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Review

Achieving sustainable performance in a data-driven agriculture supply chain: A review for research and applications

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A R T I C L E I N F O

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A B S T R A C T

The lack of industrialization, inadequacy of the management, information inaccuracy, and inefficient supply chains are the significant issues in an agri-food supply chain. The proposed solutions to overcome these challenges should not only consider the way the food is produced but also take care of societal, environmental and economic concerns. There has been increasing use of emerging technologies in the agriculture supply chains. The internet of things, the blockchain, and big data technologies are potential enablers of sustainable agriculture supply chains. These technologies are driving the agricultural supply chain towards a digital supply chain environment that is data-driven. Realizing the significance of a data-driven sustainable agriculture supply chain we extracted and reviewed 84 academic journals from 2000 to 2017. The primary purpose of the review was to understand the level of analytics used (descriptive, predictive and prescriptive), sustainable agriculture supply chain objectives attained (social, environmental and economic), the supply chain processes from where the data is collected, and the supply chain resources deployed for the same. Based on the results of the review, we propose an application framework for the practitioners involved in the agri-food supply chain that identifies the supply chain visibility and supply chain resources as the main driving force for developing data analytics capability and achieving the sustainable performance. The framework will guide the practitioners to plan their investments to build a robust data-driven agri-food supply chain. Finally, we outline the future research directions and limitations of our study.

1. Introduction

There is increased awareness and growing concern for environmental, social, and economic effects on food production and consumption. This has led to increasing pressure from consumer organizations, social and environmental advocacy groups, agro-based organizations and policymakers to develop sustainable supply chains (Allaoui et al., 2017). The current consumption patterns and ever-increasing population poses severe concerns on the agri-food supply chain (AFSC) (Network, 2012). The sustainable outcome of an AFSC is based on achieving a balance between economic growth, environmental protection, and social development. The main difference between a consumer supply chain and the AFSC is that the raw materials in AFSC are grown using different agricultural practices, and both the human and animals consume the final products. However, both the supply chains have suppliers, focal companies, customers, logistics and distribution networks, and retailing centers as their principal components (Miranda-Ackerman and Azzaro-Pantel, 2017). Since the world summit on sustainable development, there have been many initiatives for sustainable development in different sectors (Van Huijstee et al., 2007). The agriculture sector has received the highest prominence among these sectors for achieving sustainable growth with the focus on adopting best management practices in agriculture and farming, and improvements in the social and ecological conditions (Potts et al., 2014; Castro and Swart, 2017; Dentoni and Peterson, 2011). The significant issues that need to be addressed to achieve sustainable AFSC are lack of involvement of the small farmers, lack of stringent norms to control food safety and quality (Naik and Suresh, 2018), lack of industrialization, the inadequacy of the management, and information inaccuracy (Luthra et al., 2018).

The emerging solutions to overcome these challenges should not only consider the way the food is produced but also take care of the

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societal concerns, environmental concerns, food safety and quality requirements, and economic viability. Further, these solutions should not be limited to agricultural production but cover the entire supply chain that includes food processing, packaging, distribution, and consumption (Donald, 2008; Charles et al., 2010). One of the primary focus areas in sustainability is the cooperation between the various supply chain members and the significant challenges that hinder achieving sustainable outcomes. There has been increasing use of new emerging technologies in the AFSCs which helps in improved supply chain decision making. In the recent past, we have seen emerging technologies bringing a significant impact on the supply chain sustainability (Kamble et al., 2018). Technologies such as the internet of things (IoT) supports collection and sharing of information in real-time. IoT has the potential to augment the sustainability of the AFSC through improved communication, coordination and cooperation between nodes of the supply chain (Ahumada and Villalobos, 2009). IoT and sensor technologies have been found useful in reducing the demand-supply gap and addressing the issue of food quality and security (Wang and Yue, 2017; Zhong et al., 2017). The voluminous data generated by the IoT can be analyzed by using big data analytics that may help in identifying the weaknesses of the AFSC (Verdouw et al., 2016). Blockchain technology also promises to be a significant enabler of a sustainable agriculture supply chain (Sharma et al., 2018). All these emerging technologies are driving the traditional AFSC towards a digital supply chain environment that is data-driven. With this transformation, it becomes necessary for the organizations to achieve a high level of supply chain visibility (SCV) making the required information readily available to the decision makers for developing sustainable supply chain strategies. In the literature there are few studies that have reviewed the dimensions of AFSC sustainability, which include developing perspectives on food waste and information (Irani and Sharif, 2016), identifying the drivers, barriers and indicators of sustainable supply chain performance (Govindan, 2018), understanding the dynamic capabilities of food industry (Beske et al., 2014) and collaborative behavioral factors (Dania et al., 2018). The massive and rich data that is generated in the data-driven AFSC may bring enormous challenges that include data collection, data storage, data visualization and information sharing that needs to be addressed by developing new data-driven decision models and frameworks (Zhong et al., 2017).

However, the literature on sustainable AFSC lacks decision-making or application frameworks that can help the academicians and practitioners to understand how sustainable performance can be achieved in a data-driven environment. The existing literature on AFSC lacks information on the critical components of data analytics capability (DAC) and the impact it has on sustainable performance. More information is required to understand the level of analytics used (descriptive, predictive and prescriptive), sustainable agriculture supply chain objectives attained (social, environmental and economic), the supply chain processes that contribute in developing the information visibility, and the supply chain resources used for data collection, analysis and sharing across the AFSC. More specifically, the study attempts to seek information to the following research questions (RQ):

RQ1. What sustainable performance outcomes are achieved by AFSC?

RQ2. What level of data analytics drive these sustainable outcomes?

RQ3. Which supply chain resources are deployed to develop the DAC of the AFSC?

RQ4. Which supply chain processes delivers high information visibility in an AFSC?

RQ5. How the supply chain resources, information visibility, DAC are linked together to in a sustainable AFSC?

A systematic review is conducted to investigate the landscape of state-of-art literature on the linkages between a data-driven AFSC and sustainable performance, guided by the above research questions. To this effect, we have employed theoretical lenses of resource dependency and the content analysis approach for analyzing the above research questions. Subsequently, the results of the above RQs are used to develop an application framework for data-driven sustainable AFSC that integrates the concepts of supply chain resources, SCV, DAC, and sustainable performance. The application framework will be highly useful for the AFSC practitioners to plan their investments to transform the existing AFSCs into a data-driven sustainable AFSC. The remainder of the paper is structured as follows: section 2 presents the review methodology. The review discussions are presented in section 3. Section 4 presents the implications for practitioners and proposed application framework for data-driven sustainable AFSC. The directions for future research are given in section 6, and section 7 presents the conclusions and limitations of the study.

2. Review methodology

The topic sustainable AFSC selected for the review is quite abstract and therefore, analyzing the published literature and considering them as the primary source of material was felt more effective (Jauch et al., 1980; Beske et al., 2014). As the objective of the study was to review the present status of literature in the area of sustainable AFSC, we conducted a systematic literature review combined with content analysis as proposed by Mayring (2003). The applied methodology used a four-step iterative process that consisted of: (i) material collection, (ii) descriptive analysis, (iii) category selection, and (iv) material evaluation. The dimensions and analytic categories used for classifying the contents in this approach could be derived deductively or inductively, allowing traceability and inter-subject verifiability as compared to other qualitative interpretive methods (Seuring and Gold, 2012). The dimensions and analytic categories used in our review process were derived from the existing supply chain management literature before analyzing the content from the selected papers. Similar review approaches were used by Seuring and Müller (2008), Kannan et al. (2014), Gao et al. (2016), and Arunachalam et al. (2018) and by now is a traditional approach which has been applied in many papers (Seuring and Gold, 2012).

