SUSTAINABLE AGRIFOOD SUPPLY CHAIN MANAGEMENT

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Abstract: Nowadays the agrifood system requires major transformations aimed at promoting sustainability, reducing waste and stimulating a change toward healthy sustainable diets. The scientific literature on the transition to sustainable food models continues to develop rapidly and there is an urgent need to systematize its knowledge structure and thus make future research more vigorous. In this article, we will consider and discuss all about sustainable agrifood supply chain management.
Key words: Agrifood, supply chain management, sector, life cycle, optimization, information technologies, policy-maker, consumer, food production, dominance, cargo, social, bio-safety, stakeholders, agriculture.

Introduction

The agrifood sector is one of the most regulated and protected sectors worldwide, with major implications for sustainability such as the fulfillment of human needs, the support of employment and economic prosperity, the environmental impact, the tackling of poverty, and the creation of new markets. Indicatively, the European Commission is promoting significant reforms to its Common Agricultural Policy in order to respond to the plethora of internationally emerging agrifood supply challenges. Growing environmental, social as well as ethical concerns, and increased awareness supply chain management for sustainable food networks of the impact of food production and consumption on the natural environment have led to increased pressures by consumer organizations, policy-makers, and environmental advocacy groups on agrifood companies to manage social and environmental issues across their supply chains from "farm-to-the-fork" and along products' life cycles. In this context, designing appropriate effective global strategies for handling agrifood products to fulfill consumers' demand, while responding to ever-increasing changes of lifestyle and dietary preferences, has become quite a complex and challenging task. Specifically, adverse weather conditions, volatile global food demand, alternative uses of agricultural production and fluctuating commodities' prices have led to a volatile supply of agricultural products that is expected to exceed its capacity limit in the forthcoming years. To that effect, developed countries have been increasing their agricultural production in agrifood supply chain (AFSC) operations in order to respond to the projected rise of 70% on global food demand by 2050. At the same time, the value of family farms and the development of local food SCs is clearly recognized for both the developing and developed countries. One of the most critical bottlenecks in agrifood production and distribution is the complexity and cost-efficiency of the relevant SC operations.

Modern, global agrifood networks require multi-tier supply chain management approaches due to the increased flows of goods, processes, and information both upstream and

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downstream the value chain. These increased requirements are related to the modern, emerging model of agrifood retailers, the need for vertical and horizontal integration along the, the plethora of differentiated product offerings, the market segmentation, the dominance of multinational enterprises in the food processing and retailing sectors, the need for limiting food waste and overexploitation of natural resources, as well as the branding of firms. Furthermore, SCM has been recognized as a key concept for the agrifood industry competitiveness.

The rapid industrialization of agricultural production, the oligopoly in the food distribution sector, the advancement of Information and Communication Technologies in logistics, customer concerns, and a divergence of governmental food safety regulations, the establishment of specialized food quality requirements, the emergence of modern food retailer forms, the increasing importance of vertical integration and horizontal alliances, as well as the emergence of a large number of multinational corporations, are just a few of the real-world challenges that have led to the adoption of SCM in the agrifood sector.

To this end, SCM embraces the challenge to develop and deploy efficient value chains tailored to the specifications of the modern, uncertain environment, subject to the constraints of local and cross-regional conditions, with respect to logistics means and infrastructure, access to land and water resources, allocation of harvesting areas and the various processing and storing facilities, innovative and sustainable good-practice methods, regulatory and techno-economic environments, and rapid changes of food market characteristics. In order to develop competitive and sustainable (AFSCs), there are a few critical issues that have to be first recognized:

1. the unique attributes of (AFSCs) that differentiate them from other SC networks;
2. the decisions that should be made on the strategic, operational, and tactical levels;
3. the necessary policies to ensure sustainability of the agrifood chains;
4. the appropriate innovative interventions, which are required to foster major advances and competitiveness within the evolving (AFSC) context.

