Design of sustainable supply chains for the agrifood sector: a holistic research framework

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Abstract: Agrifood sector is one of the most important economic and political areas within the European Union, with key implications for sustainability such as the fulfillment of human needs, the support of employment and economic growth, and its impact on the natural environment. Growing environmental, social and ethical concerns and increased awareness of the impacts of the agrifood sector have led to increased pressure by all involved supply chain stakeholders, while at the same time the European Union has undertaken a number of relevant regulatory interventions. This paper aims to present a methodological framework for the design of green supply chains for the agrifood sector. The framework aims towards the optimization of the agrifood supply chain design, planning and operations through the implementation of appropriate green supply chain management and logistics principles. More specifically, focus is put on the minimization of the environmental burden and the maximization of supply chain sustainability of the agrifood supply chain. The application of such a framework could result into substantial reduction of CO_2 emissions both by the additional production of other biofuels from waste, as well as the introduction of a novel intelligent logistics network, in order to reduce the harvest and transportation energy input. Moreover, the expansion of the biomass feedstock available for biofuel production can provide adequate support towards avoidance of food/fuel competition for land use.

Keywords: supply chain management, green supply chains, sustainable development, agrifood sector

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1 Introduction

The agrifood industry is a sector of key economic and political importance. It is one of the most regulated and protected sectors in the EU, with major implications for sustainability such as the fulfillment of human needs, the support of employment and economic growth, and its impact on the natural environment. According to the European Commission, more than 17 million operators and 32 million individuals are involved across the food chain (European Communities, 2008). Moreover, the food and drink sector contributes to 20%-30% of all environmental impacts in EU (Bakas, 2010). Growing environmental, social and ethical concerns, and increased awareness of the effects of food production and consumption on the natural environment have led to increased pressure by consumer organizations, environmental advocacy groups, policy-makers, and several consumer groups on agrifood companies to deal with social and environmental issues related to their supply chains within product lifecycles, from 'farm to fork' (Courville, 2003; Weatherell and Allinson, 2003; Ilbery and Maye, 2005; Maloni and Brown 2006; Vachon

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and Klassen, 2006; Welford and Frost, 2006; Matos and Hall, 2007).

Sustainability of supply chain management had gained a lot of academic and business interest during the last years (Seuring, 2012). Seuring and Müller (2008) presented a comprehensive literature review with 191 relevant papers and outline the major lines of research in the field. Moreover, in the work of Gupta and Palsule-Desai (2011), the existing literature is taxinomized under four broad categories, namely strategic considerations, decisions at functional interfaces, regulation/government policies, and decision support tools. The aim is to provide managers and practitioners with the most important issues in sustainable supply chain management decision-making. Similarly, Seuring (2012) reviewed papers on sustainable supply chains which apply quantitative models.

The aim of the proposed framework is the optimization of the agrifood supply chain design, planning and operations through the implementation of appropriate green supply chain management and logistics principles. The research objective is the minimization of the environmental burden and the maximization of supply chain sustainability of the selected product categories.

The rest of the paper is organized as follows. In Section 2, we present the emergence of green supply chain management as a key corporate strategic priority and a center of profitability, while we further focus on its importance on the agrifood sector. The proposed holistic methodological framework encompassing six thematic areas is analyzed in Section 3. Finally, we sum-up with conclusions and future research directions in Section 4.

2 Emergence of green supply chains

Although the importance of the research focal issue, that of reducing and controlling the environmental footprint of agrifood supply chains, is now recognized even from the laymen, herein we further document its value by providing a few characteristic relevant data and by summarizing the results of recent research efforts.

Today, societal stakeholders demand corporate responsibility to transcend product quality and rather extend to areas of labor standards, health and safety, environmental sustainability, non-financial accounting and reporting, procurement, supplier relations, product lifecycles and environmental practices (Bakker and Nijhof, 2002; Waddock and Bodwell, 2004; Teuscher et al., 2006). Sustainable supply chain management expands the concept of sustainability from a company to the supply chain level (Carter and Rogers, 2008) by providing companies with tools for improving their own and the sector's competitiveness, sustainability and responsibility towards stakeholder expectations (Fritz and Schiefer, 2008). Principles of accountability, transparency and stakeholder engagement were highly relevant to sustainable supply chain management (Waddock and Bodwell, 2004; Teuscher, 2006; Carter and Rogers, 2008).

