HI	HI	M	VHI	VHI	M	VHI	VHI
12	Adaptability and Scalability (F12)	HI	LW	LW	M	M	VLW	HI	M	VLW	HI	M	VLW
13	Market Demand and Consumer Awareness (F13)	LW	VLW	HI	VLW	LW	VHI	M	VLW	VHI	M	VLW	HI
14	Robust Infrastructure and Connectivity (F14)	HI	LW	LW	HI	VLW	VLW	VHI	VLW	LW	VHI	LW	LW

Table 4
Mean of the triangular fuzzy membership values.

		Average								
	CSFs	T			O			E		
1	Data Integration and Interoperability (F1)	0.563	0.813	1.000	0.125	0.313	0.563	0.000	0.188	0.438
2	Reliability and Accuracy of ICT Tools (F2)	0.688	0.938	1.000	0.000	0.063	0.313	0.000	0.125	0.375
3	User-Friendly Interfaces (F3)	0.625	0.875	1.000	0.063	0.313	0.563	0.125	0.313	0.563
4	Cost-Effectiveness (F4)	0.188	0.438	0.688	0.688	0.938	1.000	0.313	0.563	0.813
5	Access to Funding and Subsidies (F5)	0.313	0.563	0.813	0.688	0.938	1.000	0.063	0.313	0.563
6	Stakeholder Engagement and Collaboration (F6)	0.063	0.313	0.563	0.625	0.875	1.000	0.125	0.375	0.625
7	Training and Education (F7)	0.313	0.563	0.813	0.563	0.813	1.000	0.000	0.125	0.375
8	Energy consumption and efficiency (F8)	0.000	0.063	0.313	0.063	0.188	0.438	0.688	0.938	1.000
9	Supportive Policies and Regulations (F9)	0.063	0.313	0.563	0.438	0.688	0.938	0.688	0.938	1.000
10	Management Commitment and Support (F10)	0.000	0.125	0.375	0.313	0.563	0.750	0.563	0.813	1.000
11	Continuous Innovation and R&D (F11)	0.313	0.563	0.813	0.625	0.875	1.000	0.563	0.813	0.938
12	Adaptability and Scalability (F12)	0.438	0.688	0.938	0.188	0.438	0.688	0.000	0.063	0.313
13	Market Demand and Consumer Awareness (F13)	0.125	0.313	0.563	0.000	0.063	0.313	0.625	0.875	1.000
14	Robust Infrastructure and Connectivity (F14)	0.625	0.875	1.000	0.000	0.125	0.375	0.000	0.188	0.438

Table 5
TFNs are converted into the five belief degree values.

	CSFs	Tech			VLW	LW	M	HI	VHI
1	Data Integration and Interoperability (F1)	0.563	0.813	1.000	0	0	0.38	0.88	0.45
2	Reliability and Accuracy of ICT Tools (F2)	0.688	0.938	1.000	0	0	0.125	0.65	0.8
3	User-Friendly Interfaces (F3)	0.625	0.875	1.000	0	0	0.245	0.75	0.665
4	Cost-Effectiveness (F4)	0.188	0.438	0.688	0.125	0.625	0.825	0.38	0
5	Access to Funding and Subsidies (F5)	0.313	0.563	0.813	0	0.38	0.87	0.62	0.12
6	Stakeholder Engagement and Collaboration (F6)	0.063	0.313	0.563	0.8	0.63	0.87	0.62	0
7	Training and Education (F7)	0.313	0.563	0.813	0	0.38	0.87	0.62	0.12
8	Energy consumption and efficiency (F8)	0.000	0.063	0.313	0.8	0.63	1.2	0	0
9	Supportive Policies and Regulations (F9)	0.063	0.313	0.563	0.8	0.63	0.87	0.62	0
10	Management Commitment and Support (F10)	0.000	0.125	0.375	0.65	0.75	0.25	0	0
11	Continuous Innovation and R&D (F11)	0.313	0.563	0.813	0	0.38	0.87	0.62	0.12
12	Adaptability and Scalability (F12)	0.438	0.688	0.938	0	0.12	0.65	0.86	0.365
13	Market Demand and Consumer Awareness (F13)	0.125	0.313	0.563	0.27	0.85	0.62	1.2	0
14	Robust Infrastructure and Connectivity (F14)	0.625	0.875	1.000	0	0	0.245	0.75	0.665

3.2.4. *Evidential reasoning approach (ERA)*

The Evidential Reasoning (ER) approach, as proposed by Shafer (1976), is effective in dealing with imprecise data containing confidential or unclear information. This method involves making decisions based on a belief system that functions as a distribution score. Yang (2001) developed software that integrates ER Analysis (ERA) with an Intelligent Decision System (IDS) program. The IDS software receives input as belief levels for each Critical Success Factor (CSF) under various perspectives. Subsequently, the IDS generates severity ratings and rankings for each CSF.