Therefore, more frequent changes in AfSC designs are necessary and strategic actions should be taken to foster sustainability, and thus to achieve higher efficiency in logistics' operations performance and resource usage.

In general, an AfSC is encompassing a set of operations in a "farm-to-the-fork" sequence including farming, processing/production, testing, packaging, warehousing, transportation, distribution, and marketing. These operational echelons have to be harmonized in order to support five flow types, namely:

1. physical material and product flows;
2. financial flows;
3. information flows;
4. process flows; and
5. energy and natural resources' flows.

The aforementioned operations, services, and flows are integrated into a dynamic production–supply–consumption ecosystem of research institutions, industries, producers/farmers, agricultural cooperatives, intermediaries, manufacturers/processors, transporters, traders (exporters/importers), wholesalers, retailers, and consumers. Moreover, the continuous evolution of (AFSCs), and the overall complexity of the agrifood environment along with global market trends further highlight the need for integration of individual SCs into a unified (AFSC) concept. In such a structure, strategic relationships and collaborations among enterprises are dominant, while these organizations are further required to secure their brand identity and autonomy.

Methods

Why Sustainable Agrifood Supply Chain Management

The world has encountered and is expected to face even greater volatility and related challenges in the future, including economic crises, social exclusion, and climate change, with direct impact upon business activities. The design and adoption of sustainability strategies throughout business operations has emerged as a meaningful intervention to accommodate such challenges. Interestingly enough, the concept of sustainability cannot be easily defined and is, in fact, determined by academicians and decision-makers alike. Initially, researchers and practitioners were solely focused on environmental aspects to accommodate corporate needs and drive shareholder value. nonetheless, in the contemporary global contextual framework, sustainability transcends the environmental dimensions and further relates to market competition, availability of raw and virgin materials, access to energy sources and increasing global population. Hence, the concept of the "Triple bottom line" or the "Three Pillars of sustainability has been introduced to highlight the need for a balanced approach to the three P's, namely people, profit, and planet. The aforementioned dimensions provide corporate growth opportunities emanating from the adoption of sustainable good practices.

The value proposition of linking research to sustainable development is strongly acknowledged. This is further affirmed in the most recent research and development policy documents of the European union. Specifically, the European Research Area vision 2020 calls for a focus on societal needs and ambitions toward sustainable development. The three "key Thrusts" identified by the European Technology Platform on the "food for life" Strategic research Agenda 2007–2020 meet all of the criteria required to stimulate innovation, to create new markets, and to meet important social and environmental goals.

These "key Thrusts" are:

- Improving health, well-being, and longevity.
- building consumer trust in the food chain.
- Supporting sustainable and ethical production.

While, the topic of "sustainability" is inherent to SCM, it is only during the last two decades that sustainability in SCM has attracted increased academic and business interest, further reflecting the fact that SC operations are a field where most organizations can and actually implement green strategies.

Particularly, as dictated by the third "key Thrust" that ErA articulates, food chains need to operate in a manner that exploits and optimizes the synergies among environmental protection, social fairness, and economic growth. This would ensure that the consumers' needs for transparency and for affordable food of high quality and diversity are fully met. Progress in this area is expected to have important benefits for the industry in terms of reduced uses of resources, increased efficiency, and improved governance. An overview of emerging global trends, policy developments, challenges, and prospects for European agri-futures, to the need for novel strategic frameworks for the planning and delivery of research. Such frameworks should address the following five challenges:

- Sustainability: facing climate change in the knowledge-based bio-society.
- Security: safeguarding European food, rural, energy, biodiversity, and agri-futures.

• Knowledge: user-oriented knowledge development and exchange strategies.
• Competitiveness: positioning Europe in agrifood and other agricultural lead markets.
• Policy and institutional: facing policy-makers in synchronizing multi-level policies.