More specifically, in response to pressures for transparency and accountability, agrifood companies need to measure, benchmark, and report environmental sustainability performance of their supply chains; whilst on the other side, policy-makers need to measure the sectorial performance within the supply chain context for effective target setting and decision-making interventions.

Furthermore, in order to unleash value, it is important to exploit the potential of utilizing agrifood waste and the associated by-product biomasses for energy recovery and nutrient recycling, to mitigate climate change and eutrophication which are currently unexploited (Kahiluoto et al., 2011). To that end, biomass emerges as a promising option, mainly due to its potential worldwide availability, its conversion efficiency and its ability to be produced and consumed on a CO_2-neutral basis. Biomass is a versatile energy source, generating not only electricity but also heat, while it can be further used to produce biofuels (Verigna, 2006). Iakovou et al. (2010) provided a critical synthesis of the state-of-the-art literature on waste biomass supply chain management. Agrifood biomass is usually free of toxic contaminants and is determined spatially and temporally by the respective local/regional profile of the pertinent activities. It is well documented that 31% of the greenhouse-gas emissions and more than 50% of eutrophication are related to food chains, thus highlighting the need to intervene in the agrifood supply chain to ameliorate its impact on the environment (CEC, 2006). In order to promote "green" agrifood supply chains (GAFSCs) and elaborate agrifood biomass operations on large scale, the application of appropriately designed innovative policies and systems is necessary (van der Vorst et al., 2009; Negro and Smits, 2007).

Additionally, the recent post-2009 recession period has further underlined the need to turn the business focus, across the world, not only to profitability, but to sustainability as well. Today, one of the key priorities in corporate strategic design for an organization is to emerge as socially responsible and sustainable through environment protection. Companies are structuring their sustainability reports disclosing their strategy to address the growing concerns of environmental degradation and global warming. Today, 80% of the global Fortune 250 companies release their annual sustainability report, up from 37% in 2005 (Singh, 2010). As a focal part of sustainability initiatives, green supply chain management has emerged as a key strategy that can provide competitive advantage with substantial gains for the company's bottom line. In designing green supply chains, the intent is to adopt comprehensively and across business boundaries, best practices right from product conception to the end-of-life recycling stage. Under this context, green initiatives relate to tangible and intangible corporate benefits. Sustainability reports of many companies indicate that the greening of their supply chains has helped them to reduce their operating cost with increased sustainability of their business.

The result of a recent survey conducted by McKinsey documents that green supply chain management is one of the top two strategic priorities for global corporations (McKinsey, 2011). The benefits of going green are substantial. A green supply chain can not only reduce an organization's carbon footprint but also lead to reduced costs, improved reputation with customers, investors and other stakeholders, thus leading to a competitive edge in the market and therefore increased profitability.

The importance of linking research to sustainable development is strongly acknowledged, and the framework for doing so at the EU level has been set up reciprocally in the EU renewed Sustainable Development Strategy and in the Seventh Framework Programme. This is further reaffirmed in most recent EU R&D policy documents; the Communication on "A Strategic European Framework for International Science and Technology Cooperation" and the Communication on "Toward Joint Programming in Research: Working together to tackle common challenges more effectively". Furthermore, the ERA vision 2020 (within the Ljubljana process) calls for the European Research Area to focus on society's needs and ambitions towards sustainable development. The three Key Thrusts identified by ETP Food for Life Strategic Research Agenda 2007-2020 (SRA) meet all of the criteria required to stimulate innovation, creating new markets and meet important social and environmental goals. These Thrusts are:

(1) Improving health, well-being and longevity;

(2) Building consumer trust in the food chain;

(3) Supporting sustainable and ethical production.

According to the third Key Thrust, food chains should operate in a manner that exploits and optimizes the synergies among environmental protection, social fairness and economic growth. This will further 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. In July 2008, the European Commission adopted action plans for the Sustainable Consumption and Production (SCP) and a Sustainable Industrial Policy (SIP). The plans followed a 2005 Commission communication on a thematic strategy for the sustainable use of natural resources, which calls for sectorial initiatives to be launched together with economic operators. A European Retail Forum and Retailers' Environmental Action Programme (REAP) were launched in 2008 to promote voluntary action to reduce the environmental footprint of the retail sector and its supply chain, to promote more sustainable products, and to support consumers buying "green". In May 2009, the EU sustainable food chain roundtable was launched seeking to develop a methodology for assessing the environmental footprint of individual foods and drinks by 2011. The roundtable brought together farmers and suppliers, food and drink producers, packaging firms and consumer organizations to develop environmental assessment methodologies for products and means for effective consumer communication, and to report on improvements.