3.2.5. *Trade-off analysis*

Sensitivity analysis gives managers a grasp on how alterations to attribute weights and alternate performance affect the overall ranking of alternatives, making it a valuable tool. The Integrated Decision Score (IDS) offers three types of sensitivity evaluations and scoring ranges: Change weight, change input data, and trade-off analysis. This study conducts a trade-off analysis to ascertain the significance and evolving nature of crucial success factors related to the ICT integration of the agri-food sector.

4. Results and discussions

This section examines the relevance and ranking of CSFs in effective ICT integration in the agri-food sector from multiple perspectives. From an overall viewpoint, critical success factors (CSFs) offer a structured summary of their relative importance in reaching the stated objective.

4.1. Overall perspective

Table 6 provides the ranking of Critical Success Factors (CSFs). It will provide a structured assessment of essential and significant factors, revealing their relative relevance across the overall, technological, organizational, and environmental dimensions. To account for differences in the datasets, the assessment results for each factor were summed and averaged. Continuous innovation and R&D, supportive policies and regulations, and cost-effectiveness emerge as top priorities, highlighting the importance of creating a setting where solid policies back scientific developments and are financially feasible. Continuous Innovation and R&D (F11) has the highest assessment value of 0.721. Its normalized value of 9.55 % indicates that out of all the factors, it has the maximum influence on ICT integration in the agri-food sector. Digital advancements are critical to the sustainability of agriculture (Le et al., 2023). Innovation promotes circular economic practices by lowering emissions of pollutants, waste, energy consumption, and raw material utilization (Ben Amara and Chen, 2022). Efforts towards continuous research have resulted in improved sensors, IoT devices, and more effective data analysis algorithms for agriculture (Chaparro-Banegas et al., 2024).

Cost-effectiveness (F4), with an assessment value of 0.623, was ranked 3rd most crucial factor. According to a UK survey of SMEs, the most significant barrier to implementing ICTs is the high cost of technology. Managers must assess the costs and benefits of adopting new technologies(Vernier et al., 2021). Low-cost technologies such as low-cost sensors, effective data analytics platforms, and scalable IoT systems assist farmers and agribusinesses in optimizing resource utilization, minimizing waste, and reducing their carbon footprints without incurring significant financial costs (Kountios et al., 2023). With assessment values of 0.641 and 0.623, Supportive Policies and Regulations (F9) and Access to Funding and Subsidies (F5) were ranked 2nd and 4th. Governments and regulatory organizations can create policies to encourage using environmentally friendly technology and practices. These policies can take the form of government subsidies, such as low-interest loans or grants, to assist them in purchasing modern ICT instruments. According to (Acampora et al., 2023), the agri-food sector might profit from loans, incentives, and free certifications to encourage reduced carbon emissions.

A closer look at the rankings reveals that while technology reliability is a key driver, its efficacy depends on the financial and policy frameworks that encourage adoption. For example, the Reliability and Accuracy of ICT Tools obtained the most significant weightage in the technological category, emphasizing the importance of precision and efficiency in digital solutions. However, its influence is enhanced when combined with financial enablers such as Access to Funding and Cost-Effectiveness, which is placed first in the organizational category. This shows that even the most potent ICT solutions require significant financial support to be widely implemented. Similarly, environmental sustainability factors, notably energy efficiency and supportive policies, were highly valued, indicating that decarbonization initiatives must be aligned with legislative incentives and technological feasibility.