2.1. Material collection

To have holistic coverage of all the possible sustainable practices in AFSC a structured keyword search was conducted on the ISI Web of Science (WoS) database. The WoS database has a rich collection of publications like Springer, IEEE, Elsevier, Taylor, and Francis, etc., and is known for its comprehensive coverage of high impact journals published in English language (Chadegani et al., 2013) The basic search criteria included that the papers were published during the year 2010–17. The following keywords were searched to be in title or keywords: "sustainable," "supply chain," and an alternation between "food," "agri-products," "agri-food," "agriculture," and "farm." This ensured that at the first level all the selected papers (n = 128 papers) had an established link between the various dimensions of sustainability and agriculture supply chain. In the second level, the abstracts of the selected papers were reviewed for its relevance to the scope of the study. Twenty papers were excluded with the number of papers reducing to 108, as they were more focused on the agriculture supply chain and not AFSC. In the third level, the reduction in papers (to n = 94) was achieved by excluding the papers that dealt with the sustainable supply chain issues in animal husbandry (meat, wool, dairy, fish, etc.). This specific exclusion criterion was applied as the animal husbandry supply chain relates to "*the branch of agriculture that deals with the animals that are raised for meat fiber, milk, eggs, etc., and includes day to daycare, selective breeding and raising of livestock*" (Wikipedia, n. d) and differed from the primary AFSC in terms of the required quality and safety parameters, mandatory certifications (Krystallis and Arvanitoyannis, 2006) and other influencing factors in decision making such as

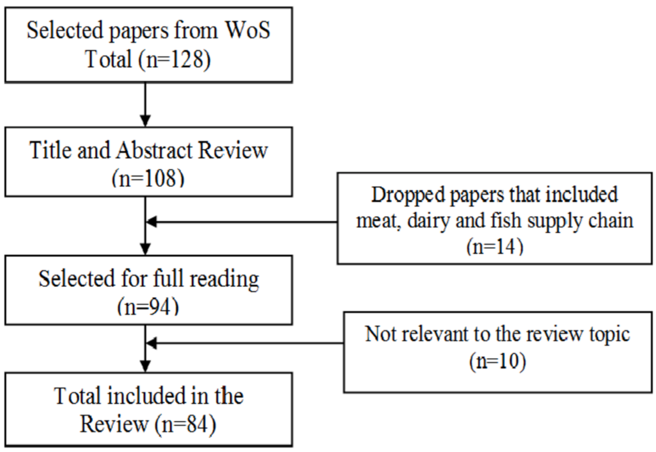

Fig. 1. Article selection process.

consumers religion and culture (Manikas et al., 2017). In the fourth level, the 94 papers were subjected to full reading by the authors resulting in the selection of 84 papers for the final review.

Further, other research papers dealing with the concepts of sustainable AFSC, cited within the selected 84 papers were also referred to get detailed insights on the topic. This snowball analysis assured that valuable knowledge within the scope of our RQs was captured from the papers not selected through our search process. Most of the articles selected for final review were obtained from the *International Journal of Production Economics (13%), Journal of Cleaner Production (13%)* and *Sustainability (12%)*. The detailed journal wise distribution of the selected 84 articles is presented in appendix 1. The planned selection process of the papers is presented in Fig. 1.

2.2. Descriptive analysis

2.2.1. Year wise publication details

Fig. 2 indicates that the number of papers published on the topic of sustainable AFSC. The trend in the publications on sustainable AFSC suggests increasing attention from researchers on this topic since 2011. The selected 84 papers are from 44 different journals, in which only three journals published ten or more papers (See Appendix 1), indicating that this topic is covered in a great variety of journals and has attracted the interest of journals with high impact factors. Further, the first authors' country affiliation reveals that majority of the publications originated from Italy and United Kingdom (thirteen papers each) followed by USA, Germany, and the Netherlands with ten, seven and six contributions respectively.

2.2.2. Sustainable AFSC papers based on the type of research methods

The authors considered three research methodologies for classification of selected papers: conceptual, empirical-surveys and empirical-case studies. The papers based on empirical-surveys and empirical-case studies are focused on visible or measurable sustainable AFSC practices and processes. The conceptual papers presented ideas, theories, frameworks, benefits and challenges in achieving a sustainable AFSC. From the selected papers 84 papers, 40 papers (47.6%) used empirical-case study approach, 28 papers (33.33%) were conceptually based and remaining 16 papers (19%) used empirical-surveys.

2.3. Review classification framework

The primary purpose of the category selection is to conceptualize the classification framework for our research. Structural dimensions and analytic categories support to organize the classification framework. Four critical structural dimensions were used to answer the research questions raised in our study: sustainable AFSC outcomes, level of analytics, SCV, and supply chain resources.

2.3.1. Sustainable performance outcomes of AFSC

Seuring and Müller (2008) define sustainable supply chain management as "*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.*" Referred to as the triple bottom line, Elkington (1998) suggests that there has to be a balanced focus on the three sustainability dimensions. An organizations failure to perform on any one of these three pillars of sustainability will make the supply chain unsustainable (Govindan, 2018). In our study, we have used the triple bottom line approach as the three sustainable outcomes of AFSC. The selected papers have been classified on social, economic and environmental dimensions of sustainability.

2.3.2. Supply chain visibility

Visibility ensures "*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*" (Schoenthaler, 2003). SCV is not only the availability of the information, but is also determined by the accuracy of the shared data, timeliness, usefulness and the structure of the data (Barratt and Oke, 2007; Bailey and Pearson, 1983; Gustin et al., 1995; Mohr and Sohi, 1995). Barratt and Oke (2007) define SCV as "*the extent to which actors within a* supply chain *have access to or share information which they consider as key or useful to their operations and which they consider will be of mutual benefit.*" The SCV for any firm is achieved from the information being collected from the downstream and upstream activities of the supply chain and includes data related to the actual sales, forecasted demand, customer preferences, reactions, inventory, manufacturing, and delivery lead times, etc.

Moreover, these downstream and upstream data can be categorized in the five areas of supply chain management processes namely: plan, source, make, deliver and return. Literature suggests developing virtual

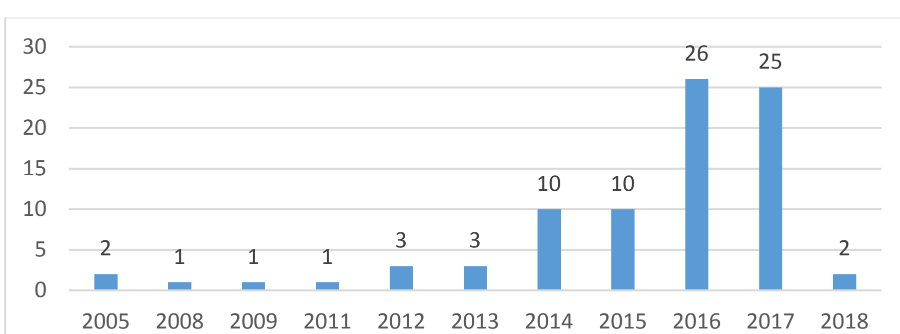

Fig. 2. Year-wise distribution of papers.

supply chains using IoT and sensors that can support the supply chain partners to control and coordinate from any location without having any physical access to the products (Verdouw et al., 2013; Verdouw et al., 2016). An active virtual SCV is expected to manage the dynamic operations of AFSC effectively (Saguy et al., 2013; Porter and Heppelmann, 2014; Verdouw et al., 2015). A virtual SCV will support monitoring, control, planning and optimization of AFSC processes in real-time, from remote locations thus addressing the various issues of AFSC sustainability (Verdouw et al., 2015). The previous studies reveal that both the visibility of demand and supply characteristics are required by the organizations (Barratt and Barratt, 2011).

The Supply Chain Operational Reference (SCOR) (Supply Chain Council, 2010) is considered as one of the rigorous supply chain performance evaluation and strategic decision-making tool (Hwang et al., 2008; Zangoueinezhad et al., 2011). When aligned with the supply chain strategy, the SCOR model improves the SCV (Ntabe et al., 2015). The level 1 of the SCOR hierarchical structure consisting of the definitions of the five supply chain management processes. The four processes viz., *Source, Make, Deliver, and Return* represents the information and physical flow, and are coordinated by the *Plan* process (Huang et al., 2005; Hwang et al., 2008; Kasi, 2005; SC Council, 2008). The source process represents all the activities and processes about the procurement of raw material, vendor management, and supplier evaluations. All the operations that are performed during the transforming of raw material into the finished products are included in the make process. All the activities concerned with the transportation and distribution of finished products are included in the deliver process, and the activities performed while returning the product to suppliers from customers is included in the return process. The demand and the supply gaps, with the use of appropriate supply chain resources, are addressed by the plan process (Persson, 2011). In our study, we use the different SCOR processes for assessing the information requirement (visibility) of the AFSC. Furthermore, the literature reports the use of SCOR framework to manage the AFSC performance management. SCOR is usually associated with the use in manufacturing industries. However, the researchers suggest that the modern data-driven agriculture supply chain is highly comparable with a production based system, incorporating the activities related to planting, breeding, processing, production, transportation, and delivery (Lianguang, 2014; Ahoa et al., 2018). SCOR framework can be used to improve information visibility, supply-demand balance, food safety standards, recall management (Lianguang, 2014) and identify performance metrics and practices in AFSC (Ahoa et al., 2018). Ahoa et al. (2018). SCOR framework is a useful tool to identify relative strengths and weaknesses, to improve the operational efficiency of AFSC (Hossain and Jahan, 2015; Weerabahu and Nanayakkara, 2015; Ramos et al., 2018; Peña-Orozco and Rivera, 2017).