An overview of emerging global trends, policy developments, challenges and prospects for European agri-futures, point to the need for new strategic frameworks for the planning and delivery of research. Such frameworks should address the following challenges:

(1) Sustainability: facing climate change in the knowledge-based bio-society;

(2) Security: safeguarding European food, rural, energy, biodiversity and agri-futures;

(3) Knowledge: user-oriented knowledge development and exchange strategies;

(4) Competitiveness: positioning Europe in agrifood and other agricultural lead markets;

(5) Policy and institutional: facing policy-makers in synchronizing multi-level policies.

Addressing these challenges can shift the European agrifood sector to the knowledge-based bio-economy, while satisfying the need for the sector (and food retailers) to remain globally competitive while addressing climate change and sustainable development concerns, such as the maintenance of biodiversity and prevention of landscape damage. Addressing these multi-faceted sustainable development challenges facing the agrifood sector in Europe and 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 (SCAR) 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; 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.

Although sustainability and environmental impact assessments have traditionally focused on agriculture (McNeeley and Scherr, 2003; Filson, 2004), researchers and policy-makers have recently made attempts to develop more systemic approaches by incorporating stages of food processing, food retailing and specifically transportation in the assessment frameworks of food supply chains (Bakker and Nijhof, 2002; Heller and Keoleian, 2003; Green and Foster, 2005). Various approaches have been developed to measure sustainability of the food supply chains that identify effects at regional, industrial, and firm levels. Some specific sustainability assessment frameworks developed for the food sector include: farm economic costing (Pretty et al., 2005); lifecycle approach to sustainability impacts (Heller and Keoleian, 2003; Blengini and Busto, 2009; Roy et al., 2009); food miles (Coley et al., 2009; Kemp et al., 2010); energy accounting in product lifecycle (Carlsson-Kanayama et al., 2003); mass balance of food sectors (Risku-Norjaa and Mäenpääb, 2007; Lopez et al., 2008; Ortiz, 2008); ecological footprint (Gerbens-Leenes et al., 2002; Collins and Fairchild, 2007; Burton, 2009; Ridoutt et al., 2010; Mena et al., 2011); and farm sustainability indicators (Fernandes and Woodhouse, 2008; Meul et al., 2009; Nickell et al., 2009; Gómez-Limón and Sanchez-Fernandez, 2010; Rodrigues et al., 2010).

Finally, there has been an emergent set of research efforts related to benchmarking and performance measurement. However, most of this research is oriented towards the improvement of individual firms or processes rather than the analysis of entire supply chains (McNeeley and Scherr, 2003; Filson, 2004). Few efforts have been made to measure supply chain performance, while the focus has primarily been on efficiency and other economic-related performance, whereas in the current research framework there is a strong emphasis on environmental performance. Thus, there is a need to capture environmental performance throughout the entire supply chain. The enhancement of such measurements by incorporating stakeholder aspects and additional environmental dimensions is rare or does not exist at all (Bakker and Nijhof, 2002).

3 Holistic methodological framework

Figure 1 exhibits conceptually the main echelons encountered in agrifood supply chains. A comprehensive framework that tackles holistically and interdisciplinary all aspects of green supply chain management in the agrifood sector should be spanning across: sustainable farming, reverse logistics (waste management and packaging reuse), green procurement and sourcing, transportation, energy consumption efficiency, green marketing, green accounting, and corporate social responsibility (CSR). To that effect, six distinct thematic areas are identified, with each of them having a number of issues that need to be tackled (Figure 2).

The interdependencies of the six thematic areas and their impact on the six supply chain management echelons are captured in Table 1.

