Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 22, Issue 2, 2022
PRINT ISSN 2284-7995, E-ISSN 2285-3952

MAPPING SUSTAINABILITY ASSESSMENT METHODS IN AGRI-FOOD SUPPLY CHAINS: A CIRCULAR ECONOMY PERSPECTIVE

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Abstract

The agri-food sector is critical for humanity because it has mutual links to all pillars of sustainable development. Circular economy is an emerging paradigm that aims to change human and organizational behaviour and practice patterns by taking a different approach to production and consumption. A shift to a circular model tries to put a stop to the imprudent use of natural resources and replace it with a philosophy of reusing, repurposing and regenerating. The supply chains of the agri-food system constitute a significant area of intervention in the transition of the sector towards sustainability. In this vein, one may find a growing literature on existing tools, techniques and methods (such as material flow analysis, water footprint, social life cycle analysis, etc.) which can be used for the sustainability assessment of (existing and planned) agri-food networks. This paper adopts a circular economy perspective and discusses the afore-mentioned methods with respect to their potential to depict the transformation of the current inefficient, wasteful, and linear production and consumption model.

Key words: *circular economy, agri-food supply chain, quantitative methods, sustainability*

INTRODUCTION

Food systems are becoming increasingly vulnerable to change drivers, and the use of circular economy in the agri-food sector is a vibrant topic of contemporary research. Food waste is considered as one of the five priority sectors, in the EU's action plan stated in 2015. In addition, the United Nations, in the Sustainable Development Goals, established a goal of decreasing per capita food waste by half at the retail and consumer level, as well as minimizing food losses throughout the manufacturing and agri-food supply chains. Food waste is a phenomenon that takes place during production, in shops, in restaurants and catering facilities but also at home [12, 9].

According to the EU's action plan, a future step would be to create a common methodology, based on guidelines given by the Commission, and a platform for all members of the EU, in order to be able to measure the amount of food waste and to define relevant indicators but also take measures to make a clear legislative framework about waste, food and feed; make food donation and the utilization of leftover foods and by-products easier; and take actions on date marking alteration, especially the 'best before' [9].

Food systems have been characterized by traditional management approaches, and the last 50 years has been a major contributor in the environmental deterioration, natural resources depletion and pollution from field to fork [12]. Based on this, in the EU's action plan, a plan towards circular economy has been fostered.

The model of circular economy in the agri-food sector holds great potential since it could have a very important outcome, that could be beneficial for food security, create price stability, and resilience in the economy but also environmental prosperity while preserving natural resources and minimizing environmental impacts [16].

In order to be able to make an assessment on the progress towards this more sustainable production model, it is important to describe the adoption of circular economy, and the effectiveness of the plan both on the EU and the national level using reliable indicators. Eurostat, has collected relevant data, in order to form the basis for this monitoring system. At the same time a Resource Efficiency Scoreboard and a Raw Materials Scoreboard, which contain a set of indicators and analysis related to these two matters, would be a great guide in order to assess and keep a track of the progress. In cooperation with the EU Member States and the European Environmental Agency, the Commission has been developing a simple but effective set of regulations in the form of a framework for the transition to a circular economy, which will include key indicators that encapsulate the model's core aspects [9].

In this paper, the focus is mainly on the production plants, and we will try to explore the current state of measurement indices, used currently in the production and manufacturing sector, in order to better monitor and report sustainability matters as well as try to figure the ability to cooperate in a model of circularity in the agri-food sector.

MATERIALS AND METHODS

This paper is based upon, relevant bibliography that revolves around the current and emerging paradigm of circular economy with a specificity of application of the agri-food systems. The set of papers was refined after evaluation of the authors in order to form a basis to identify potential interventions of indices and certifications that are currently used in production systems and food manufacturing enterprises with the prospect of setting a higher pace in the transition of circular economy and sustainability.

It has been proposed that in order to shift towards circular economy there are five factors that need to be monitored: starting from redesigning the products, then redesigning the processes, creating innovation in the current business model, reducing or reusing of the produced waste, creating internal regulation frameworks, increasing the possibilities of collaboration, financial and fiscal stimulation, and finally altering consumer behavior make the set of the factors that need to be monitored [23].

The ReSOLVE framework has proposed a set of actions that are based on three classification criteria: Optimize, loop, and regenerate [12]. Increasing product performance and efficiency while eliminating waste across the production process and in the supply chain by developing new loops is part of the optimization of activities across the food supply chain. Reusability or even infinite life, such as glass or steel in packaging, characterizes a regeneration mentality in which resources are utilised in a cyclical manner. Furthermore, single-material usage and contamination are prevented, and new technology aimed at recovery operations is used. Indices that are used to explain and to measure in order to be able to compare the impact on several phenomena, such as climate change by measuring water or carbon footprint, energy consumption and other have been developed.