Addressing these challenges could usher the European agrifood sector to the knowledge-based bio-economy, while ensuring that the sector (and food retailers) remains globally competitive further addressing climate change and sustainable development concerns, such as the maintenance of biodiversity and prevention of landscape damage. Meeting these multi-faceted sustainable development challenges facing the agrifood sector worldwide, will require a major overhaul in the current agriculture research system. recent foresight work under the aegis of Europe's Standing Committee for Agricultural research, has highlighted that in the emerging global scenario for European agriculture, research content needs to extend to address a diverse and often inter-related set of issues relating to sustainable development, including food safety/security, environmental sustainability, biodiversity, bio-safety and bio-security, animal welfare, ethical foods, fair trade, and the future viability of rural regions. These issues cannot simply be added to the research agenda. rather, addressing them comprehensively and holistically in agriculture research requires new methods of organizing research, in terms of priority-setting, research evaluation and selection criteria, and in bringing together new configurations of research teams, as well as managing closer interactions with the user communities and the general public in order to ensure that relevant information and knowledge is produced and the results are properly disseminated.

To sum up, the nature of the overall decision-making process in sustainable AFSCs is purely dynamic, as it unfolds in real-time within an uncertain environment that changes continuously bringing new challenges and opportunities. Consequently, the decisions along with the associated implemented strategies should be continuously evaluated and reconsidered in order to ensure the long-term efficiency and sustainability of an AFSC.

Results

Hierarchy of Decision-Making for AFSCs

Designing, managing, and operating AFSCs involves a complex and integrated decision-making process. This is even more accentuated when AFSCs deal, for example, with fresh, perishable, and seasonable products in the context of high volatility of supply and demand. In general, the design and planning of sustainable AFSCs needs to address a wide range of issues including crops planning, harvesting practices, food processing operations, marketing channels, logistics activities, vertical integration and horizontal cooperation, risk and environmental management, food safety, and sustainability assurance.

Strategic Level

The strategic decisions involve all stakeholders that are interested in participating in a sustainably driven SC network of agricultural goods. Thus, decisions at the strategic level of the hierarchy span the following aspects: selecting the appropriate farming technologies, SC partnership relations, design of SC networks, establishment of a performance measurement system along the AFSC, and finally, quality assurance. below, these decisions are further discussed, while a synthesis of the relevant and up-to-date research efforts is provided.

Tactical and Operational Levels

In this subsection, we discuss the decision-making process at the tactical and operational levels for managing AFSCs. we first address the common characteristics that the AFSCs display when compared with the traditional SCs and then proceed by pointing out unique and challenging issues, including the planning of harvesting and logistics operations along with transparency and traceability issues.

Harvesting Planning

The role of harvesting planning on the performance of the entire AFSC is of pivotal importance. one of the most critical issues that needs to be tackled is the extreme vulnerability of harvesting planning to disruptions, such as weather conditions and poor sunlight, plant diseases, poor soil performance, and so on. At the same time, during the planning of agricultural operations several environmentally sustainable practices must be adopted in order to reduce GHG emissions, maintain biodiversity and foster ecological resilience. These challenges are even more accentuated in the case of perishable goods, where time is a critical parameter that affects planning throughout all echelons of an AFSC. In this case, the trade-off between the quality of the products (time to reach the market) and the incurred costs (due to agrifood spoilage and wastage) needs further scrutiny and due diligence. The decisions related to the harvesting operations involved in an AFSC include: (i) the scheduling of planting and harvesting; and (ii) the effective resource management among competing crops. Throughout the literature, factors such as timing of planting and harvesting, planting varieties, fertilizer utilization, water consumption, labor scheduling, and post-harvesting operations have been recognized as very important for cost minimization and maximization of yielded quality. In addition, several researchers have adopted the concept of life Cycle Analysis in order to assess the sustainable efficiency of on-farm operations.