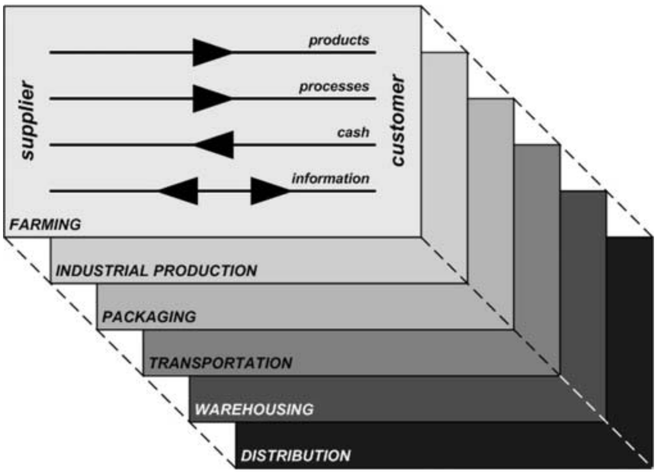

Figure 1 Supply chain management echelons.

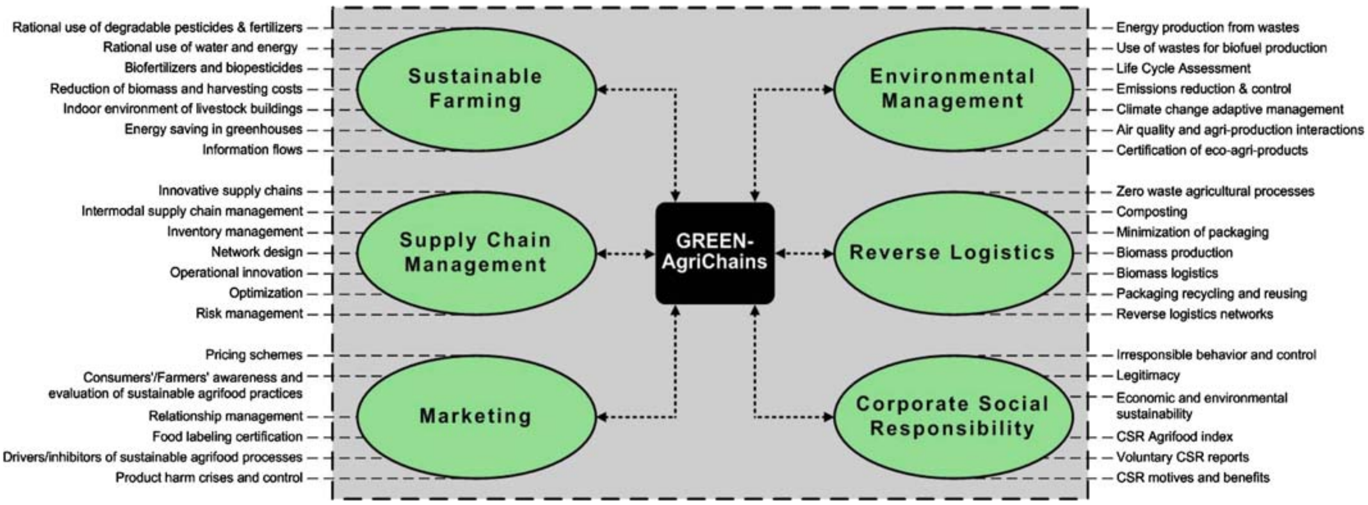

Figure 2 Conceptual framework.

Table 1 Benefits for supply chains from the implementation of green practices

	Farming	Industrial Production	Packaging	Transportation	Warehousing	Distribution
Supply Chain Management			x	x	x	x
Sustainable Farming	x					
Reverse Logistics	x	x	x	x	x	x
Marketing		x	x			
Environmental Management	x	x	x	x	x	x
Corporate Social Responsibility	x	x	x	x	x	x

Each of the six thematic areas is discussed further below, aiming to reveal the need towards the initiative taken to optimize the production chain.

3.1 Supply chain management

Focus needs to be given on sustainability improvement of supply chain and logistics operations in the agrifood industry, including research in supporting information systems and reducing the energy and pollution from transportation. Although most of the problems are sector-independent, there are few unique characteristics of the agrifood industry that differentiate traditional approaches. Such characteristics include the perishability of most agrifood products that highlight the importance of timely delivery as well as the need for developing “cold” supply chains and the requirement for product traceability along the supply chain, which is closely related to the visibility of supply chain. Indicatively, Sarkis et al. (2011) and Seuring and Müller (2008) presented a comprehensive review of issues that need to be tackled within this thematic area.

