Journal of Food and Agricultural Technology Research
https://globalpresspk.com/
ISSN: 3007-0953 (Online)
ISSN: 3007-0945 (Print)

Data-driven Approach to Assessing the Sustainability of Agricultural Supply Chains: A Review of Frameworks and Methodologies

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Abstract: Lack of industrialization, inadequate management, misinformation, and inefficient supply networks are major challenges faced by the agriculture and food industry. Addressing these challenges requires considering not only food production techniques but also social, environmental, and economic factors. The integration of cutting-edge technologies, such as the Internet of Things, blockchain, and big data, is increasingly popular and can assist in establishing sustainable supply chains. The shift to a digital environment, propelled by these technological advancements, is transforming the agricultural supply chain. To evaluate the use of analytics and the achievement of sustainable agriculture supply chain goals, we conducted a review of 84 scholarly articles published between 2000 and 2017. The objective was to understand the extent of analytics usage, data collection processes, and resources employed in the supply chain. Our findings provide a practical framework for professionals in the agri-food supply chain, emphasizing the significance of supply chain visibility and resources in the development of data analytics and sustainable performance. This framework serves as a guide for professionals to strategically allocate investments towards a robust, data-driven agri-food supply chain. Finally, we explore future research avenues and discuss the limitations of our study.

Keywords: Agriculture, Sustainability, Food Security and Supply Chain

Article History:
Received: 27 February 2023; Revised: 12 March 2023; Accepted: 17 April 2023
Online: 12 June 2023; Published: Volume (2) Issue (1) July 2023
https://doi.org/10.69501/aydkq369

1. Introduction

There is an increasing awareness and concern about the impacts of food production and consumption on the environment, society, and the economy. Consequently, there is growing pressure from consumer advocacy groups, social and agro-based organizations, environmental advocacy groups, and legislators to establish sustainable supply chains (Allaoui et al., 2017). The agri-food supply chain (AFSC) is facing significant challenges due to current consumption habits and continually growing population (Network, 2012). Achieving a sustainable outcome for an AFSC depends on finding a balance between economic expansion, the preservation of the natural environment, and societal progress. The primary distinction between an AFSC and a consumer supply chain lies in the fact that raw materials in an AFSC are cultivated using diverse agricultural techniques, and both humans and animals consume the finished goods. In a consumer supply chain, only humans utilize the raw materials. Nevertheless, both types of supply chains share common components, including suppliers, retailing hubs, transportation and distribution networks, focal firms, and customers (Miranda-Ackerman et al., 2017). Since the Global Summit on Sustainable Development, numerous initiatives promoting sustainable development across various sectors have been launched (Van Huijstee et al., 2007). Notably, the agriculture sector has been a focal point of these efforts, aiming to achieve sustainable growth through the implementation of best management practices in agriculture and the improvement of both social and ecological conditions (Dentoni and Peterson, 2011). To achieve a sustainable agri-food supply chain (AFSC), significant challenges must be addressed, including the limited involvement of small farmers, insufficient regulations for food safety and quality control, underdeveloped industrialization, poor management practices, and misinformation (Luthra et al., 2018).

The resolution of these challenges should take into account not only the method of food production but also the interrelated factors of social dynamics, environmental sustainability, food security, and economic feasibility (Charles et al., 2010). These solutions should extend across the entire supply chain encompassing agriculture, consumption, distribution, packaging, and processing rather than being limited to agricultural production alone. The field of sustainability focuses on overcoming challenges through cooperation among multiple participants in the supply chain. Technological advancements, particularly in agri-food supply chains (AFSCs), have facilitated better decision-making in the supply chain and have a significant impact on its long-term viability (Kamble et al., 2018). The integration of IoT technologies has empowered real-time collection and dissemination of information, thereby enhancing sustainability outcomes. The Internet of Things holds the potential to enhance the long-term viability of AFSC's by facilitating enhanced communication, coordination, and collaboration across the many nodes of the supply chain (Ahumada and Villalobos, 2009). The effectiveness of the Internet of Things (IoT) and sensor technologies in addressing food quality and security, as well as minimizing the demand-supply gap, has been well-established (Wang and Yue, 2017). The substantial data produced by IoT devices can be evaluated through big data analytics, assisting in identifying weak points within AFSC's (Verdouw et al., 2016). Moreover, blockchain technology holds the potential to play a role in facilitating sustainable agricultural supply chains (Sharma et al., 2018). These emerging technologies are transforming the traditional AFSC into a data-driven digital supply chain environment. With this shift, achieving a high degree of supply chain visibility (SCV) becomes crucial for enterprises, providing decision-makers with accessible information to formulate sustainable supply chain plans. Despite the significance of AFSC sustainability, academic literature lacks comprehensive reviews. Irani and Sharif (2016) have focused on developing a comprehensive perspective on food waste and the associated information. Similarly, Govindan (2018) has investigated the key drivers, barriers, and indicators that influence sustainable supply chain performance. Beske et al. (2014) have delved into the dynamic capabilities of the food industry, while Dania et al. (2018) have explored the collaborative behavioral factors. The massive data generated by the data-driven AFSC presents several challenges, including data visualization and sharing, data collection and storage, and information management. Addressing these challenges necessitates the development of new data-driven decision models and frameworks (Zhong et al., 2017).

The current literature on Sustainable Agricultural and Food Supply Chain (AFSC) lacks practical guidance for academics and professionals to comprehend achieving sustainability in a data-driven environment. There is a dearth of information on the key aspects of Data Analytics Capability (DAC) and its effect on sustainability within AFSC. Further investigation is necessary to determine the type of analytics employed (prescriptive, predictive, or descriptive), the fulfillment of sustainable agriculture supply chain objectives (economic, environmental, and social), the supply chain procedures that increase information transparency, and the resources utilized for data collection, analysis, and sharing within the AFSC. The aim of this project is to investigate potential answers to the following research questions (RQ):

RQ1: What long-term and sustainable performance results are accomplished by AFSC?