2.3.3. Level of analytics

The selected papers were classified in three analytic categories viz., descriptive, predictive and prescriptive analytics. The chosen taxonomy for the level of analytics has been widely adopted in the literature (Wang et al., 2016a; Barbosa et al., 2017; Nguyen et al., 2017). Descriptive analytics is considered the most straightforward analytical technique with the purpose to describe and summarize the past and the present events in meaningful information (Barbosa et al., 2017). Descriptive analytics deals with the identification of problems and opportunities using necessary statistical tools and techniques (Wang et al., 2016a). Predictive analytics uses statistical and other mathematical methods to find predictive patterns based on past historical data (Delen and Demirkan, 2013). The prescriptive analytics uses multi-criteria decision-making (MCDM) techniques, optimization, and simulation techniques and goes way beyond the descriptive and predictive analytics.

2.3.4. Supply chain resources

A firm's competitive advantage is an outcome of efficient management of supply chain resources and requires high coordination between the firm's activities, information sharing capability, and its stakeholders. Managing the supply chain resources is a complex activity and involves decision-making processes at various levels (Reefke et al., 2014; Correia et al., 2017). As per the resource-based view (RBV), the sustainable competitive advantage can be achieved through the acquisition of, and control over supply chain resources. The RBV further explains that the supply chain resources and capabilities are associated with a competitive advantage (Wernerfelt, 1984; Barney, 1991; Peteraf, 1993). The supply chain resources can be categorized into tangible (e.g., physical) and intangible (e.g., organizational knowledge) assets that support the activities related to production and delivery of goods and services (Penrose, 1959; Grant, 1991; Amit and Schoemaker, 1993; Gupta and George, 2016.). However, the achievement of such an advantage is determined by the extent to which the organization has acquired and developed these resources and capabilities (Barney, 1991). Barney (1991), Peteraf (1993) and Rungtusanatham et al. (2003) identified five characteristics of resources, referred VRINN (valuable, rare, not imitable, imperfectly mobile and not substitutable), these resources support the firms in achieving a sustainable competitive advantage. In the supply chain management literature these resources are classified in six types namely: financial, physical, human (managerial and technical skills), organizational, technological and intangible (reputation, brand recognition, data-driven culture, and organizational learning) (Braganza et al., 2017). The detailed SLR classification for the selected 84 papers is presented in Appendix II. The papers presented in each category are not necessarily mutually exclusive.

3. Review findings on data-driven sustainable agriculture supply chain

3.1. Sustainable agri-food supply chain

The literature on AFSC sustainability suggests that the majority of the environmental and social initiatives result in the enhanced economic performance of the supply chain. There exists a considerable overlap between the environmental, social, and economic sustainability dimensions. The findings suggest that a balanced approach incorporating ecological, social, and economic performance is required to achieve sustainable AFSC. Our study reveals that the environmental concerns have received more attention in the literature (92%, 77 out of 84 papers), followed by economic (54%, 46 out of 84 papers) and social (51%, 43 out of 84 papers) sustainability dimensions. The findings indicate that the various agents involved in the AFSC have not solely focused on attaining social or environmental goals, neglecting the financial objectives. The multiple aspects of sustainable AFSC that emerged from our review are discussed below.

3.1.1. Social sustainability in AFSC

Development of shortened supply chain as a competitive and survival strategy for the small farmers was found to be the central theme of research for the papers dealing with social sustainability. The short supply chain facilitates the high involvement of farmers in the supply chain, community development, and youth development. The initiatives such as the development of open markets and regional food hub are found to have a positive influence on the farmer's communication skills and interpersonal relations (Chiffoleau et al., 2016; Giampietri et al., 2016; Berti and Mulligan, 2016). Few studies identified that the alternative supply chain, such as wholesale produce auctions through competitive bidding (Johnson et al., 2016), an organic community supported farming (Doernberg et al., 2016), and focusing on local products (Schmitt et al., 2016) provide more opportunities for the farmers. However, the literature identifies issues such as inadequate access to land, high rentals, limited processing capacity, and hostile political environment as the significant challenges to develop alternative supply chains. The inclusion of the small farmers in the supply chain and providing a robust institutional arrangement is highly essential to achieve social sustainability goals of an AFSC leading to increased productivity, rural development and land sparing (Jelsma et al., 2017). Shukla and Tiwari (2017) recommend that the decisions in AFSC should be data-driven and involve the small farmers. Other studies dealt with the use of alternate packaging material at the retail stores for inducing resource-efficient behavior in both suppliers and consumers, and also support the social benefits by providing higher transparency (Beitzen-Heineke et al., 2017). Youth involvement, as a social outcome of AFSC, can be improved by developing the linkages between the hotel industry and AFSC (Thomas-Francois et al., 2017a, 2017b).

3.1.2. Environmental sustainability in AFSC

Majority of the papers selected for the review (77 out of 84 papers) addressed the issue of environmental sustainability in AFSC. Most of the studies carried the life cycle assessments of the production systems (Recanati et al., 2018; Rebolledo-Leiva et al., 2017; Miranda-Ackerman et al., 2017; Egilmez et al., 2014; Dobon et al., 2011a, 2011b). The studies on environmental sustainability in AFSC can be categorized into three main categories viz., the issue of carbon footprints (Miranda-Ackerman and Azzaro-Pantel, 2017), food waste (Sgarbossa and Russo, 2017; Irani and Sharif, 2016) and food quality and security due to the extended supply chains (Ting et al., 2014; Kaipia et al., 2013; Irani and Sharif, 2016; Derqui et al., 2016; Sun et al., 2017). The organizations in an AFSC are required to be proactive in developing practices, which encourage resource recovery from waste (Sgarbossa and Russo, 2017; Xia et al., 2016). The literature on AFSC identifies prevention as the best solution to address the problem of food waste. Derqui et al. (2016) reports that the literature on food waste minimization are mostly focused on economic considerations, and the social and environmental concerns are often neglected. Increasing population, their aspirational needs, climate change, soil erosion and irrigation, water scarcity, and the declining incremental levels of yield are identified as the critical challenges for food security (Irani and Sharif, 2016). Development of short supply chains and preference for local food products was also found to be an effective strategy for preservation and development of urban agriculture, addressing the issue of food quality and security (Cojocariu, 2012; Thomson et al., 2017).

3.1.3. Economic sustainability

The studies on economic sustainability are aimed at reducing the overall supply chain costs and deal with specific solutions to minimize the transportation and supply chain design costs (Musavi and Bozorgi-Amiri, 2017). Most of these studies had the social and environmental impact as the secondary objectives, that included minimization of total carbon emissions, water footprint, and jobs created (Allaoui et al., 2017; Accorsi et al., 2016). Similar to the strategies recommended for socially and environmentally sustainable AFSC, short supply chains and buying local food products are identified as the sustainable strategy providing ecological, health and socio-economic benefits (Schmitt et al., 2017; Ilbery and Maye, 2005). Collective action strategies with robust institutional arrangement by the farmers (Jelsma et al., 2017), alternative packaging (Battini et al., 2016), partially guaranteed prices (Tang et al., 2016), and revenue sharing contracts between the buyers and farmers (Yan et al., 2015) are also identified as effective strategies for developing economically sustainable AFSC.

3.2. Data-driven agri-food supply chain

With the use of smart equipment and sensors in the farming processes, the AFSC is becoming more data-driven, and data enabled (Wolfert et al., 2017). Various applications of IoT and cloud computing technologies are pushing the traditional agricultural practices towards smart farming (Sundmaeker et al., 2010). The data available through these technological advances is so large and complex that the conventional data processing applications are inadequate to analyze them. The new data-driven supply chains will be required to equip themselves with a set of data analysis techniques and technologies with new levels of integration so that meaningful intelligence from these complex datasets are extracted making the supply chain efficient (Hashem et al., 2015). As the stakeholders in the AFSC that includes the farmers, agricultural corporations and government scientists are requesting for more access to large datasets to drive their decision making, not more is emerging on how these data is going to be understood and managed (Bronson and Knezevic, 2016). We reviewed all the selected papers on the level of analytics viz., descriptive, predictive and prescriptive analytics. The discussions on the level of analytics in AFSC with sustainable objectives are discussed in this section. It was found from that the majority of the papers used descriptive analytics (74%, 62 out of 84 papers), followed by prescriptive analytics (21%, 18 out of 84 papers). It was surprising to find that the studies on achieving sustainable AFSC used very little of predictive analytics (5%, four out of 84 papers).