3.2 Sustainable farming

Agriculture is one of the most important contributors to today's most serious environmental problems. The use of chemicals pesticides for the weed and the pest control, the use of artificial fertilizers, the improper management of animal wastes and other wastes produced from biomass production and the use of high levels of water for irrigation, led to the degradation of the rural environment. Moreover, agriculture consumes considerable amounts of energy, either directly for operating machinery and equipment on the farm, as well as for heating of agricultural buildings (greenhouses, livestock buildings, etc.) or indirectly for the production of fertilizers and pesticides used in the crops.

Reduction of the energy use in agriculture in a sustainable manner is attained by the energy production (methane and biohydrogen) through the anaerobic degradation of the organic wastes, by the use of energy saving systems in agricultural buildings and of innovative systems for harvest and tillage. The bio-fertilizers produced after the fermentation of the animal wastes can be used instead of artificial fertilizers, the high amounts of wastewater after treatment can be used for irrigation purposes, and the use of an integrated farming system including crop rotation could minimize the use of chemical pesticides for weed and pest control. The adoption of these practices can play an important role towards attaining sustainable agriculture. Indicatively, in the work of Acs et al. (2005), the technical, economic, and environmental aspects of organic farming are thoroughly assessed.

3.3 Reverse logistics

Reverse logistics presents a critical area towards green supply chains for the agrifood sector. A special focus needs to be placed on reusing agrifood containers and recycling packaging materials or re-designing packaging to use less material. Additionally, all the operations linked to the reuse of products and materials in the agrifood supply chain, for example, the logistics activities of collecting and processing of products/ materials and used pieces, should be examined towards the direction of reassuring their sustainable restoration. Indicatively, critical issues within reverse logistics are investigated through content analysis of the published literature in the work of Pokharel and Mutha (2009).

3.4 Marketing

The main focus regarding this area is on market performance, pricing policies and customers’ satisfaction in the agrifood supply process. Goals should include inter alia pricing, relationship management (covering numerous stakeholders such as producers, suppliers and consumers). Auspiciously, Johns and Pine (2002) reviewed the literature relating to consumer studies in food industry. Specific issues that need to be tackled are:

1) Pricing scenarios based on the food characteristics (organic products presented as premium products serving niche markets) and the methods adopted for their production (e-labeling, soil fertilized with by-products, recycled water, etc.).

2) Consumers’ attitudes and behaviors towards products that result from sustainable ways of production, (i.e., products grown with renewable energy, for instance, recycled water, photovoltaic, biomass used as fertilizer, etc.).

3) Consumers’ attitudes towards eco-labeling, food

safety assurance, agrifood standards, and third-party certification.

4) Drivers and inhibitors of sustainable agrifood productions (elements such as ethics, social values, sustainability attitudes, trust, social desirability, image management constructs are considered).

5) Consumers' knowledge of organic products selling points in order to increase their selling power/efficiency.

6) Consumers' knowledge and attitudes towards agriculture entities' Corporate Social Responsibility (CSR) and Corporate Social Irresponsibility activities (CSI).

7) Whether CSR serves as a protection measurement against product harm crises (such as suppliers' and consumers' outcries and boycotts).

8) Consumers'/farmers' willingness to consume/ produce food grown with renewable energy sources (for instance recycled water, photovoltaic, biomass used as fertilizer etc.).

3.5 Environmental management

An area of great concern is associated with biodiversity, soil quality and water habitats as well as the emissions due to production and logistics operations. Environmental management of supply chains is assessed in numerous studies during the past years. Indicatively, Hassini et al. (2012) reviewed the literature on sustainable supply chains during the last decade, while Walker et al. (2008) studied the critical factors towards the implementation of "green" supply chain management initiatives. Within the proposed framework, the following issues need to be addressed:

1) Rational use of pesticides and fertilizers.

2) Rational water and energy use: consumption and nature of raw materials (including water) used in agrifood production and their energy efficiency, best irrigation practices, water planning, crop management plan.

3) Life Cycle Analysis: assessment of agrifood environmental burden throughout products' life cycle (from cradle to grave), applications of the LCA methodology to food product systems and to food consumption patterns, support of information sharing and exchange of experience regarding environmental conscious decision-making in the agrifood chain, provision of background for the sustainability of the agrifood sector.

4) Emissions reduction and control: best available techniques, greenhouse gas emissions mitigation strategies, economic and technical viability of upgrading existing installations, use of low-waste technology/less hazardous substances, comparable processes/facilities/ methods, technological advances and late changes.