4.2. Technological perspective

According to the study, the accuracy and reliability of ICT tools (F2) (Rank 1, Assessment value 0.857), robust infrastructure and connectivity (F14) (Rank 2, Assessment value 0.817), and user-friendly interfaces (F3) (Rank 3, Assessment value 0.813) score highest among technological considerations. Inappropriate measurements of battery-operated devices can be caused by various factors such as failures, phony inputs, harsh weather, electromagnetic radiation, and data manipulation (Elijah et al., 2018). It's essential to ensure the credibility and precision of sensors, data analytics, and IoT devices since they furnish precision data for informed decision-making. The development of ICT infrastructure is crucial for stimulating economic expansion. The main forces are internet access and the facilities for cellular telecommunication (Makini et al., 2020). Farmers, regardless of their degree of IT skill, require user-friendly interfaces to employ current technology effectively. User-friendly software promotes a better grasp of big data analytics and other sophisticated technologies, raising the adoption rate of accurate agricultural technology and enhancing its overall efficacy (Osinga et al., 2022).

4.3. Organizational perspective

Looking at it from the organizational viewpoint, cost-effectiveness (F4) (0.862), access to funding and subsidies (F5) (0.862), continuous innovation and R&D (F11) (0.817), and Stakeholder Engagement and Collaboration (F6) (0.817) are the essential factors that have a crucial influence in boosting successful ICT integration in the agri-food sector. Improved contact with stakeholders ensures comprehension and dealing with everyone's demands and concerns, developing more appropriate and effective ICT solutions (Jäger et al., 2023). According to studies, environmental pressures such as stakeholder engagement and governmental backing are crucial in reducing global carbon emissions (Diniz et al., 2021). Stakeholder involvement may promote ownership and

Table 6
Assessment value and rank of CSFs.

S.No	CSFs	OVERALL		Tech		Org		Env	
		Assessment Value	Rank	Assessment Value	Rank	Assessment Value	Rank	Assessment Value	Rank
1	Data Integration and Interoperability (F1)	0.494	10	0.76	4	0.487	8	0.23	11
2	Reliability and Accuracy of ICT Tools (F2)	0.438	13	0.857	1	0.297	11	0.192	13
3	User-Friendly Interfaces (F3)	0.563	5	0.813	3	0.37	10	0.29	7
4	Cost-Effectiveness (F4)	0.623	3	0.444	10	0.862	1	0.565	6
5	Access to Funding and Subsidies (F5)	0.603	4	0.564	7	0.862	1	0.37	9
6	Stakeholder Engagement and Collaboration (F6)	0.563	6	0.365	12	0.817	3	0.49	7
7	Training and Education (F7)	0.51	9	0.564	7	0.762	5	0.192	13
8	Energy consumption and efficiency (F8)	0.448	12	0.288	13	0.225	13	0.862	1
9	Supportive Policies and Regulations (F9)	0.641	2	0.37	11	0.687	6	0.862	1
10	Management Commitment and Support (F10)	0.533	8	0.192	14	0.63	7	0.762	5
11	Continuous Innovation and R&D (F11)	0.721	1	0.565	6	0.817	3	0.77	4
12	Adaptability and Scalability (F12)	0.477	11	0.687	5	0.445	9	0.297	10
13	Market Demand and Consumer Awareness (F13)	0.535	7	0.49	9	0.2975	11	0.817	3
14	Robust Infrastructure and Connectivity (F14)	0.399	14	0.817	2	0.192	14	0.225	12

authority for the problem along with probable resolutions and ensure that the diverse range of knowledge needed to handle complex institutions is incorporated. This might accelerate the pace at which technology improves and spreads.

4.4. Environmental perspective

Similarly, factors like energy consumption and efficiency (F8) (0.862) and Supportive Policies and Regulations (F9) (0.862) were ranked first from the environmental perspective. Energy consumption and efficiency are critical for successfully integrating ICT into the agri-food sector because they substantially impact operational sustainability, cost-effectiveness, and the environment. Energy-efficient ICT tools lower operative expenses while making sustainable agriculture more accessible and affordable, especially for smallholder farmers. Market Demand and Consumer Awareness (0.816) and Continuous Innovation and R&D (0.777) were ranked 3rd and 4th. With an increased customer preference and market demand for environmentally friendly food items and low-carbon products, the agri-food industry is forced to adopt ICT solutions that reduce carbon emissions, conserve resources, and protect the environment are becoming polluted(Moreira-Dantas et al. (2023); Nguyen et al. (2019) assert that consumers and producers must be encouraged and informed about the benefits of purchasing and preparing a diet that leads to low carbon emissions. Growing consumer knowledge puts additional pressure on farmers to use ICT solutions that assure sustainable agricultural practices. Furthermore, market demands may encourage farmers to invest and innovate, creating more technological yet less expensive ways.