RQ2: At what degree of data analytics can these long-term results become possible?

RQ3: Which resources from the supply chain are used in the development of the DAC for the AFSC?

RQ4: Which procedures within the supply chain of an AFSC give a high level of information visibility?

RQ5. How are the resources of the supply chain, information visibility, and DAC connected to one another in an AFSC that is sustainable?

A systematic review was conducted to investigate the latest research on the relationship between data-driven Agricultural Food Supply Chain (AFSC) and sustainable performance. The review was based on previously established research questions and was approached using the resource dependence theory and content analysis method. The findings from the review were used to develop an application framework for data-driven sustainable AFSC, incorporating concepts of supply chain resources, Supply Chain Value (SCV), Direct Agricultural Chain (DAC), and sustainable performance. This framework can be beneficial for AFSC practitioners in planning their investments and transforming current AFSCs into data-driven sustainable AFSCs. The paper is organized as follows: Section 2 presents the review approach, Section 3 provides a review of the findings, and Section 4 discusses the implications for practitioners and a suggested application architecture for data-driven sustainable AFSC. Section 6 offers suggestions for future research, and the final section summarizes the findings and limitations of the study.

2. Review methodology

The choice of the sustainable Agricultural Food Supply Chain (AFSC) issue for this review stems from its relatively abstract nature, leading to the determination that an analysis of published literature would be more effective (Beske et al., 2014). Given the investigative goal of examining the current state of research in the field of sustainable AFSC, an in-depth content analysis was conducted, involving a comprehensive evaluation of the relevant literature, aligning with the approach suggested by Mayring (2003). The approach that was employed consisted of a four-step iterative procedure that included the following steps: (a) material collection, (b) descriptive analysis, (c) category selection, and (d) material assessment. When compared to other qualitative interpretative approaches, this methodology allows for greater levels of traceability and inter-subject verifiability because of the fact that the dimensions and analytic categories that are utilized for content classification may be obtained either deductively or inductively (Seuring and Gold, 2012). Before conducting an analysis of the material presented in the chosen papers, we based the dimensions and analytic categories that we utilized in our review process on the previously published research in the field of supply chain management. Review methods that are comparable to those employed by Seuring and Müller (2008) and Arunachalam et al. (2018) are examples of what is now considered a conventional strategy that has been used in a great number of studies (Seuring and Gold, 2012).

2.1.Accumulation of source materials

A thorough keyword search was carried out on the ISI Web of Science (WoS) database to provide a comprehensive overview of the environmentally friendly techniques employed by the Agricultural and Food Supply Chain (AFSC). The WoS database is renowned for its extensive coverage of high-impact journals published by leading publishers such as Springer, IEEE, Elsevier, Taylor & Francis, etc., and it boasts a vast collection of articles from these and other reputable sources (Chadegani et al., 2013). The search criteria required that the articles be published between 2010 and 2017 and contain phrases such as "sustainable," "supply chain," and variations of words related to food, agri-products, agri-food, agricultural, and farm in the title or keywords. This ensured that all selected papers (n = 128 articles) had a clear connection to the sustainability aspect of the agricultural supply chain. The next step involved screening the abstracts of the chosen publications to determine their relevance to the research purpose. Twenty articles were removed, reducing the number to 108, as their primary focus was not on AFSC but rather on the agricultural supply chain. In the third stage, the number of articles was further reduced to n = 94 by eliminating those that dealt with the challenges of sustainable supply chains in animal husbandry. This was done to narrow the focus as the animal husbandry supply chain differs from the primary AFSC in terms of quality and safety parameters, certifications (Krystallis and Arvanitoyannis, 2006), and other influencing factors (Manikas et al., 2017). Finally, the authors thoroughly reviewed each of the 94 articles, resulting in the selection of 84 papers for the final review.

2.2.Descriptive analysis

2.2.1. Publication information organized by year

The number of publications on sustainable AFSC is depicted in Figure 2. A noticeable surge in papers related to this topic has been evident since 2011, indicating a growing interest among academics. In Appendix 1, it is revealed that three journals published ten or more papers, highlighting the widespread coverage of this subject across various journals with varying impact factors. The 84 papers selected for this study were drawn from 44 different journals. Analyzing the country of origin of the first authors reveals that the majority of publications originated from Italy and the United Kingdom, each contributing 13 papers, followed by the United States of America, Germany, and the Netherlands with 10, 7, and 6 contributions, respectively. Eco-friendly AFSC papers, categorized according to the study techniques used

When classifying the various publications, the writers took into consideration three different types of research methodologies: conceptual, empirical-surveys, and empirical case studies. The articles that are based on empirical surveys and empirical case studies center their attention on behaviors and procedures that are either observable or quantifiable from a sustainable AFSC perspective. In the conceptual papers, concepts, theories, and frameworks were provided, along with the advantages and difficulties of building a sustainable AFSC. Out of the 84 publications that were considered for this research, 40 of them utilized an empirical-case study strategy (which accounts for 47.6%), 28 of them were conceptually based, and the remaining 16 papers (19%) used an empirical-survey approach.

2.3. Evaluate the framework for categorization

The conceptualization of the categorization framework for our investigation is the major objective of the category selection process. The organizational components of the categorization framework are the structural dimensions and the analytic categories. In order to address the research questions that were posed by our study, we made use of four important structural dimensions:

sustainable AFSC results, degree of analytics, supply chain value, and supply chain resources.