5) Climate change adaptive management: impacts of climate changes on different ecosystems, consequences to agricultural production, changes in the seasonal and annual patterns of agricultural production, extreme weather events and disaster management, adaptation measures towards climate change.

6) Interactions between air quality and agri-production: crop damages from air pollution, forecasting of agricultural production, quality of food production.

7) Certification of eco-agrifood: eco-labeling, tracing of food and feed, food safety assurance, agrifood standards, third-party certification.

3.6 Corporate Social Responsibility (CSR)

The mitigation of irresponsible behavior, opportunities for corporations' legitimacy, commitment of agriculture business to economic and environmental sustainability (harmonious use of environmental and human resources, i.e., use of local communities, work equality, work opportunities to both genders, respect of minorities etc.) should be thoroughly explored. Specific issues that need to be tackled are:

1) Mitigation of resources waste, use of alternative eco-friendly power, equal opportunities (work and supply), respect of local communities (e.g., local small farmers), promotion of environmentally friendly-farming methods.

2) Use of CSR activities to promote corporate actions and strategies but not in the expense of society's interests and well-being (pollution, considering resource scarcity, i.e., use of recycling water).

3) Use of CSR activities for corporations' legitimization. For instance, large corporations could be particularly benefited, while small and medium sized enterprises could also use them as promotional tools.

4) Establish CSR agriculture Index tackling the following issues: (a) beneficial product and services, (b) pollution prevention, (c) recycling (of resources and byproducts), (d) clean energy, and (e) management systems which target social equality.

5) Production of voluntary CSR reports. A CSR publication provides accountability over and above legal obligations while competition pressures are alleviated.

6) Relationships among CSR activities, financial performance, sales increase and consumers' satisfaction/loyalty.

7) Comparing and contrasting agriculture entities' CSR and Corporate Social Irresponsibility.

8) Criteria for the detection of cases where CSR activities are intended to mask Corporate Social Irresponsibility.

9) Agriculture CSR resulting benefits (achievement of relationship management with customers, suppliers, sellers etc.).

10) Corporate Social Irresponsibility actions and their potential outcomes (such as boycotts, effects on brand image, pricing policies, and advertising etc.).

11) Adoption of CSR activities as protection measurements against product (harms) crises (such as suppliers' and consumers' outcries and boycotts).

Indicatively, Kong (2012) and Cuganesan et al. (2010) analytically examined Corporate Social Responsibility issues within the agri-food industry.

4 Conclusions

The proposed framework for the optimized design of green supply chains for the agrifood sector is expected to foster sustainable regional economic and social development in two major axes, namely rural development and agriculture sector. Taking into account that over 60% of the population of the in the EU-27 resides in rural areas, which cover 90% of the EU territory, the rural development is a vitally important policy area. Farming and forestry remain crucial sectors for the land use and the management of natural resources in the EU's rural areas. These sectors can be, also, considered as well as a platform for economic diversification in rural communities. The strengthening of rural development policy has, therefore, become an overall EU priority. The proposed framework is focused on the development of state-of-the-art supply chain management methodologies for increasing farmers' income through the optimization of the farming operations and through the reduction of the operational cost in the farm. Biomass or biofuel production can also have a positive impact on agricultural employment and rural development, particularly when conversion facilities are of smaller-scale and are, also, located near crop sources in rural districts. Finally, new crops can, also, be introduced as economically profitable alternatives to declining crops (i.e. cotton), according to the European CAP (Common Agricultural Policy).

In respect to sustainable development, the proposed framework needs to focus on the development of green operations that will lead to new environmentally benign supply chain design and operations replacing less sustainable practices. Moreover, the application of such a comprehensive framework could result into major reduction of CO_2 emissions, helping the EU to achieve at least a 20% reduction of greenhouse gases by 2020 compared to 1990 levels and an objective for a 30% reduction by 2020. This may be achieved both by the additional production of others biofuels from wastes, as well as the introduction of a novel intelligent logistics network, in order to reduce the harvest and transportation energy input. Last but not least, the expansion of the biomass feedstock available for biofuel production can provide adequate support towards avoidance of food/fuel competition for land use. The impact of the proposed framework on the Environment and Sustainable Development is thus in accordance with a number of EU policies, such as Environmental Technologies Action Plan, Common Agricultural Policy, Climate action and renewable energy package and the EU Sustainable Development Strategy.

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