Technological, organizational, and environmental forces interplay displays synergies and potential clashes. For example, although continuous innovation and R&D (F11) are valued highly in all dimensions, they need exemplary management commitment and support (F10) for their implementation, which has a low ranking in the technological frame. Equally, Supportive Policies and Regulations (F9), which are highly ranked in the environmental area, need to be balanced with Cost-Effectiveness (F4) and Access to Funding (F5) in the organizational area for feasibility. In contrast, the Reliability and Accuracy of ICT Tools (F2) are highly ranked in technology but lower in organizational and environmental priorities, showing a possible disparity in adoption strategy. Attending to these synergies and conflicts can assist in framing a balanced approach for ICT implementation in the agri-food industry.

Past research has mainly focused on infrastructural and technical limitations as key hindrances to ICT adoption in agriculture (Tata and McNamara, 2018). noted issues of internet connectivity, exorbitant costs, and poor training, while (Mulungu et al., 2025)identified digital literacy gaps, inadequate infrastructure, and unavailability of local language content. Other studies (Cole and Fernando, 2021)concluded that restricted user capacity and insufficient training diminish the success of ICT interventions. These studies concentrate mainly on access-related problems, implying that technological constraints deter extensive ICT use. While all these studies cite basic ICT access and user training as significant restraints, the present findings paint a more panoramic and strategic view. The results suggest repeated innovation, policies favoring development, and R&D are more essential determinant factors of ICT adoption than common obstacles such as infrastructure and e-literacy. This emphasizes a paradigm shift in the discussion from just offering ICT access to building an ecosystem that encourages innovation, policy coordination, and long-term investment in ICT for agriculture. By realigning the focus from infrastructural shortfalls to innovation systems, this research presents new evidence for policy-makers and business leaders. Rather than focusing exclusively on ICT access and digital literacy, policies need to prioritize R&D investments and create responsive regulatory mechanisms to boost the pace of agricultural digital technology adoption.

4.5. Trade-off analysis

Additionally, a trade-off analysis is carried out in the study to ascertain the significance and evolving nature of crucial success factors related to the ICT integration of the agri-food sector. The factors are categorized in Table 7 according to how dynamically they behave. Decision-makers can prioritize actions for ICT integration in the agri-food industry using the structured framework that the trade-off analysis offers. It identifies regions that need specific policy responses by grouping critical success factors (CSFs) into various quadrants. As seen in Fig. 2, the study generates six scenarios utilizing the CSF assessment results for two criteria on the axes X and Y. According to these scenarios, CSFs are then categorized into different quadrants. We may split the graph into four quadrant frameworks that categorize CSFs based on their comparative strengths and weaknesses. The assessment values of the X and Y variables are comparatively low in Quadrant (Q)1, indicating areas where neither technological nor organizational aspects are sufficiently developed, indicating the need for foundational improvements in both technological and organizational aspects. Although the Y factor's assessment value is still comparatively low in Q2, the X factor's is relatively high. The factors in Quadrant 2 suggest substantial technological advancements but weak organizational readiness, requiring investments in training, change management, and institutional reforms. The assessment scores of factors X and Y are high in Q3, suggesting ideal scenarios where technological and organizational factors will support ICT integration. Quadrant 3 is a good place to scale up and replicate best practices. In contrast, Quadrant 4 identifies circumstances where organizational preparedness is good, but technology infrastructure requires improvement, urging more R&D spending.