2.3.1. The results of AFSC's efforts to ensure sustainable performance

"The management of material, information, and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e., economic, environmental, and social into account which are derived from customer and stakeholder requirements," according to Seuring and Müller (2008)'s definition of sustainable supply chain management. Elkington (1998) proposes that there has to be a focus that is balanced on the three different aspects of sustainability. This idea is known as the triple bottom line. Should any one of these three pillars of sustainability be neglected by a firm, the supply chain will become unsustainable (Govindan, 2018). As one of the three sustainable outcomes of AFSC, our research used the triple bottom-line method. The papers that were chosen for further consideration have been arranged according to social, economic, and environmental aspects of sustainability.

2.3.2. Visibility across the supply chain

"That important information is readily available to those who need it, inside and outside the organization for monitoring, controlling, and changing supply chain strategy and operations, from service acquisition to delivery" is what visibility ensures. "That important information is readily available to those who need it, inside and outside the organization" (Schoenthaler, 2003). SCV is not just the availability of the information, but also the correctness of the structure of the data, usefulness, timeliness, and the shared data. It is defined by all of these factors (Barratt and Oke, 2007). SCV is defined by Barratt and Oke (2007) as "the degree to which players within a supply chain have access to or exchange information that they regard to be essential or beneficial to their operations and that they believe will be of mutual benefit." The supply chain value (SCV) of any company can be calculated using the information that is gathered from both the upstream and the downstream activities of the supply chain. This information includes details about actual sales, delivery lead times, manufacturing, customer preferences and reactions, anticipated demand, inventory, and as well as other relevant information.

In addition, this upstream and downstream data may be arranged according to the five stages of the supply chain management process, which are the plan, source, manufacture, deliver, and return stages respectively. According to the research that has been conducted, the Internet of Things (IoT) and sensors should be used to develop virtual supply chains. These supply chains should enable partners in the supply chain to control and coordinate activities from any location without having direct physical access to the products (Verdouw et al., 2013). It is anticipated that an active virtual SCV would handle the dynamic activities of AFSC in an efficient manner (Saguy et al., 2013). A virtual SCV will provide monitoring, control, planning, and optimization of AFSC operations in real time and from distant places, therefore solving the different challenges that are associated with AFSC's capacity to maintain its sustainability (Verdouw et al., 2015). According to the findings of past research, businesses must ensure that they have visibility into both the features of the demand and the supply markets (Barratt and Barratt, 2011).

The Supply Chain Operational Reference (SCOR) model, developed by the Supply Chain Council in 2010, is considered a robust tool for evaluating supply chain performance and facilitating strategic decision-making (Hwang et al., 2008). The implementation of the SCOR model in combination with the supply chain strategy can lead to an improvement in Supply Chain Value (SCV) (Ntabe et al., 2015). The SCOR framework consists of a hierarchical structure, with level 1 comprising definitions of the five key supply chain management processes, including Source, Make, Deliver, Return, and Plan. The Source process encompasses all activities related to raw material acquisition, vendor management, and supplier evaluation. The Make process encompasses the entire production process, from procurement of raw materials to product distribution. The delivery process encompasses the transportation and distribution of finished products, while the Return process encompasses the return of finished products from customers to suppliers. The Plan process coordinates the aforementioned processes and addresses both demand and supply gaps using necessary supply chain resources (SC Council, 2008). Our research leverages the SCOR processes to assess the information demand (visibility) of the AFSC. The implementation of the SCOR framework can lead to recall management, food safety standards, supply-demand balance, improved information visibility (Lianguang, 2014), and identification of performance metrics and practices in AFSC (Pea-Orozco and Rivera, 2017). The SCOR framework can also help identify relative strengths and weaknesses, leading to increased operational efficiency in AFSC.

2.3.3. Scope of the Analytical Measures

The articles selected for further investigation were categorized into three types of analytics: prescriptive, predictive, or descriptive. The chosen taxonomy for classifying the levels of analytics, as described by Nguyen et al. (2017), is widely accepted in the research community. Descriptive analytics, as noted by Barbosa et al. (2017), is considered to be the most basic analytical approach and aims to describe and summarize past and present events through relevant information. The objective of descriptive analytics, as established by Wang et al. (2016a), is to detect issues and potential opportunities through the application of appropriate statistical methods, tools, and processes. Predictive analytics, as described by Delen and Demirkan (2013), utilizes statistical and mathematical tools to identify trends that may be forecasted based on historical data. Prescriptive analytics, which goes beyond descriptive and predictive analytics, incorporates multi-criteria decision-making (MCDM) approaches, optimization techniques, and simulation techniques.

A company can attain a competitive edge through the effective management of its supply chain resources; however, this necessitates a high level of coordination among the company's operations, its stakeholders, and its ability to share information. Managing the resources of the supply chain is a complex operation that involves decision-making processes at various levels. (Correia et al., 2017). According to the resource-based view (RBV), a durable advantage in terms of competition may be attained via the acquisition of control over supply chain resources as well as their use. The RBV continues its explanation by stating that a competitive advantage might be related to the resources and capabilities of the supply chain (Peteraf, 1993). The assets that support the activities linked to the production and distribution of products and services may be divided into two categories: tangible (e.g., physical) and intangible (e.g., organizational knowledge). These categories can be applied to the supply chain resources (Gupta and George, 2016.). The degree to which a company has been able to acquire and develop the relevant resources and competencies, on the other hand, will determine the amount to which it will be successful in gaining such an edge Rungtusanatham et al. (2003) proposed the concept of VRINN, which encompasses five key attributes of resources that enable firms to sustain a competitive advantage. These qualities are valuability, rarity, nonimitability, imperfect mobility, and non-substitutability. As revealed by previous research in the field of supply chain management, these resources can be classified into six types: human, (including technical and managerial expertise), physical, financial, organizational, intangible (such as data-driven organizational culture, brand recognition, reputation, and learning), technological, and (Braganza et al., 2017). The 84 selected publications were analyzed through a comprehensive Systematic Literature Review (SLR) categorization, as presented in Appendix II. Note that the categorization of papers in each category may overlap with others.