3.2.1. Descriptive analytics

Majority of the papers (62 out of 84 papers) selected for review used descriptive analytics for analyzing the sustainable AFSC. The life cycle assessment was found to be the widely used descriptive analytics tool addressing the environmental concerns of the AFSC (Recanati et al., 2018; Garofalo et al., 2017; Gamboa et al., 2016; Peano et al., 2015). Descriptive analytics finds application in analyzing the extensive misuse of resources addressing the issue of food waste (Kiil et al., 2017; Sgarbossa and Russo, 2017; Derqui et al., 2016; Irani and Sharif, 2016; Kaipia et al., 2013; Xia et al., 2016), in design and development of alternate supply chains (Forssell and Lankoski, 2015). Many studies used descriptive analytics to study the effectiveness of short supply chains using different strategies, that included development of farmer markets or food hubs (Giampietri et al., 2016; Berti and Mulligan, 2016), community selling (Fayet and Vermeulen, 2014), improved communication between the farmers and the retailers (Tsuchiya et al., 2015), collaborative farming (León-Bravo et al., 2017; Heard et al., 2018) and competitive bidding markets (Johnson et al., 2016). Different studies demonstrating the benefit of emerging technologies such as RFID (Yan et al., 2015), biotechnology (Björnberg et al., 2015) and postharvest technologies (Chimphango and Görgens, 2015) for improved traceability used descriptive analytics.

3.2.2. Predictive analytics

Only four percent of the studies used predictive analytics. Its applications ranged from developing a real-time data monitoring system for maintaining the quality sustainability of the products using a pre-warning system, identifying safety risks (Wang and Yue, 2017), predicting the sustainable performance (Bourlakis et al., 2014) and evaluation of green wrapping films for use in packaging of fruits (Giuggioli et al., 2016).

3.2.3. Prescriptive analytics

Twenty-one percent of the selected papers used prescriptive analytics. Majority of the studies using prescriptive analytics were based on using Multi-criteria Decision Making (MCDM) techniques. Analytic hierarchy process and the ordered weighted averaged aggregation method was used for optimizing the supplier selection (Allaoui et al., 2017). A combination of TOPSIS, VIKOR, and GRA methods in a fuzzy environment was used for green supplier evaluation (Banaeian et al., 2018). MCDA techniques were also used for designing green supply chain network design (Miranda-Ackerman and Azzaro-Pantel, 2017; Validi et al., 2014), identifying the key barriers to the implementation of green supply chain management practices (Wang et al., 2016b), and evaluating the supply chain sustainability performance (Yakovleva et al., 2012). Data Envelopment Analysis (DEA) was used to maximize productivity and reduce the greenhouse gas emissions involved carbon footprint assessment (Rebolledo-Leiva et al., 2017). Meta-heuristics was used for determining the number and location of the facilities (Kannan et al., 2014) and solving the hub location-vehicle scheduling model with the consideration of perishability of products total CO_2 emission of the network (Musavi and Bozorgi-Amiri, 2017). Nonlinear optimization problem and constraint programming were used for the sustainable design of refrigerated automated storage and retrieval systems to minimize the total yearly cost of the automatic storage facility (Meneghetti and Monti (2015). Van Der Vorst et al. (2009) performed discrete simulation integrating the parameters of food quality, logistics, and sustainability.

3.3. Supply chain visibility

3.3.1. SCV across different SCOR processes

The analysis of the distribution of papers based on the information used for decision-making in different SCOR area reveals that the plan area has received the maximum attention from the researchers (64%, 54 out of 84 papers), followed by the deliver process (25%, 21 out of 84 papers). The source and make have received very little attention with seven percent (six out of 84 papers) and three percent (three out of 84 papers) published in these areas respectively. We found that there are no papers on the return process. This may be because the agri-products are consumption items and in most of the cases the activity of returning the food products to the producer in a closed loop supply chain does not arise.

3.3.2. Data analytics and supply chain visibility

To get insights on which supply chain areas contribute for increased SCV and what type of analytics are deployed to process the collected data, we analyzed the selected papers on how the different levels of analytics are applied across the different SCOR areas. The summarized result is presented in Table 1.

Table 1 reveals that the plan area received maximum attention in the literature with 54 papers (77%). Forty-two papers in this area used descriptive analytics in the form of empirical studies and concept based papers. Out of the remaining papers in the plan process, nine papers used prescriptive analytics, and only three papers used predictive analytics. Out of the six papers in the source process five of them used descriptive analytics, one paper used prescriptive analytics. None of the papers in the source process used predictive analytics. Similar trends were observed in the make and deliver area with descriptive analytics gaining more focus, followed by prescriptive analytics. All three papers in the make process used descriptive analytics. In the deliver process the descriptive papers were used in twelve studies (57%) and prescriptive analytics in eight papers (38%). The findings from Table 1 indicate that descriptive and prescriptive analytics is the most preferred techniques for analyzing the issues concerned with sustainable performance in AFSC.

3.3.3. Supply chain resources

Fig. 3 shows the different supply chain resources deployed by the organizations to develop the visibility and DAC to achieve sustainable objectives. Organizational resources were found to be implemented to a maximum extent followed by human resources (42%). The other resources viz., technological, intangibles and financial resources were found to be used to a moderate extent (21%, 22%, and 17% respectively). Physical resources were used in only eight percent of the studies.

The papers were analyzed to understand how these resources are deployed across the different SCOR areas to achieve improved visibility. Table 2 presents the detailed cross-tabulation for the supply chain resources and SCV. The results reveal that supply chain resources are widely used for achieving improved visibility for the plan and the deliver areas.

Table 1
Level of analytics across SCV processes.

Supply chain visibility	Analytics		
	Descriptive	Predictive	Prescriptive
Plan	42	3	9
Source	5	0	1
Make	3	0	0
Deliver	12	1	8
Total	**62**	**4**	**18**

3.3.4. Organizational resources

The review highlights the presence of a high level of internal integration of the organizational resources to provide increased SCV on the plan process. It is identified from the literature that the quantification of the AFSC evaluations is done for environmental impact studies using organizational resources (Recanati et al., 2018; Gamboa et al., 2016). The organizational resources are deployed to evaluate the preferences of the local products over global products (Schmitt et al., 2017). It is understood that the information sharing influences the performance of AFSC, but the supply chain performance depends on how, and for which purpose the information is used (Kaipia et al., 2013). Organizational resources are highly utilized for designing sustainable AFSC network design (Allaoui et al., 2017; How and Lam, 2017; Galal and El-Kilany, 2016; Accorsi et al., 2016; Miranda-Ackerman et al., 2017). Organizational resources are deployed to support the small farmers for sustainable access (Fayet and Vermeulen, 2014) and the development of alternate food network (Forssell and Lankoski, 2015; Zanoni and Zavanella, 2012). Assuring the quality of the food in the supply chain involves data mining resources, which is considered as an integral part of organizational capabilities (Ting et al., 2014).

The organizational resources in the source process mostly contribute to addressing the sustainability issues concerning the management of multiple tiers of partners. These issues include complexities in maintaining contractual relationships, lack of transparency on transactions and low involvement of the sub-suppliers in the AFSC (Grimm et al., 2014). Organizational resources in the make process offer increased SCV by developing a sustainable production system, focused on reducing the greenhouse emissions (Rebolledo-Leiva et al., 2017) and increasing the production yield (Jelsma et al., 2017). The organizational resources enhance the SCV of the deliver process to a great extent, through AFSC network optimization (Musavi and Bozorgi-Amiri, 2017; Kannan et al., 2014). Organizational resources contribute in reducing food waste, through the development of efficient and innovative solutions to assure quality and distribution sustainability (Battini et al., 2016; Validi et al., 2014; Manzini et al., 2014; Kaipia et al., 2013). Various other strategies such as design and development of short food supply chain (Aubry and Kebir, 2013), improvement in the food retailing practices (Chkanikova and Mont, 2015) and zero-packing grocery stores (Beitzen-Heineke et al., 2017) are highly reliant on organizational resources.

3.3.5. Technological resources

Agriculture is considered to be an early adopter of technology for the attainment of economic and environmental benefits (Heard et al., 2018). Björnberg et al. (2015) recommend the AFSC's to focus on research and development of emerging technologies for agricultural intensification. Agricultural biotechnology is seen as a potential tool for increased food production. RFID is found to be a useful technique to reduce losses in agricultural product transportation (Yan et al., 2015). Big data is identified as a potential information technology tool in AFSC (Shukla and Tiwari, 2017; Ahearn et al., 2016). Big data can be used to understand and satisfy consumer needs by offering the required product attributes (Ahearn et al., 2016). The significant aspect of an AFSC is the

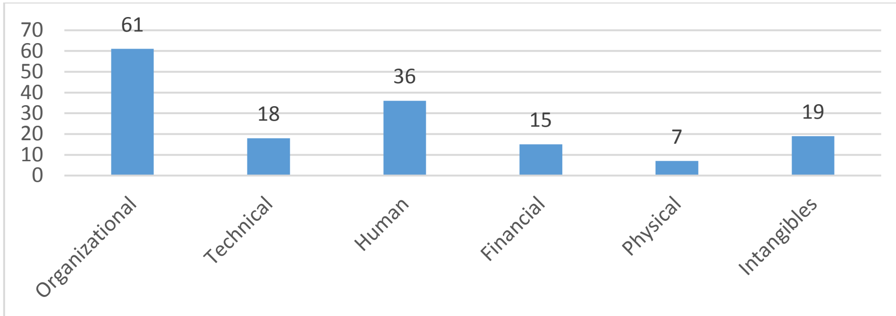

Fig. 3. Supply chain resources deployed in sustainable AFSC.