Plotting a graph with organizational criteria on the Y-axis and technological criteria on the X-axis would reveal that Energy consumption, efficiency, Market Demand, and Consumer Awareness occupy the Quadrant Q1, and they need significant improvement from both technological and organizational standpoints. In the Quadrant (Q2), we have factors like Data Integration and Interoperability, Reliability and Accuracy of ICT Tools, User-Friendly Interfaces, Adaptability and Scalability, and Robust Infrastructure and Connectivity, which suggests that while the technology exists, organizational adoption barriers must be addressed. Access to funding and subsidies, training and education, continuous innovation, and R&D occupied Q3. Finally, in Q4, we can see factors like cost-effectiveness, stakeholder engagement and collaboration, supportive policies and regulations, and management commitment and support. This indicates that while organizational readiness exists, technological support must be strengthened. It is critical to remember that the outcome of this scenario may vary based on whether we prioritize technology difficulties from an organizational perspective or technological issues from a managerial perspective. Plotting a graph with technological viewpoints on the Y-axis and organizational perspectives on the X-axis would result in different factors filling each quadrant than in the preceding example.

5. Implications of the study

This study has several implications for researchers, managers, and

Table 7
CSFs: A trade off Analyses.

Scenarios		Quadrant 1	Quadrant 2	Quadrant 3	Quadrant 4
X	Y				
T	O	8, 13	12, 14, 2, 3, 1	11, 5, 7	4, 6, 9, 10
T	E	6	7, 5, 12, 1, 14, 2, 3	11,	13, 4, 9, 8, 10
O	E	14, 2, 12, 1, 3	7, 5, 6	4, 11, 9, 10	8, 13
O	T	8, 13	10, 9, 6, 4	7, 11, 5	14, 2, 3, 12, 1
E	O	2, 14, 1, 12, 3	13, 8	10, 9, 11, 4	5, 6, 7
E	T	6	4, 10, 8, 9, 13, 7	11	2, 14, 1, 12, 5, 3