3. Review of the results of the data-driven sustainable agricultural supply chain

3.1.A sustainable supply chain for agri-food products

The research conducted on the AFSC's commitment to sustainability revealed that the majority of the environmental and social initiatives result in an improvement in the economic performance of the supply chain. The study found that there is a significant amount of overlap between the environmental, social, and economic components of sustainability. In order to achieve a sustainable AFSC, it is imperative to adopt a holistic approach that considers all ecological, social, and economic factors. The literature review showed that the majority of publications (92%) focused on environmental issues, followed by economic (54%) and social (51%) elements of sustainability. The results indicate that the agents involved in the AFSC do not solely concentrate their efforts on achieving social or environmental goals, but also consider financial objectives. This research revealed several key features of a sustainable AFSC that were uncovered during the investigation. These features will be discussed in the subsequent paragraphs.

3.1.1. Social sustainability in AFSC certification

The central theme of research on social sustainability with regard to small farmers is the development of a shorter supply chain as a competitive and survival strategy. The emphasis on social sustainability necessitates the shortening of the supply chain to enable farmers to actively contribute to the growth of the community and youth. Studies have revealed that efforts such as the establishment of open markets and regional food hubs have a positive impact on farmer-to-farmer communication and relationships (Berti and Mulligan, 2016). Alternative supply chains, including wholesale produce auctions through organic community-supported farming (Doernberg et al. 2016), and competitive bidding (Johnson et al., 2016), offer additional opportunities for small farmers. The major hindrances to the development of these alternative supply chains are poor land access, high rent costs, restricted processing capacities, and an unfavorable political environment. In order to achieve the social sustainability objectives of an Agricultural and Food Supply Chain (AFSC) and enhance productivity, rural development, and land conservation, it is crucial to involve small farmers in the supply chain and establish a stable institutional framework (Jelsma et al., 2017). Shukla and Tiwari (2017) recommend that AFSC decision-making should be data-driven and involve small farmers. Studies examining the implementation of alternative packaging materials in retail outlets aim to promote resource-efficient behavior among suppliers and customers and offer increased transparency (Beitzen-Heineke et al., 2017). The hotel industry and AFSC can benefit from a strengthened relationship, resulting in positive youth engagement, a social outcome of AFSC (Thomas-Francois et al., 2017a; 2017b).

3.1.2. Environmental sustainability in AFSC

The examination of environmental sustainability in AFSC was a prevalent theme in 77 out of 84 publications selected for review. The research predominantly focused on analyzing the life cycle impacts of production systems, as demonstrated by Dobon et al. (2011a, 2011b). The research can be categorized into three primary areas: carbon footprints (Miranda-Ackerman and Azzaro-Pantel, 2017), food waste (Irani and Sharif, 2016), and the impact of extended supply chains on food quality and security (Sun et al., 2017). It is imperative that AFSC member organizations implement procedures that support resource recovery from waste, as highlighted by Xia et al. (2016). Preventative measures were found to be the most effective approach to address food waste, as per Derqui et al. (2016). The majority of research on reducing food waste was focused on economic aspects, while social and environmental factors were frequently overlooked. Key challenges faced by the food security industry include increasing population, rising consumer demands, climate change, land degradation, irrigation and water scarcity, and declining production levels (Irani and Sharif, 2016). Short supply chains and the preference for locally sourced food products were found to be effective strategies for promoting urban agriculture and ensuring food quality and security (Thomson et al., 2017).

3.1.3. The capacity to maintain a healthy economy

Economic sustainability studies aim to reduce supply chain costs by exploring cost-saving solutions, including transportation and supply chain design (Musavi and Bozorgi-Amiri, 2017). These studies also consider the secondary objectives of minimizing carbon emissions, and water footprints, and increasing employment opportunities (Accorsi et al., 2016). Short supply chains and local food procurement have been identified as sustainable options that offer socio-economic benefits, health, and ecological (Ilbery and Maye, 2005). Other strategies for promoting economically sustainable agriculture food supply chains (AFSC) include collective action and revenue-sharing contracts between buyers and farmers (Yan et al., 2015), partially guaranteed prices (Tang et al., 2016), alternative packaging (Battini et al., 2016), and robust institutional arrangements among farmers (Jelsma et al., 2017).

3.2. A supply chain for agri-food that is driven by data.

The Agricultural Food Supply Chain (AFSC) is undergoing a transformation towards an increased reliance on data-driven and data-enabled practices, driven by the widespread adoption of data-enabled smart technology and sensors in agricultural operations (Wolfert et al., 2017). The prevalence of the Internet of Things (IoT) and cloud computing technologies in agricultural settings is accelerating the transition from conventional farming methods to "smart farming." (Sundmaeker et al., 2010). The resulting massive and complex datasets challenge traditional data processing tools and require new data-driven supply chains to adopt innovative data analysis methodologies and technologies for efficient data integration (Hashem et al., 2015). Despite the demand from stakeholders such as farmers, agricultural corporations, and government scientists for access to large datasets to support decision-making, there remains a lack of clarity on how these data will be understood and managed (Bronson and Knezevic, 2016). An examination of 84 articles was conducted to assess the degree of analytics employed, including descriptive, predictive, and prescriptive analytics. The findings reveal that the majority of articles (74%) utilized descriptive analytics, followed by prescriptive analytics (21%), and a small amount of predictive analytics (5%) was found to be employed in research on sustainable AFSC.