Table 2
Supply chain visibility and supply chain resources integration.

Supply chain visibility	Supply chain resources					
	Organizational	Technical	Physical	Human	Financial	Intangible
Plan	43	11	2	23	6	13
Source	3	1	1	3	3	2
Make	2	2	0	3	0	2
Deliver	13	4	4	7	6	4

ability to retrieve past information that can be used to track the origin of the products improving the visibility of the plan area (Wognum et al., 2011). The technological resources are found to support the visibility of the make process with the use of postharvest technologies (Chimphango and Görgens, 2015). The technical resources play a significant role in improving the visibility of the deliver process by providing real-time data monitoring system (Wang and Yue, 2017). It is expected that autonomous vehicles will transform the supply chain in the future (Heard et al., 2018). Technological resources are also deployed for developing cold chain management and inventory control systems, making the AFSC environmentally sustainable (Yang et al., 2017).

3.3.6. Physical resources

The contribution of the physical resources in enhancing the SCV and DAC was observed to be higher in the make and the deliver area. Yan et al. (2015) proposed the concept of the sustainable factory system that requires less labor, water, nutrition, pesticides, and can be operated in a controlled environment using artificial light, temperature, humidity, carbon dioxide, water supply, and cultivation. In the deliver process, the physical resources contribute in creation of regional and local food hubs (Berti and Mulligan, 2016), selection of packaging solutions (Battini et al., 2016), and design of refrigerated automated warehouses for green food supply chain (Chen et al., 2016; Meneghetti and Monti, 2015).

3.3.7. Human resources

Human resources play a significant role in improving the visibility of the plan area in AFSCs. The attitudes of human resources and their support for sustainable development programs are found to be a significant component of sustainability orientation (Emamisaleh and Rahmani, 2017). The views and opinions of the human resources on different aspects of AFSC such as linking tourism with agriculture (Thomas-Francois et al., 2017a, 2017b; Sun et al., 2017) and expected trade-offs of integrated assessment (Gamboa et al., 2016) are highly significant in the planning process. Further, the interpersonal trust and working to standards are critical requirements for developing a sustainable local and more conserved AFSC (Smith, 2008). Human resources enhance the visibility improvement of the source area through the development of collaborations, roundtable and partnerships between the various stakeholders (Castro and Swart, 2017). In the make area, human resources contribute to increased visibility through the development of institutional setup for farmers. It is suggested that small farmers combine and participate in the supply chains to substantially increase productivity, thereby contributing to both rural development and land sparing (Jelsma et al., 2017).

3.3.8. Financial resources

Financial benefits have been one of the primary objective of planning and designing AFSC networks. However, it is also recommended to consider carbon or greenhouse emissions instead of relying highly on costs or level of service (Galal and El-Kilany, 2016; Accorsi et al., 2016). Companies need to spend more money on achieving more sustainable solutions, making it necessary for them to attract private investments to address environmental issues (Rueda et al., 2017). In the source process, the benefits of partially guaranteed contracts between the farmers and the buyers are expected to be a strategy offering mutual benefits to both the parties (Tang et al., 2016).

3.3.9. Intangible resources

The intangible resources which support improved visibility of the plan area include the external drivers and influencers that determine the consumer needs and demands. It is found that the external drivers of the organizations affect the internal drivers (Emamisaleh and Rahmani, 2017). Consumers and corporations are increasingly interested in making their AFSC sustainable and reduce the environmental impact of food, fiber, feed, and fuel production (Thomson et al., 2017; Rohm et al., 2017). Intangible dimensions, such as high dependence of developing countries on tourism for economic development, and strengthening the agriculture and tourism linkages as a strategy to maximize economic gains is an essential aspect of the studies in sustainable AFSC (Thomas-Francois et al., 2017a, 2017b). The AFSC should consider the intangible benefits while planning the supply chain networks to address the socio-economic challenges such as unemployment, low income, food insecurity, and poverty (Thomas-Francois et al., 2017a, 2017b). Adoption of big data will be an essential tool for analyzing consumer demands and responding to them (Ahearn et al., 2016). The use of intangible resources for the improvement of visibility in the source process stresses the organizations to push for new initiatives. The literature considers the issue of food safety, traceability of the agricultural produce, and the consumer willingness to pay more for traceability of the agricultural products (Sun et al., 2017). Wholesale auctions, where the consumers can come in direct contact with the producers need to be explored for the benefit of the alternative food systems (Johnson et al., 2016).

3.4. Summary of the review findings

3.4.1. Sustainable performance outcomes of AFSC

The review findings reveal that the social performance of the AFSC is closely linked with the welfare and well-being of the farming and the rural communities. The farmers will not be able to deliver their best functioning in poor social conditions. The AFSC performance on social sustainability dimension is measured on the organization's ability to develop attractive farming livelihoods, adaptive rural communities, empower the farmers to build robust rural social infrastructure, ability to generate employment and youth development. The environmental sustainability performance of the AFSC is measured on the extent to which the available natural resources are protected during the production, delivery, and consumption of the farm produce. The amount of GHG emissions, water footprints, energy savings during the production and consumption process, the quality of food produced and the amount of food wastage are the critical performance parameters that are considered. The economic sustainability performance of the AFSC means that a firm is managed in a way that ensures its long-term profitability. However, to be economically sustainable, a firm does not have to make profits every year and may include increased productivity, reduced operating costs, and higher yield as its objectives.

3.4.2. Supply chain visibility

The findings reveal that information collection and sharing is highly valuable and beneficial for the AFSC to remain competitive, addressing the challenges of food perishability, demand-supply variations, safety, and sustainability. Higher SCV across different SCOR areas help the organizations to gain visibility on the various planning and operational aspects of the AFSC, including the network design issues, inventory status, physical movement of the products, and process visibility. The review highlights that high SCV helps in improving the DAC and sustainable AFSC performance. However, the performance improvement depends on how meaningful, useful and quality data is captured and shared through the SCOR processes. The study further reveals that various supply chain resources are deployed for improving the SCV and DAC.

3.4.3. Integrated Supply chain resources

The findings reveal that organizational resources help in collecting the abundant amount of data, information, and knowledge that is available as an outcome of the improved visibility in different SCOR processes. The firms should be able to derive value from these organizational resources. The technological resources refer to the requirement of advanced data storage systems; RFID and sensor technologies, ERP systems, and inter-organizational systems. Human resources refer to the required human skills for performing data analysis and also carrying out analysis of the data collected from them. For a firm to build capability on human resources, needs to hire highly skilled data scientists for analysis and management of the data. Physical resources mainly refer to the make and delivery process of the SCOR model. It involves all the physical resources used during the movement of the raw materials and the goods. Material handling equipment's, transport vehicles, storage equipment are included. Intangible resources refer to the quality of interactions and communications with the customers of the organization. These resources relate to the capability of the firm to collect information from the customers and use them to develop new products/services or modify the existing products/services. Financial performance refers to the final desired outcome of the data analytic capabilities. These could be short-term financial gains and may have an impact on the overall economic sustainability of the organization.

3.4.4. Data analytics capability

The integration of supply chain resources and enhanced SCV leads to improved DAC. It refers to the outcome of the internal integration that results from a set of interconnected systems and processes facilitating the decision-making processes (Schoenherr and Swink, 2012; Williams et al., 2013). Internal integration mainly involves the combination of data and information systems and is described by the way the firm "structures its organizational practices, procedures and behaviors into collaborative, synchronized and manageable processes" (Zhao et al., 2011). The data analytic capability is a result of how the collaboration between different functional areas have occurred in the firm and how well the various firm's resources are deployed leading to the alignment of organizational goals and performance outcomes (Schoenherr and Swink, 2012).

4. Managerial implications and application framework

4.1. Implications from the review findings

The above review findings reveal that different research methodologies and level of analytics that relates to descriptive, predictive and prescriptive analytics are used in analyzing sustainability issues in AFSC. More specifically the review confirmed that to achieve sustainable performance there is a need to have a high level of SCV and integration of the firm's resources. The findings identified SCV and supply chain resources as the antecedents of DAC that leads to sustainable supply chain performance. It is therefore implied that the organization's information collection strategy should be based on which sustainable outcomes are needed to be achieved by the AFSC (Zhu et al., 2018). The information is generated from different supply chain process namely: the plan, source, make, deliver and return. The managers should identify and select those processes that will contribute highly in achieving sustainable AFSC performance. For example, if the organization wants to minimize the total carbon footprints of its supply chain, it would like to analyze the data collected from the make and the delivery process that deals with the food processing and transportation activities. Therefore, the organization would be required to have strong visibility for these two SCOR areas.