Emerging Trends and Technologies in Primary Production

On a global scale, GHG emissions from agriculture account for almost 14% of total emissions. Agriculture production is the most important source of nitrous oxide (n2o) from organic and mineral nitrogen fertilizers, and methane (CH4) from livestock digestion processes and stored animal manure. At the Eu-27 level, emissions from agriculture account for 9.2% of total emissions (corresponding to 462 Mt of CO2 equivalent in absolute numbers). However, this figure does not include agriculture-related emissions such as the emissions from agricultural land use (57 Mt Co2 in Eu-27 accounting for approximately 1% of the total emissions of all sectors), from fossil fuel use in agricultural buildings and agricultural machinery for field operations, which account for around 1% of Co2 emissions of all sectors [following the reporting scheme of the united nations framework Convention on Climate Change (unfCCC) these emissions are accounted in the “energy” inventory], and emissions from the manufacturing of fertilizers and animal feed. finally, it is worth noting that although agricultural emissions of N2O and CH4 rose globally by approximately 17% in the period 1990–2007, mainly due to the increased production in developing countries, during the same period in the Eu-27, agricultural emissions declined by approximately 20% mainly due to reductions in livestock numbers and the improved fertilizer applications. Additional reductions

in n2o and CH4 emissions could be achieved by various farm management practices including, among others, the overall reduction of external inputs (e.g., by employing precision agriculture principles and ICT tools), and the implementation of alternative tillage systems. These issues are further discussed in the following sections.

Conclusions

SCM is widely accepted as an area of critical importance for the agrifood sector. SC stakeholders involved in both the design and the execution of AFSCs are called to address systemically an array of complex and often interwoven decisions spanning all levels of the natural hierarchical decision-making process. To that effect, this chapter captures comprehensively and in a novel interdisciplinary framework, both the associated challenges and the complexity of the decision-making process for the design and planning of AFSCs. We began by presenting the generic system components along with the unique characteristics of AFSC networks that differentiate them from traditional SCs. we proceeded by identifying and discussing the most critical issues for the design and planning of AFSCs, along with the most relevant emerging technologies, as well as by presenting a critical synthesis of the related existing state-of-the-art literature efforts in order to identify major gaps, overlaps, and opportunities. These issues were further mapped accordingly on the recognized natural hierarchy of the relevant decision-making process. Our critical analysis reveals the following key findings:

• Even though SCs of the agrifood sector have been addressed by the research community, there is a lack of integrated systemic approaches that could support effectively the design and planning of such networks.

• There is a need for the development of appropriate channels for exchanging information and data alongside the promotion of the required mechanisms for collaboration and coordination within modern AFSCs in order to address various challenges stemming from the dynamic nature and the inherent high levels of complexity of these SCs.

• The decision-making process concerning the logistics operations should be closely interrelated to other key attributes such as transparency, food safety, and traceability.

• The integration of QMSs in the AFSCs focusing on the optimization of processes, the economy, and governance is a critical aspect for ensuring a sustainability-driven flow of information, processes, and materials.

• More integrated and sophisticated measurement systems have to be developed and standardized for the continuous monitoring and evaluation of the AFSCs' performance in terms of sustainability aspects.

• Even though in the general SCM literature there is a significant volume of relevant research, a number of core customized decisions regarding the configuration of AfSC networks are still lacking. Targeted research actions have to overcome the difficulties imposed by the structure and complexity of the relationships across an entire agrifood chain toward the development of dedicated decision-making approaches for this type of network.

• The implementation of advanced engineering and systems engineering approaches (such as satellite-based navigation, remote sensing and monitoring, and robotic systems) in primary production provides great potential to amend environmental impacts in both large-scale and small-holder agricultural production systems. In parallel, a widespread adoption of less intensive methods in terms of soil preparation and in-field traffic, are expected to reduce the agricultural impact on global Co2 balance and prevent soil degradation as a "growth medium."

We envision that the presented decision-making framework, along with the respective critical synthesis, which merge the worlds of operations management, SCM, and agriculture could provide a platform of great value for researchers and practitioners alike to build upon, in their evolving efforts toward the scientific development and management of highly competitive and sustainable AFSCs.

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