3.2.1. Descriptive and Analytical Statistics

In the majority of the 84 papers selected for evaluation, descriptive analytics was utilized to examine the sustainable AFSC (62 out of 84). The life cycle assessment was found to be the most commonly employed descriptive analytics method for addressing the environmental issues of AFSC (Peano et al., 2015). Descriptive analytics can also be useful in analyzing the overuse of resources in the combat against food waste (Xia et al., 2016). This was demonstrated in the design and implementation of alternative supply chains (Forssell and Lankoski, 2015). Several studies utilized descriptive analytics to assess the effectiveness of short supply chains employing various strategies, such as the establishment of farmer markets or food hubs (Giampietri et al., 2016), community selling (Fayet and Vermeulen, 2014), improved communication between farmers and retailers (Tsuchiya et al., 2015), and collaborative farming (León-Bravo et al (Johnson et al., 2016). Descriptive analytics was also employed in several studies to demonstrate the benefits of new technologies, such as postharvest technologies (Chimphango and Gorgens, 2015), biotechnology (Bjornberg et al., 2015), RFID (Yan et al., 2015), in improving traceability.

3.2.2. Analytical modeling and forecasting

According to Wang and Yue (2017), the utilization of predictive analytics was restricted to a mere 4% of the studies conducted. The scope of its application included the implementation of a real-time data monitoring system and the identification of potential safety hazards. Additionally, Bourlakis et al. (2014) applied predictive analytics for the prediction of sustainable performance. Furthermore, Giuggioli et al. (2016) utilized predictive analytics for the assessment of green wrapping films for fruit and vegetable packaging.

3.2.3. The use of prescriptive analytics

Approximately twenty-one percent of the selected papers employed prescriptive analytics. The majority of these research projects were based on the implementation of Multi-criteria Decision Making (MCDM) techniques. In order to optimize the supplier selection process, Allaoui et al. (2017) utilized an analytical hierarchy procedure and an ordered weighted average aggregation technique. Banaeian et al. (2018) employed TOPSIS, VIKOR, and GRA techniques along with a fuzzy setting to evaluate green vendors. MCDA techniques were also utilized in the design of a green supply chain network (Validi et al., 2014), Data Envelopment Analysis (DEA), evaluation of supply chain sustainability performance (Yakovleva et al., 2012) was utilized by Rebolledo-Leiva et al. (2017), and identification of key barriers to green supply chain management implementation (Wang et al., 2016b) to increase productivity while reducing greenhouse gas emissions associated with carbon footprint assessment. Meta-heuristics were used by Kannan et al. (2014) to determine the number of facilities and their locations and by Musavi and Bozorgi-Amiri (2017) to solve the hub location-vehicle scheduling model while considering total CO2 emissions and product perishability. Meneghetti and Monti (2015) employed a constraint programming and nonlinear optimization problem to achieve the goal of reducing the annual cost of an automated storage facility through the sustainable design of chilled automated storage and retrieval systems. Van Der Vorst et al. (2009) conducted a discrete simulation incorporating factors such as sustainability, logistics, and food quality.

3.3. Visibility across the supply chain

3.3.1. SCV throughout all of the various SCOR procedures

The study of the allocation of scientific publications in regard to decision-making data in SCOR domains reveals that the Plan area has garnered the most attention from researchers, comprising 64% of the overall distribution. The Deliver process received the second highest attention, with 25% of the articles published. The Source and Make areas, however, received relatively limited attention, with only 7% and 3% of the articles published, respectively. The investigation found that there were no scientific papers regarding the Return process. This could be attributed to the fact that agri-products are consumable items, and in most cases, there is no activity involving the return of food goods to their original source as part of a closed-loop supply chain.

3.3.2. Organizational resources

The evaluation results indicate a high level of internal integration of organizational resources that contributes to improved Supply Chain Value (SCV) during the planning process. According to Gamboa et al. (2016), the quantification of the Agricultural Food Supply Chain (AFSC) assessments is performed for environmental impact assessments utilizing organizational resources. Schmitt et al. (2017) found that organizational resources are employed to analyze the preference for local items over global products. Kaipia et al. (2013) acknowledge that information sharing impacts AFSC performance, but the effectiveness of the supply chain relies on how and for what purpose the information is utilized. Allaoui et al. (2017) observe that organizational resources are leveraged to design a sustainable AFSC network. Fayet and Vermeulen (2014) and Forssell and Lankoski (2015) report that organizational resources are utilized to help small farms secure sustainable access and establish alternative food networks. Ting et al. (2014) recognize that assuring food quality in the supply chain requires data mining resources, which are considered an intrinsic aspect of organizational competencies.

The effective utilization of organizational resources in the sourcing phase has a substantial impact on addressing sustainability issues related to managing different stakeholder levels. These challenges involve difficulties in maintaining contracts, lack of transparency in dealings, and limited involvement of sub-suppliers in the Agricultural Food Supply Chain (AFSC) (Grimm et al., 2014). The application of organizational resources in the production process enhances the Sustainable Competitive Value (SCV) by constructing a sustainable manufacturing system, reducing carbon emissions (Rebolledo-Leiva et al., 2017), and improving production output (Jelsma et al., 2017). The utilization of organizational resources optimizes the AFSC network and significantly improves the SCV of the delivery process (Musavi and Bozorgi-Amiri, 2017). Furthermore, implementing organizational resources leads to a decrease in food waste through the implementation of innovative and efficient quality solutions for sustainable distribution (Kaipia et al., 2013). To further enhance the SCV, additional measures such as the design and creation of short food supply chains (Aubry and Kebir, 2013), zero-waste grocery stores (Beitzen-Heineke et al., 2017), and the advancement of food retail practices (Chkanikova and Mont, 2015) are largely dependent on the availability of organizational resources.