Further, the findings from the review imply that the managers should evaluate the existing SCV and improve them in case they are not sufficient to achieve the performance targets. The supply chain resources need to be deployed in such cases to improve the SCV and the DAC. It is therefore required that the managers should communicate the significance of attaining high SCV in the development of the DAC to all its partners and stakeholders in the supply chain. The primary purpose of having high visibility is to collect and share the data across the AFSC. However, it is the DAC of the firm that derives the information and knowledge from the available data. The DAC also requires the use of different firm's resources viz., organizational, technological, financial, physical, intangibles and human resources as the information is dispersed across the supply chains. Hence, in this study, we call the attention of the managers to integrate all the available resources for drawing meaningful interpretations from the collected data. The managers should aim at developing strategies, where visibility and resource integration are aligned with each other. New technological resources like blockchain may be used for achieving a high level of integration by the managers for attaining the sustainable objectives for improved transparency and tracking of the agro-food products in the supply chain.

Based on the above findings and derived implications we propose an application framework referred to as data-driven AFSC framework. The proposed framework will guide the practitioners in deciding the appropriate methodologies, level of analytics, data accuracy, and the use of proper supply chain resources for developing DAC and improved sustainable performance. The framework has four main dimensions namely: SCV, integration of supply chain resources, DAC and

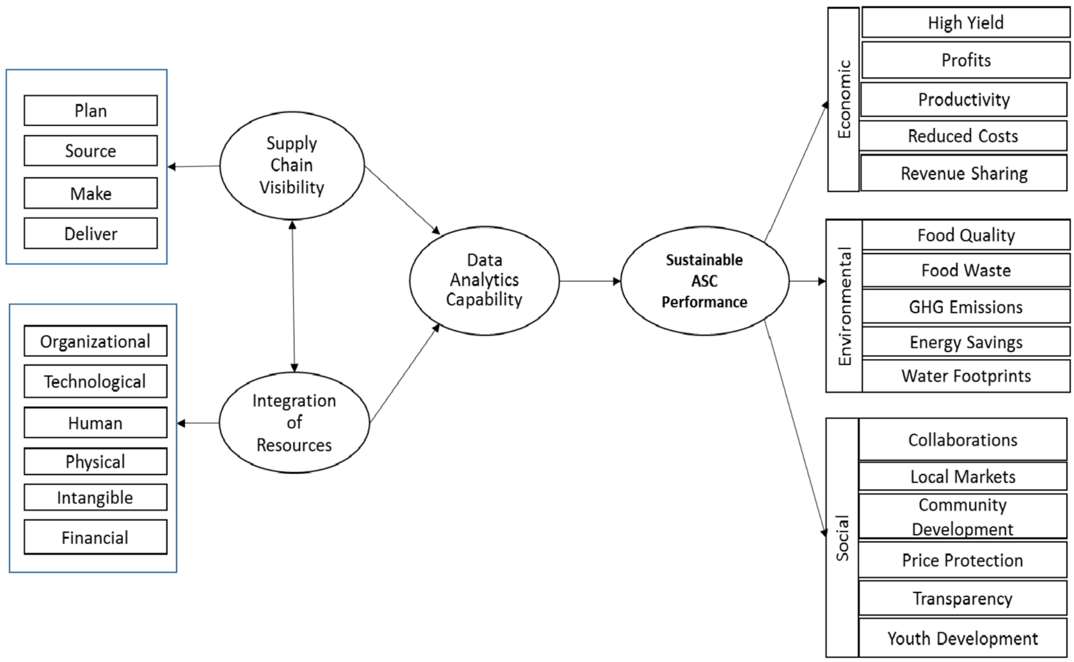

Fig. 4. Data-driven AFSCM framework.

sustainable performance. In this framework, we conceptualize DAC as the "*the ability to utilize resources to perform analytics task, based on the interaction between IT assets and other firm resources*" (Cosic et al., 2015). In the absence of the DAC, the organizations will not be in a position to exploit the SCV benefits to its potential. Schoenherr and Swink (2012) identify the need for collaboration between the different functional areas within the firm for alignment with the organization's goal and improved performance. The collaboration is an outcome of the internal integration achieved through interconnected systems and processes facilitating improved decision making. The proposed framework is presented in Fig. 4.

4.2. The utility of application framework

The performance management system of an AFSC is considered to be complicated, consisting of the following processes: i) Identifying the performance measures ii) Target setting iii) Planning iv) Communication with supply chain partners v) Monitoring the progress and vi) Reporting and feedback.

The DAC can improve the performance of the SCOR processes if used and appropriately implemented providing high business value to the organizations (Trkman et al., 2010). It is therefore required that the organizations make sufficient investments in developing the DAC. The investments are needed to be made on the various supply chain resources that will enhance the SCV and DAC. The proposed framework can help on deciding investments to be made on different supply chain resources and the visibility dimension to be focused. The DAC includes data collection, aggregation, analysis and sharing of the information for the use by the decision makers. The organizations should ensure that the DAC and the data requirements are aligned, the more complex the decision to be made, the higher will be the information requirements. The information visibility is governed by the use and management of different supply chain resources such as organizational, physical, technological, financial, and human resources. The organization needs to identify the supply chain areas (plan, source, make and deliver) from where the information is to be collected and the extent to which it will contribute to the AFSCs sustainable outcomes. Any imbalance between the DAC and SCV (information sources) may not add to the desired results. When the SCV is poor than expected, the organizations will fail to meet the performance targets. In contrast, if the organization posses more than the required SCV, the performance targets are achieved inefficiently. Possessing more than the needed SCV may increase the DAC but attracts high consumption of supply chain resources leading to increased investments.

It is understood that the supply chains have different needs depending upon their maturity levels and hence it is difficult to propose a generalized solution that may work for all the situations (Cadez and Guilding, 2008). In our application framework, no single optimal strategy can be applied for the deployment of supply chain resources. However, the application framework can guide the AFSCs on identifying the significant SCOR areas that improve the information visibility and supply chain integration. However, the AFSC's are required to prioritize their performance outcomes.

Further, we recommend the AFSCs to use the supply chain maturity model to assess their maturity (de Oliveira et al., 2012). This will help them to set the performance objectives and also decide in which SCOR areas the supply chain resources are to be deployed. The supply chain maturity model is a process-oriented model with information as an essential driver for success. The description of the different levels of the supply chain maturity model is presented in Table 3.

de Oliveira et al. (2012) argued that the supply chain maturity level decides the SCV and data analytics capabilities of an organization Their study suggests the level wise investments be made for developing BDAC in the different SCOR areas as shown in Table 4.

The proposed application framework contributes to the literature by providing a decision-making framework for transforming the traditional AFSC into a data-driven AFSC with sustainable objectives.

5. Future research directions

The proposed framework and findings from the systematic review suggest some future directions to capitalize on the research development of data-driven sustainable AFSC. These are discussed in this section.

5.1. Improving the supply chain visibility

- SCV provides organizations with high availability of data. Getting access to the data in most of the developing countries is difficult because of poor infrastructure and high costs associated with the

Table 3
Summary of supply chain maturity model.

Level	Description
I (Foundation)	• Focused on building an underlying structure. • Sourcing is the focus area.
II (Structure)	• Distribution and demand planning processes get structured
III (Vision)	• Planning, source, make, deliver are viewed distinctly • Focus on the development of cross-functional teams and supply chain integration.
IV (Integration)	• Firms focus on establishing long-term collaborative relationships with all their supply chain stakeholders. • Strategic planning team focus on selecting supply chain partners and building long-term relationships with stakeholders
V (Dynamics)	• supply chain attains a high level of integration • Firm's take control of demand and capacity constraints by establishing a pull system through the development of a close relationship with customers

data collection procedures. Future studies should focus on how small farmers in the developing economies should be equipped with these technologies and how they can be made affordable making them sustainable. More specifically the future studies in AFSC should focus on the following aspects aligning with the objectives of achieving improved agricultural sustainability;

o Developing new forms of advisory and support systems to build capabilities to use data-driven information, knowledge, skills, and technology.
o Developing general standards for data collection, sharing, interoperability, accessibility, and accuracy.
o How to promote open technologies for farming and on-farm processing of farm products as also for data and information.
o Developing strategies for governing the data management and sharing platforms, ensuring transparency, recognition of ownership and traceability of data.