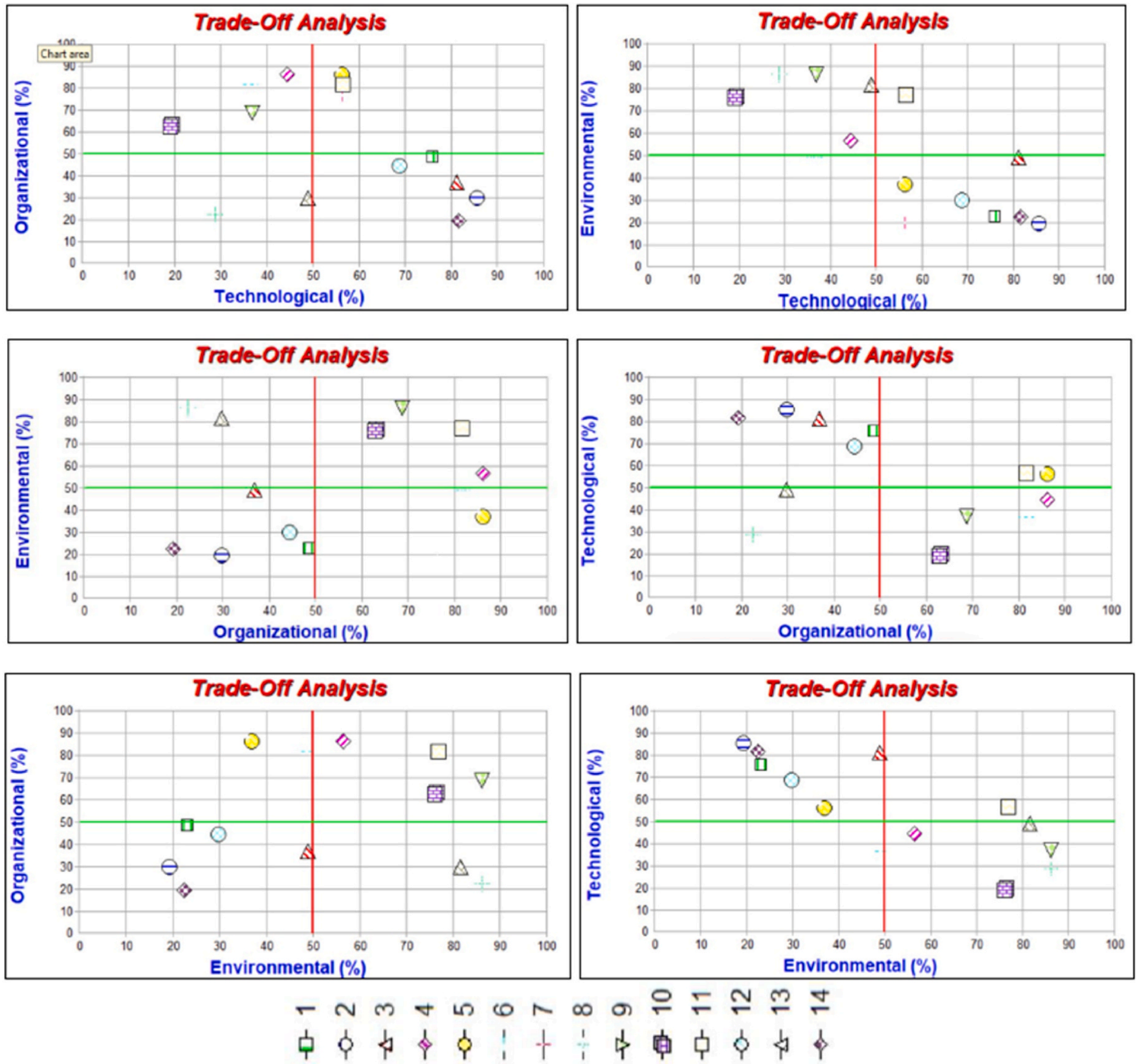

Fig. 2. Trade-off analysis of the CSFs.

professionals.

5.1. Theoretical implications

The study examines several essential constructs, encompassing critical dimensions such as technical, environmental, and organizational. To accomplish decarbonization objectives, the study offers a comprehensive list of crucial elements of success for ICT integration in the agri-food sector., which will be helpful to future scholars and current practitioners. From a TOE standpoint, the prioritized list of critical success factors seems promising in offering guidance for further action. Adopting these factors can result in a carbon-neutral supply chain, leading to more sustainable and healthier environments for future generations. Implementing these significant improvements can elevate people's quality of life by encouraging nutritious and balanced food intake, increasing awareness of the necessity of cleaner surroundings, and helping to create a healthier future. The interplay of important forces can promote sustainable operations in industry and assist managers in developing efficient, carbon-free food supply chains.

5.2. Practical implications

There is a growing movement towards decarbonization and achieving carbon neutrality, with countries, cities, and big businesses vowing to meet these targets. Several major corporations, including Danone, Nestle, and PepsiCo Inc., have consented to a UN-sponsored initiative to control carbon emissions to keep global warming to 1.5 °C (Sharma et al., 2024). Consistent with this perspective, this study has significant implications, translating into several suggestions for the farming community, policymakers, and other agri-food corporations. Continuous innovation and R&D and supportive government policies were identified as the most essential drivers of total impact. The findings stress these factors' critical role in the successful ICT integration in agri-food systems. Several projects have emphasized how continuous innovations and R&D may improve market openness in India. Innovative **farming projects in Gujarat** have been implemented to monitor soil moisture levels, weather conditions, and crop health. By incorporating market data into farming methods, the initiative also showed how IoT can promote price transparency (Madrewar et al., 2024). Another project, AgriBlockIoT, was proposed by (Nagarajan et al., 2022), which uses a blockchain-based approach to agri-food supply chain management, allowing IoT devices to be integrated to produce and utilize digital information along the supply chain. The study's recommendation for continued technological development in agriculture is reinforced by these innovations, demonstrating how digital advancements can improve farmers' access to markets, optimize resource use, and increase productivity through real-time data integration, market transparency, and automated decision-making. The findings highlight the need for industry stakeholders to integrate their business models with governance policies, allocate resources to growth-oriented innovations, and forge strong alliances with R&D centers. Enhancing training initiatives and innovation dissemination platforms can boost industry competence to harness technology for integrating ICT for green transformation and sustainable growth.

Efforts are needed from both the public and private sectors in terms of funding to develop innovative and scalable ICT solutions. Under the Digital India program, the Indian government and public-private partnerships are creating and distributing several cutting-edge, networked technologies to improve the availability, usability, and accessibility of agricultural services at the farm level. The government promotes digital agricultural techniques through projects such as the National e-Governance Plan in Agriculture (NeGP-A), Kisan Call Centers, AgriClinics, Direct Benefit Transfer (DBT) schemes, and numerous applications. Private endeavors include digital start-ups in agriculture (such as CropInfo), echoupal (of ITC), mobile apps (such as Monsanto's FarmRise), and more. There is a need to open paths for redesigning the processes, inspire fresh thinking, and incorporate crowd-sourced research and development innovations to realize trealizetal disruption in the agriculture of developing countries.