3.3.3. Technological resources

Agriculture is known for its early adoption of technology to achieve economic and environmental gains (Heard et al., 2018). Björnberg et al. (2015) suggest that the Agricultural Food Supply Chain (AFSC) should prioritize researching and adopting technologies that increase agricultural productivity. Agricultural biotechnology is viewed as a potential solution to enhance food production. The use of Radio Frequency Identification (RFID) technology has been shown to minimize losses during the transportation of agricultural commodities (Yan et al., 2015). Big data is considered a valuable information technology tool for the AFSC that can be used to understand customer preferences and provide the desired product qualities (Ahearn et al., 2016). The AFSC's ability to recall previous information is critical, as it allows for tracking the origin of goods and increasing supply chain visibility. Technical resources, such as post-harvest technology, play a vital role in enhancing the visibility of the production phase (Chimphango and Görgens, 2015). Real-time data monitoring systems, facilitated by technological resources, are imperative for improving the visibility of the delivery process. The arrival of autonomous vehicles is predicted to have a substantial impact on the supply chain in the future (Heard et al., 2018).

3.3.4. Physical resources

The impact of physical resources on the enhancement of Supply Chain Value (SCV) and Direct Agricultural Chain (DAC) was found to be more pronounced in the production and delivery phases. Yan et al. (2015) proposed a sustainable manufacturing system that requires reduced usage of labor, water, fertilizers, and pesticides and operates within a controlled environment that includes cultivation methods, water supply, carbon dioxide, humidity, temperature, and artificial light. In the delivery phase, the development of refrigerated automated warehouses for sustainable food supply chain (Meneghetti and Monti, 2015), physical resources play a role in the establishment of regional and the choice of packaging solutions (Battini et al., 2016), local food hubs (Berti and Mulligan, 2016).

3.3.5. Human resources

The significance of human capital cannot be overstated in elevating the prominence of the AFSC planning zone. The support and attitude of human resources towards sustainable development initiatives are crucial elements in promoting sustainability (Emamisaleh and Rahmani, 2017). It is imperative to consider the views and perspectives of human resources regarding various AFSC aspects, such as trade-off evaluations in integrated assessments and the integration of agriculture with tourism (Sun et al., 2017) during the planning process. Building a sustainable and conserved local AFSC requires trust between individuals and compliance with standards (Smith, 2008). Through the formation of partnerships, discussions, and collaborations among stakeholders, human resources enhance the visibility of improvement in the source area (Castro and Swart, 2017). In the production phase, human resources contribute to heightened visibility through the creation of institutional support for farmers. It is recommended that small farmers engage in supply chains to boost production, thereby advancing rural development and land preservation (Jelsma et al., 2017).

3.3.6. Financial resources

The main goal in constructing Agricultural and Food Supply Chain (AFSC) networks has been to achieve financial gains. However, it is advised to prioritize reducing carbon or greenhouse gas emissions instead of just focusing on cost and service quality (Accorsi et al., 2016). In order to achieve more sustainable outcomes, companies need to invest extra resources, thus attracting private investments is crucial to address environmental issues (Rueda et al., 2017). In the sourcing phase, partially binding agreements between growers and purchasers are viewed as a mutually advantageous solution for both sides (Tang et al., 2016).

3.3.7. Intangible resources

The intangible resources that contribute to increased visibility of the plan area encompass external drivers and factors that influence consumer demands and expectations. Emamisaleh and Rahmani (2017) found that external drivers of companies have an impact on internal drives. There is a growing trend of consumers and companies prioritizing sustainability in their Agricultural Food Supply Chain (AFSC) and reducing the environmental impact of fuel, feed, fiber, and food production (Rohm et al., 2017).

The significance of intangible elements, such as the strong dependence of developing nations on tourism for economic development and the requirement to fortify the connection between agriculture and tourism for optimal financial gain, is a vital component of sustainable Agricultural Food Supply Chain (AFSC) research (Thomas-Francois et al., 2017). The AFSC should take into account intangible benefits when constructing supply chain networks to tackle socio-economic challenges such as joblessness, low income, food insecurity, and poverty. The utilization of big data will be essential in comprehending customer requirements and adapting accordingly (Ahearn et al., 2016). The use of intangible resources to improve source process transparency prompts companies to explore new possibilities. The literature highlights the difficulties of food security, agricultural product traceability, and customer willingness to pay for traceable agriculture (Sun et al., 2017). Studies on wholesale auctions, where customers can directly interact with farmers, can aid in alternative food systems (Johnson et al., 2016).

3.4. Review findings summary

3.4.1. Long-term, sustainable results of AFSC's performance

The evaluation findings indicate that the social performance of the Agricultural and Food Supply Chain (AFSC) is deeply interconnected with the well-being of farmers and rural communities. In light of the poor socioeconomic conditions, it is unrealistic to expect optimal performance from the farmers. The AFSC's social sustainability performance is assessed based on its ability to empower farmers to promote youth development, establish strong rural social infrastructure, develop adaptive rural communities, create attractive farming livelihoods, and create employment opportunities. The extent of natural resource conservation during the production, distribution, and consumption of farm produce is used as a metric to evaluate the AFSC's environmental sustainability performance. The evaluation takes into consideration crucial performance factors such as greenhouse gas emissions, water usage, energy savings, food quality, and food waste. The economic sustainability performance of the AFSC is achieved when the company is managed in a manner that ensures its long-term profitability. However, a company's goal should not be limited to achieving profits annually but should focus on improving productivity, reducing operating expenses, and increasing yields.

3.4.2. Visibility across the supply chain

The findings demonstrate the cruciality and benefit of collecting and exchanging information for the Agricultural Food Supply Chain (AFSC) to maintain its competitiveness in addressing issues such as food perishable nature, demand and supply fluctuations, safety, and sustainability. An elevated Supply Chain Value (SCV) across all domains of the Supply Chain Operations Reference (SCOR) model enables firms to gain visibility on various planning and operational elements of the AFSC, including physical item movement, inventory management, network design challenges, and process transparency. The review indicates that a high SCV leads to an improvement in both the Direct Agricultural Chain (DAC) and the overall performance of the AFSC. However, the extent of performance enhancement will depend on the collection and sharing of relevant, helpful, and high-quality data through SCOR practices. The study also shows that various supply chain resources are utilized to enhance the SCV and DAC.