- Data-driven supply chains promise to bring a radical change in the transformation of the AFSC, attaining sustainable goals. The advances in the sensor technologies, computing technologies, and availability of data offer numerous opportunities for information sharing and efficient decision making. It is expected that these new developments, like blockchain, internet of things and big data technologies will shorten the agricultural supply chains offering social benefits to the deprived communities. Future studies should be conducted to investigate how these technologies will benefit the farming community and which supply chain resources will be required to attain the same.
- The review reveals that very few financial inclusion initiatives backed with technological resources are taken up for sustainable AFSC. Such initiatives will most benefit the remote communities, who are generally dependent on the agricultural produce for income generation. In most of the cases, the farmers possess assets that are not recognized as collateral by the lending institutions. These assets include livestock, land, and harvests. Future studies should focus on how these illiquid assets can be brought into the collateral system by deploying suitable technologies like IoT and Blockchain. Future studies should also focus on developing new business models and tools to integrate the governments effectively, farmers, banks, insurance companies, market intermediaries, cooperatives, etc. for data-driven participation in AFSC. Such integrations should provide scope for interaction among the different stakeholders in the AFSC with sustainable objectives.

5.2. IoT applications in sustainable AFSC for improved supply chain visibility

IoT is found to have significant use in reducing food wastage (Sundmaeker et al., 2010). However, the IoT technologies lack adoption in emerging economies (Verdouw et al., 2016). Future studies should focus on identifying the different IoT adoption barriers in AFSCM. Future studies may explore the possibilities of implementing IoT in achieving sustainable AFSC in the following SCOR processes:

- Make process

The following research questions may be investigated:

o To what extent the IoT based technologies can be used for differentiating and tracking the raw materials, semi-processed and finished products?
o How can the RFID tags be used in combination with electronic product codes for making production processes stable?

- *Deliver process*
o The studies in this process may focus on evaluating the improvements in carbon footprints with the use of IoT-based technologies. For example, future studies may focus on the use of GPS for vehicle tracking and the corresponding benefits it provides to the AFSC to make it sustainable.
- The implementation of IoT in the AFSC should be aimed at improving sustainable performance. In most of the cases, the data generated by IoT devices will help to fulfill the customer's requirements of transparent, quality and authentic supply chains. These IoT devices will support in the successful implementation of the blockchain and the big data technologies providing the AFSC with the highest level of visibility. Traceability of food products, transparency, authenticity, and quality of the agro-products in an AFSC will be highly dependent on the level of SCV that is achieved.
- Further studies will be required to ascertain the data requirements from the various SCOR processes fulfilling the sustainable performance requirement. Future studies should also address evolving

Table 4
Investment Strategy and supply chain Maturity Level.

Supply chain Maturity level	*Investments needed in the following SCOR processes*	*Reasons*
Level I	Plan, Source and partly Make.	• Poorly defined (ad hoc) processes • Focus on planning operations on deciding on which resources to be exploited
Level II	Deliver	• defined processes • Focus on fulfilling the orders of its customers.
Level III	Make	• Focus shifts on aligning make process, to supply high-value products and services to customers.
Level IV and V	Source	• Focus on cooperation and collaborations with customers and suppliers • Strategic partnership/alliances

sustainable AFSC performance metrics and measures, as it is expected that the implementation of IoT technologies will change the way the AFSC operations are presently performed. In an IoT, based system data about all the processes in the supply chain will be captured automatically and in real-time without the interference of the human element. Studies should focus on how these initiatives will have an impact on the sustainability dimensions of AFSC.

5.3. Blockchain technology for better integration of supply chain resources

- In agriculture, blockchain based data management can be beneficial especially around data that relates to land and resource use records, purchase and use of pesticides and other harmful agents, traceability and even flows of finance across the whole value chain. The blockchain is arguably not just a new technology, and not even just a potentially disruptive technology, it is foundational technology: "It has the potential to create new foundations for our economic and social systems." The blockchain is one of the significant technological resources that promote the DAC by providing the AFSC with technology infrastructure for things like digitization, automation, and tracking, all of which are essential to drive the farmers' sustainability initiatives.
- The present literature highlights the increasing demand from the consumers for complete information on the product, reflecting the need for more transparent and lack of trust in the current AFSC. Also, there is increasing importance attached to eco-labeling and supplier certification initiatives for achieving sustainable AFSC. These initiatives will help the AFSCs to address the issue of increasing cases of fraud and product adulteration. The above problems if left unaddressed may pose a severe challenge to food security, food quality, and AFSC sustainability. The present AFSC has to ensure sustainability at two levels, i.e., physical and digital level. The digital layer should provide reliable and trustworthy information on the origin and provenance of food products in the physical layer (Ge et al., 2017). Future studies should focus on how blockchain and other emerging technologies will support the AFSC in increasing transparency and automated processes. Research studies are required to focus on how blockchain technology can ensure the permanence of the records and ensure auditable information sharing across the different stakeholders in the AFSC (Lin et al., 2017).
- The multinational companies dominate the present AFSCs as they are the prime buyers in the market. Usually, they decide the prices and crops to be grown by the farmers in a given season. The literature identifies initiatives like community farming for shortening the AFSC. The objective of the community farming is that the farmer buys a share in the farm and sells the farm produce directly to the co-operative throughout the year. The two benefits observed from this arrangement is the financial support provided by the co-operative at the beginning of the season, and the consumers know their farmers well in advance getting cheaper, seasonal, and locally-grown produce. Future studies should investigate how the blockchain in AFSC can address the issues of authority, distribution, and shareholding in the operation of community-sponsored agriculture.

5.4. Developing big data analytics capability

- Big Data platforms are essential to handle the amount of data generated by the IoT, which is all the data coming from all the interconnected 'things' that send data over the Internet. In agriculture, big data and IoT are currently mainly associated with information collected by sensors, satellites or drones, GIS combined with genomic details or climate data, which can all help farmers optimize their farm operations. BDA applications in AFSC is increasing at a faster pace. BDA is used for smart sensing and monitoring of the farms using robotics and sensors (Faulkner and Cebul, 2014), for intelligent analysis and planning by predicting the crop health, yield modeling (Noyes, 2014) and precision farming (Sun et al., 2013). Big data with cloud computing technologies uses weather data, yield data soil types, market information and agricultural data (Wang et al., 2014). Big data is expected to bring a significant change in the scope and organization of smart farming (Wolfert et al., 2017) with the development of the new technologies like IoT, wirelessly connecting all the physical systems within a supply chain has become more comfortable, providing real-time access to data. Wolfert et al. (2017) identify the following challenges for adoption of BDA in AFSC.

o Ownership of data and associated privacy and security issues
o Quality of big data
o Availability of skilled human resources for big data analysis
o Sustainable integration of data
o The openness of the platforms

The scope of the present study was to review the data analytics applications for achieving sustainable performance in AFSC. However, we have observed that there are very few studies using BDA with the focus on sustainable AFSC. BDA can contribute significantly in attaining v AFSC. BDA was used to provide a sustainable supply of farm products and also higher traceability and transparency to the consumers (Shukla and Tiwari, 2017; Wang and Yue, 2017). More studies are required to be conducted with the specific objectives of achieving sustainable performance in AFSC. Future studies should focus on addressing the BDA implementation issues identified by Wolfert et al. (2017) while concentrating on sustainable AFSC.

6. Conclusions and limitations of the study

The present study makes a significant contribution towards the research gaps identified in the literature, providing useful information on what sustainable performance outcomes are accomplished by a data-driven AFSC, which supply chain resources are used to develop DAC and which supply chain processes provide high supply chain information visibility. Based on a systematic literature review of 84 research papers the study advances the literature by providing useful information on the above-identified gaps. The review findings reveal that a data-driven AFSC aims at achieving the social, environmental and economical sustainable performance outcomes. Our study revealed that the data in an AFSC is collected from all the four supply chain process viz., plan, source, make and deliver. However, the plan and deliver supply chain processes contribute highly in developing DAC, compared to the source and make process. The AFSC was found to use different supply chain resources for data collection and analysis. The data-driven AFSC relied more on organizational and technological resources for developing the DAC. The study also highlights the increasing role of human and physical resources in enhancing the SCV. Based on the findings of the study we propose an application framework that identifies the SCV and integration of supply chain resources as the main antecedents in developing a robust DAC, which in turn leads to the achievement of the sustainable AFSC. The findings from this study may serve as a foundation for both the researchers and practitioners. The researchers may like to consider the significant factors presented in the framework and validate it statistically in different AFSC environments. The practitioners may focus on developing technologies that will enhance SCV and also identify the resources that may contribute towards strengthening the data analytics capabilities required to attain the sustainable performance of the AFSC.

The authors recognize that the study has a few limitations. While the authors have conducted a literature search using the WoS database to identify the relevant articles, it is possible that some research articles could have been missed in this review. Additionally, the analysis and synthesis are based on the authors' interpretation of the selected articles. The authors attempted to avoid these issues by cross-checking papers independently and thus deal with embedded bias, but errors might have occurred.