Government agencies or policymakers are responsible for establishing suitable conditions restricting agricultural carbon emissions. Emission-based taxes are an ideal market mechanism for indirectly lowering carbon footprints through trade. Without such rules or regulations in place, it is impossible to formalize and enforce emission control. It is worth noting that India does not have an explicit carbon tax. The vast majority of its carbon levies are implied. According to Ojha et al. (2020), an explicit carbon price has yet to be devised to regulate carbon emissions in Indian SCs. Like several other countries, India has pledged to decrease carbon emissions, but this will be difficult to achieve if the carbon tax is not formalized quickly.

Integrating effective ICT technology to reduce carbon emissions takes a significant investment, frequently resulting in initial losses and no profit. Despite a gradual decline in adoption costs, farmers are discouraged from exploring ICT-based practices due to cost concerns. Farmers are worried about the time it takes for their investments to return and the challenges of using them(Bacco et al., 2019). These obstacles could be addressed to create an environmentally friendly future for developing economies like India with the proper financial and technological support. Angel investors' investments in green practices and the technical expertise provided through Krishi Vigyan Kendras pave the way for sustainable adoption. Concerns about the usage of ICT include data security and user privacy. Devices integrated into agricultural supply chains may be vulnerable to hacking, which could lead to either improper data collection or altered device functionality. To track and regulate the use of ICT in the agri-food sector, new rules, legislation, or regulations that are applicable globally will undoubtedly need to be introduced. Many rural areas lack good internet connectivity, making applying ICT-based solutions challenging. Adoption of low-power, long-range wireless connection can be a solution to address this problem.

6. Conclusions, limitations, and future scope

This study aims to address the significant amount of carbon emissions produced by the food system, from farm to fork. Following a literature assessment, the study identified 14 crucial success factors for ICT integration. These factors are ranked in order of relevance to prioritize the most significant ones. According to the findings, the top three factors that could lead to the successful integration of ICT in the agri-food sector are Continuous Innovation and R&D, Supportive Policies and Regulations, and Cost-Effectiveness. It is worth noting that cost-effectiveness was ranked 1st and 3rd from the organizational and overall perspective and 6th from the environmental perspective. However, the cost-effectiveness of the ICT solutions is the foundation for achieving the decarbonization targets. From the standpoint of sustainable development, the study's conclusions offer valuable details about how ICT integration in the agri-food industry might help developing nations meet their decarbonization targets. When devising measures to lower carbon emissions in the agriculture and food industry, policymakers, regulators, and other stakeholders should consider the relative significance of these crucial elements, which will eventually contribute to sustainable development.

This study has several limitations, yet it substantially contributes to the literature. This study used insights from industry professionals and domain expert knowledge and opinions to create a subjective FERA model; there is a likelihood of subjectivity in responses, which may influence the broader applicability of the study's findings. Furthermore, the expert selection and sampling approach could also introduce biases, as the expert's viewpoints may be shaped by their experience in the industry or particular regional contexts. Additionally, the process of defining fuzzy membership functions requires careful calibration, as improper assignment of linguistic variables can lead to inconsistencies in results. FERA also tends to be computationally intensive, especially when dealing with large datasets, requiring significant processing power and expertise in fuzzy logic. Lastly, its interpretability can be complex for decision-makers unfamiliar with fuzzy set theory, potentially limiting its practical applicability in industry settings. Future studies could use a survey technique based on questionnaires with suitable respondents to address biases and incorporate a more diverse respondent base, integrating a mixed-method approach to strengthen the reliability of the results. Although the study found 14 factors that affect ICT integration, further studies considering other factors could produce more thorough and nuanced results. In addition to the technological, organizational, and environmental viewpoints already considered in this study, different perspectives, such as operational, economic, political, and legal, could be added to the model in subsequent research. The utilization of a limited pool of experts is another constraint. A more extensive and varied group of experts could offer a more global viewpoint. Future research can address these limitations to increase the study's generalisability.

CRediT authorship contribution statement

Isha Sharma: Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Bishal Dey Sarkar:** Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Sandeep Jagtap:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Funding acquisition, Formal analysis.

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.

Data availability

Data will be made available on request.

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