3.4.3. Resources that are integrated across the supply chain

The results indicate that organizational resources play a role in the collection of the vast quantity of data, information, and knowledge that is accessible as a result of better visibility in various SCOR processes. This was discovered by looking at the findings. It is expected that the companies would be able to generate value using these organizational resources. The technical resources include the need for inter-organizational systems, enterprise resource planning (ERP) systems, RFID and sensor technologies, and sophisticated data storage systems. The term "human resources" refers to the human talents that are necessary for doing data analysis and also for carrying out analysis of the data that has been acquired from them. Employing highly qualified data scientists for the analysis and administration of data is essential for a company that wants to improve its capabilities in the area of human resources. When discussing the SCOR model, "physical resources" most often relate to the "make" and "delivery" processes. It entails the utilization of any and all physical resources that are required for the transportation of both raw materials and finished commodities. The scope of this purchase includes storage equipment, transport vehicles, and material handling types of equipment. Intangible resources are the quality of an organization's relationships and communications with its clients and other stakeholders, such as shareholders. These resources are related to the capacity of the company to gather information from consumers and utilize that information to generate new goods and services or alter the ones that are already on the market. The term "financial performance" refers to the consequence of the data analysis skills that were ultimately intended. There is a possibility that these are short-term financial advantages, which may or may not have an effect on the organization's overall economic viability.

3.4.4. Data analytics capabilities

A more robust Direct Agricultural Chain (DAC) is achieved through the integration of supply chain resources and expanded supply chain visibility. This term denotes the outcome of internal integration, resulting from a network of interconnected systems and processes that facilitate decision-making procedures (Schoenherr and Swink, 2012). Internal integration predominantly involves the alignment of data and information systems, defining the way a company "organizes its organizational practices, procedures, and behaviors into collaborative, synchronized, and controllable processes." (Zhao et al., 2011). The data analytic capability of the company is a direct result of the manner in which the company's various functional areas have collaborated with one another and of the efficiency with which the company's various resources have been deployed, which has led to the alignment of organizational goals and performance outcomes (Schoenherr and Swink, 2012).

4. Implications for management and the whole application architecture

4.1.Implications stemming from the results of the review

As per the findings of the mentioned study, various research approaches and analytics levels, including descriptive, predictive, and prescriptive analytics, are employed in evaluating sustainability challenges in Agricultural Food Supply Chains (AFSC). To be more specific, the assessment revealed that achieving sustainable performance necessitates a high level of Supply Chain Visibility (SCV) and the integration of the company's resources. According to the results, supply chain visibility and the resources available inside the supply chain are the antecedents of DAC that contribute to sustainable supply chain performance. As a result, it is indicated that the organization's strategy for information collecting should be based on whatever sustainable objectives are required to be realized by the AFSC (Zhu et al., 2018). The information is created from several processes throughout the supply chain, including planning, sourcing, manufacturing, delivering, and receiving returns. The managers need to determine which processes will contribute significantly to the achievement of a sustainable AFSC performance and then pick those procedures. For instance, if the company wants to reduce the total carbon footprints caused by its supply chain, it will want to conduct an analysis of the data collected during the manufacturing and delivery processes, specifically the parts of those processes that deal with the activities of food processing and transportation. As a result, it would be necessary for the organization to have a high level of visibility for each of these SCOR regions.

Furthermore, the evaluation conclusions indicate that management should analyze the current Supply Chain Visibility (SCV) and make enhancements if deemed insufficient to achieve performance goals. In such situations, leveraging available resources within the supply chain becomes crucial for improving both SCV and the Direct Agricultural Chain (DAC). It is necessary, as a result, for the managers to convey to all of the supply chain's partners and stakeholders the relevance of achieving a high SCV in the process of developing the DAC. The major objective of maintaining high visibility is to facilitate the collection and distribution of data within the AFSC.

On the other hand, the DAC of the company is the one that extracts the information and knowledge from the data that is accessible. As a result of the information being spread across the supply chains, the DAC necessitates the use of a variety of the company's resources, including organizational, technical, financial, physical, intangible, and human resources. As a result, we feel it is important to bring to the notice of managers the need to integrate all of the resources that are now accessible in order to derive relevant interpretations from the data that has been gathered by this research. The managers have to strive to build strategies that integrate visibility and resources in such a way that they are compatible with one another. For the purpose of obtaining a high degree of integration and accomplishing the sustainable goals for increased transparency and monitoring of agro-food products in the supply chain, new technical resources such as blockchain may be leveraged by managers.

In light of the results presented here and the related implications, we would like to suggest an application framework that will be known as the data-driven AFSC framework. For the purpose of creating DAC and improving sustainable performance, the suggested framework will direct practitioners in making decisions on the suitable methodology, degree of analytics, data correctness, and usage of relevant supply chain resources. The framework is comprised of four primary aspects, including DAC, sustainable performance, supply chain value (SCV), and integration of supply chain resources. Within the context of this architecture, we conceive DAC as "the capacity to deploy resources to complete analytics job, depending on the interaction between IT assets and other company resources" (Cosic et al., 2015). In the event that the DAC is not present, the organizations will be unable to take full use of the opportunities presented by the SCV advantages. According to Schoenherr and Swink (2012), there is a need for cooperation across the many functional areas of the company in order to ensure that the business is aligned with the aim of the organization and that performance is enhanced. The internal integration that was accomplished via integrated systems and procedures that allowed for enhanced decision-making was the cause of the successful partnership that resulted.