Appendix 1. Journal wise distribution of selected papers

Journal Name	No. of Articles
International Journal of Production Economics	11
Sustainability	11
Journal of Cleaner Production	10
Production Planning and Control	3
International Journal of Production Research	3
British Food Journal	3
SCM: An International Journal	2
Journal of Rural Studies	2
Resources Conservation and Recycling	2
Computers in Industrial Engineering	2
Computers and Operations Research	2
Advanced Engineering Informatics	1
Agric Hum Values	1
Agricultural and Env. Letters	1
Agriculture	1
Annals of the American Association of Geographers	1
Annals of Tourism Mgmt.	1
Applied Economic Perspectives and Policy	1
Chemical Product and Process Modeling	1
Cogent Business and Mgmt.	1
CSR and Env. Mgmt	1
CyTA - Journal of Food	1
European Journal of Operations Research	1
Food Control	1
Food Policy	1
Foods	1
International Journal of Physical Distribution and Logistics Management	1
Int. Bus. Review	1
Int. Food and Agribusiness Mgmt Rev.	1
Int. J. Simul. Model.	1
Journal of Enterprise Mgmt.	1
Journal of Env. Mgmt.	1
Journal of Food Engineering	1
Journal of Industrial Ecology	1
Land Use Policy	1
Landscape and Urban Planning	1
Metalurgia Int.	1
Packing Tech. and Sci.	1
Royal Soc. B: Biological Sciences	1
Rural Sociology	1
Science of the Total Environment	1
Sustainable Chemistry and Engineering	1
Sustainable Development	1
Tourism Planning and Development	1
Total	**84**

Appendix II. Systematic Literature Review

Author	Research Approach	Level of Data Analytics	SC Visibility	Type of Sustainability			SC Resources					
				Soc	Eco	Env	Org	Tec	Hum	Fin	Phy	Int
Recanati et al. (2018)	ECS	DS	P			✓	✓					
Kiil et al. (2017)	ECS	DS	D		✓	✓	✓			✓		
Allaoui et al. (2017)	C	PS	P	✓	✓	✓	✓		✓	✓		
Miranda-Ackerman and Azzaro-Pantel (2017)	ECS	PS	D			✓		✓		✓	✓	✓
How and Lam (2017)	ECS	PS	P				✓					
Castro and Swart (2017)	C	DS	S		✓	✓	✓			✓	✓	
Musavi and Bozorgi-Amiri (2017)	C	PS	D		✓		✓					
Schmitt et al. (2017)	ECS	DS	P	✓	✓	✓	✓					
Jelsma et al. (2017)	ES	DS	M	✓	✓	✓	✓		✓			
Emamisaleh and Rahmani (2017)	ES	DS	P	✓	✓	✓	✓		✓			✓
Thomas-Francois et al., (2017a, 2017b)	ES	DS	P	✓			✓		✓			✓
Sun et al. (2017)	ES	DS	S	✓	✓	✓				✓		✓
Gaitán-Cremaschi et al. (2016)	ECS	PS	P	✓		✓	✓					
Gold et al. (2017)	C	DS	P	✓	✓	✓	✓					✓
Wang and Yue (2017)	ECS	PD	P		✓	✓		✓				
Shukla and Tiwari (2017)	C	DS	M	✓		✓	✓	✓	✓			
Hadiguna and Tjahjono (2017)	ECS	PS	P	✓	✓	✓	✓					
Giuggioli et al., (2016)	ECS	PD	D	✓	✓	✓			✓			
Thomas-Francois et al., (2017a, 2017b)	C	DS	P	✓					✓			✓
Sgarbossa and Russo (2017)	ECS	DS	P			✓	✓					
Chiffoleau et al. (2016)	C	DS	P	✓			✓		✓			

Doernberg et al. (2016)	ES	DS	P	✔		✔			✔			
Giampietri et al. (2016)	ES	DS	D	✔	✔	✔			✔			
Chen et al. (2016)	ECS	DS	D			✔	✔					✔
Tang et al. (2016)	C	DS	S		✔				✔	✔		
Ely et al. (2016)	C	DS	P	✔		✔	✔	✔				
Galal and El-Kilany (2016)	C	DS	P		✔	✔	✔					
Berti and Mulligan (2016)	C	DS	P			✔		✔				✔
Derqui et al. (2016)	ES	DS	D	✔	✔	✔	✔		✔			
Gamboa et al. (2016)	C	DS	P			✔	✔			✔	✔	✔
Johnson et al. (2016)	ES	DS	S	✔	✔	✔	✔		✔			✔
Accorsi et al. (2016)	ECS	PS	P		✔		✔			✔		
Irani and Sharif (2016)	C	DS	P	✔		✔	✔					✔
Battini et al. (2016)	ECS	DS	D		✔	✔	✔			✔	✔	
Meneghetti and Monti (2015)	ECS	PS	D			✔				✔	✔	
Tsuchiya et al., (2015)	ES	DS	P				✔					✔
Peano et al. (2015)	ECS	DS			✔	✔	✔		✔			
Björnberg et al. (2015)	ECS	DS	P			✔		✔	✔			
Chkanikova and Mont (2015)	C	DS	D		✔	✔	✔					
Yan et al. (2015)	ECS	DS	P		✔	✔		✔		✔		
Forssell and Lankoski (2015)	C	DS	P				✔		✔			
Chimphango and Görgens (2015)	ECS	DS	M					✔	✔			
Fayet and Vermeulen (2014)	ES	DS	P				✔		✔			✔
Kannan et al. (2014)	ECS	PS	D	✔	✔	✔	✔					
Validi et al. (2014)	ECS	PS	D				✔			✔		✔
Bourlakis et al. (2014)	ES	PD	P	✔	✔	✔	✔		✔			
Beske et al. (2014)	C	DS	P	✔	✔	✔						
Ting et al. (2014)	ECS	DS	D			✔						
Gold et al. (2013)	C	DS	P	✔	✔	✔	✔					
Aubry and Kebir (2013)	ECS	DS	D			✔	✔		✔			
Kaipia et al. (2013)	ECS	DS	P	✔	✔	✔		✔		✔		
Zanoni and Zavanella (2012)	ECS	PS	P		✔	✔	✔	✔	✔			
Yakovleva et al. (2012)	ECS	PS	P	✔	✔	✔	✔		✔			
Cojocariu (2012)	C	DS	D			✔	✔					
Smith (2008)	C	DS	P	✔	✔	✔	✔		✔			
Ilbery and Maye (2005)	ECS	DS	P	✔	✔	✔	✔					
Kannan (2018)	C	DS	P	✔	✔	✔	✔		✔			
Banaeian et al. (2018)	ECS	PS	S			✔		✔				
Yang et al. (2017)	ECS	PS	D		✔	✔		✔		✔		
Miranda-Ackerman et al. (2017)	ECS	PS	P	✔	✔	✔	✔		✔			
Rueda et al. (2017)	C	DS	P		✔	✔				✔		
Beitzen-Heineke et al. (2017)	ES	DS	D	✔		✔			✔			✔
Xia et al. (2016)	ECS	DS	D	✔		✔	✔	✔				
Wang et al., (2016a, 2016b)	ECS	PS	D		✔	✔	✔		✔			
Dania et al. (2018)	C	DS	P	✔	✔	✔	✔		✔			✔
Heard et al. (2018)	C	DS	P	✔	✔	✔		✔			✔	
Thomson et al. (2017)	C	DS	P			✔	✔		✔			
Rohm et al. (2017)	ECS	DS	P	✔	✔	✔	✔					✔
León-Bravo et al. (2017)	ECS	DS	P	✔		✔	✔		✔			
Kirwan et al. (2017)	C	DS	P	✔	✔	✔	✔					
Garofalo et al. (2017)	ECS	DS	P			✔	✔					
Freidberg (2017)	C	DS	P			✔	✔	✔				
Tasca et al. (2017)	ECS	DS	P			✔	✔					
Akhtar et al. (2016)	ES	PD	P	✔	✔	✔	✔		✔			
Manning and Soon (2016)	C	DS	P	✔	✔	✔	✔					
Ahearn et al. (2016)	ECS	DS	P			✔		✔				✔
Bloom (2015)	ECS	DS	P	✔	✔	✔	✔		✔			
Grimm et al. (2014)	ES	DS	S	✔		✔	✔		✔			
Darkow et al. (2015)	ES	DS	D			✔	✔		✔			
Manzini et al. (2014)	ECS	PS	D			✔		✔			✔	
Egilmez et al. (2014)	ECS	PS	P			✔	✔					
Van Der Vorst et al. (2009)	ES	DS	P	✔	✔	✔	✔	✔	✔			✔
Hamprecht et al. (2005)	ECS	DS	P	✔	✔	✔	✔					
Wognum et al. (2011)	C	DS	P	✔	✔	✔	✔		✔			

C: Conceptual, D: Deliver, DS: Descriptive, Eco: Economical, ECS: Empirical-case study, Env: Environmental, ES: Empirical survey, Fin: Financial, Hum: Human, Int: Intangibles, M: Make, Org: Organizational, P: Plan, PD: Predictive, Phy: Physical, PS: Prescriptive, S: Source, Soc: Social, Tec: Technological.

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