4.2.The advantages of using an application framework

An AFSC is considered to have a sophisticated performance management system, encompassing the following processes: I Establishing the criteria for measuring performance ii) Establishing goals and objectives; iii) Planning; iv) Communicating with partners in the supply chain; v) Tracking and evaluating progress; and vi) Reporting and providing feedback.

If the DAC is used and effectively deployed, it has the potential to enhance the effectiveness of the SCOR processes, hence offering great commercial value to the businesses. Because of this, it is imperative that the organizations put significant resources into creating the DAC. It is necessary to make investments in the different supply chain resources that will boost the SCV and DAC. These investments should be made as soon as possible. The framework that has been provided may be useful in assisting with decisions on expenditures to be made on various supply chain resources and the visibility dimension that should be focused on. The DAC is responsible for the collecting of data, the aggregation of that data, the analysis of that information, and the communication of that information with decision-makers. The companies need to make sure that the DAC and the data requirements are in sync with one another. The more difficult the choice that has to be taken, the more detailed the information requirements will need to be. The use and management of various supply chain resources, including organizational, physical, technical, financial, and human resources, all have a role in determining the level of information visibility. The organization has to determine the amount to which the information will contribute to the AFSC's sustainable outcomes, as well as the sections of the supply chain (plan, source, manufacture, and deliver) from which the information will be gathered. Any kind of disparity between the DAC and SCV (information sources) could not contribute to the outcomes that you want. If the SCV is lower than what was anticipated, the companies will not be able to reach their performance goals. On the other hand, if the company has a SCV that is more than what is necessary, the performance goals will be reached in an inefficient manner. Having a supply network volume that is more than what is required may raise the DAC, but it also encourages a high consumption of supply chain resources, which leads to larger investments.

It is common knowledge that supply chains have varying requirements based on the stages of development they have reached; as a result, it may be challenging to suggest a one-size-fits-all solution that will be effective in all circumstances (Cadez and Guilding, 2008). Within the confines of our application framework, it is not possible to use a single, ideal method for the distribution of supply chain resources. The application framework, on the other hand, may direct the AFSCs in the direction of finding the major SCOR areas that increase information visibility and supply chain integration. On the other hand, the AFSCs are obligated to rank the importance of their performance results.

Furthermore, we propose that Agricultural Food Supply Chains (AFSCs) utilize the Supply Chain Maturity Model (SCMM) to assess their maturity level (de Oliveira et al., 2012). With this information, they can set performance goals and decide where to allocate supply chain resources in the SCOR regions. The SCMM is a process-based approach that highlights the importance of information as a key factor for success. Table 3 presents the various stages of the SCMM, each of which is explained in greater detail below.

According to de Oliveira and colleagues (2012), the capabilities of an organization in terms of SCV and data analytics are determined by the maturity level of its supply chain. Based on their research, it is recommended that investments be made step by step in order to develop BDAC in the various SCOR regions, as shown in Table 4.

A decision-making framework for changing the conventional AFSC into a data-driven AFSC with sustainable aims is provided by the suggested application framework, which makes a contribution to the existing body of research.

5. The results of the investigation, as well as its limitations

The current investigation bridges substantial gaps in the academic literature by offering noteworthy perspectives on the sustainable results gained through a data-driven Agricultural and Food Supply Chain (AFSC). It examines the role of supply chain resources in the formation of the Direct Agricultural Chain (DAC) and the supply chain methods that provide a high level of supply chain visibility. Furthermore, the research determines which supply chain assets are utilized in the development of DAC. The study, which was based on a comprehensive analysis of 84 previous research publications, contributes to the advancement of the body of knowledge by filling in the information gaps that were previously discovered. According to the conclusions of the assessment, a data-driven AFSC works toward the achievement of economic sustainable performance, and environmental, and social objectives. According to the findings of our research, the data included in an AFSC is compiled using information from each of the four processes that make up a supply chain. In contrast to the process of sourcing and manufacturing, the supply chain procedures of "plan" and "deliver" contribute much more to the development of DAC. It was discovered that the AFSC utilizes a variety of supply chain resources for the purpose of data collecting and analysis. In order to construct the DAC, the data-driven AFSC relied more on the organizational and technical resources available to it. The research also emphasizes the growing significance of both people and physical resources in the process of improving the SCV. We suggest an application framework that, on the basis of the results of the research, identifies the supply chain value (SCV) and the integration of supply chain resources as the primary antecedents in the development of a strong DAC, which, in turn, leads to the attainment of the sustainable AFSC. The results of this study might provide a basis for further investigation by both academics and professionals in the field. It is possible that the researchers will want to take into account the major aspects mentioned in the framework and verify them statistically in a variety of AFSC settings. The practitioners may choose to concentrate on the development of technologies that will improve SCV as well as the identification of resources that may contribute to the consolidation of the data analytics skills necessary to achieve the AFSC's needed level of sustainable performance.

The authors acknowledge limitations in the conducted research. Although a comprehensive literature search was performed using the WoS database to identify relevant articles, it is possible that certain studies were overlooked. This is due to the nature of the comprehensive review. The authors' interpretation of the selected articles serves as the foundation for both analysis and synthesis. Efforts were made to mitigate these limitations through independent cross-checking of the publications, thereby addressing the issue of embedded bias. However, it must be noted that errors may still have occurred.

6. Conclusion

In conclusion, the incorporation of advanced technologies, including the Internet of Things, blockchain, and big data, is gaining popularity and holds the potential for the establishment of sustainable supply chains. The shift towards a data-driven digital environment in the agricultural supply chain is propelled by these technological advancements. Our findings contribute a practical framework for professionals in the agri-food supply chain, emphasizing the significance of supply chain visibility and resources in fostering the development of data analytics and sustainable performance. This framework acts as a guide for professionals to strategically allocate investments toward building a robust, data-driven agri-food supply chain.

Acknowledgment

We thank the worthy reviewers for their comments on improving the quality of the manuscript.

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