In the European Environment Agency report [10], five main categories have been introduced:

(1) Reduction of natural resource uses and input materials: the depletion of the ecosystem is currently at a high and unsustainable rate mainly caused by the effect of the traditional production model. There is a need to create more with less, preserve the natural resources and this could only be possible if the raw materials, water and energy are used efficiently.

(2) Reduction of emissions: it refers to both direct and indirect emissions of agri-food systems.

(3) Reduction of the loss of materials: reducing production energy by avoiding waste creation, limiting incineration and landfilling, and reducing waste production, and losing materials through closed-loop models, higher recovering rates, and recycling of products.

(4) Increase of the renewable and recyclable resources shares: reduce emissions throughout the whole material cycle and achieve overall reduced pollution through cleaner practices along the material cycles, reduce raw material intake and implement sustainable sourcing.

(5) Longer value durability: extension of the life of products, adopting new business models based on services that can be described

In publications made on the matter of circular economy, [7] has identified the "building blocks" for promoting the adoption of the circular economy paradigm; the framework contains four types of actions:

(1) Adapting to the circular model by redesigning the processes and the production, several actions can be taken such as eco-design methods oriented towards product re-use, refurbishment and recycling, and use of materials with less hazardous output materials.

(2) Adoption of innovative business models such as product service systems instead of ownership and customer-to-customer channels.

(3) Cascade/reverse skills in order to support closing material loops and incorporating secondary materials.

(4)Collaboration between cycles of productions and sectors, which fosters the development of a collaborative environment across the value chain, by preventing of by-products going to waste through industrial symbiosis.

[8] finally proposed a four levels framework for supporting measurement of the circular economy paradigm adoption by identifying:

(1) the processes to monitor,
(2) the actions involved,
(3) the requirements to be measured, and
(4) the implementation levels of the circular economy paradigm

RESULTS AND DISCUSSIONS

The difficulties of attaining supply chain sustainability have sparked substantial debate in the literature and among industry [11], while the circular model holds is the most promising. In order to be able to measure if a system is efficient but also to facilitate comparisons, an attempt to gather the most widely accepted indices has been made. As the physical and organizational sizes of activities grow, achieving circularity becomes more difficult. In order to improve their efficiency with a clear objective, to optimise their supply chain with effective and efficient practices taking into consideration, material flows, integration of the supply chain and the value stream [4].

Measuring indices coupled with green accounting methods can be used at the level of an organization, food processing unit as well as municipality level, country or even worldwide in order to assess and report on the sustainability levels of an organization [6].

In that way, we can consider how the universal map of flows is built and gain a deeper grasp of current biomass, nutrient, and energy movements within these systems, as well as how these flows are related at various geographical scales [14]. In this section we provide an overview of the methodological approaches that have been developed in order to tackle various sustainability issues, mostly from an environmental viewpoint. Our objective is to examine whether they could be suitable for addressing circular economy practices and challenges, despite the fact they have originally been developed for the traditional linear models.

In their study, [8] provided various methods that aim at dealing with material and energy flows as well as with aspects such as land use and consumption. In addition, currently developed indices that take into consideration social impacts are analysed.

Material flow indices include the Water Footprint which is used and as an indication shows the potential impact on the environment that is related to freshwater. The Material Inputs Per Unit of Service approach may be used to assess the effects of a certain type of material flow, such as the material input of a product, service, or process. The approach of Ecological Rucksacks refers to the entire sum of material inputs lessened by the product's mass, and it describes the influence that the items utilized have on the environment. A systematic evaluation of the flows and stocks of materials within a system characterized in place and time is described as Material Flow Analysis, which constitutes a multiple indicator-based assessment. The use of this index has increased over the last decades especially in the plastic packaging sector but also several other materials and geographical areas [19]. It is commonly used in Environmental and Economic Accounting to create the framework for internationally comparable data on the environment and its link to economic, environmental and social matters. The development of sustainable accounting and of a financing system described as ”green” is an emerging global financial centre following the evolution of the sustainable global development [21]. Through a system specified in place and time, Substance Flow Analysis is used to estimate the fluxes and stocks of particular compounds that pose a risk to the environment and human health.

A material flow analysis could support the adaptation of the methods in reducing input and use of the natural resources, as well as deducing material loss.

The indicator of the Nutrient Flow is promising in cases where nutrient recycling and bioenergy production are considered, especially in a non-compete cases with food production. A ‘Nested circularity’ supported by research based on this index suggests localizing food systems by closing nutrient, biomass and energy loops is a sustainable solution [14].

Nutrient pollution, has been studied mostly from the environmental perspective. The heavy use of pesticides and fertilization in Agriculture or wastewater treatment has been measured by applying this index, in their study [15] conclude that nutrient pollution is the most import cause of pollution of water.

Economically extended-Material flow analysis, has also been suggested as an approach for investigating the links between economically motivated human behaviour and resource use. The model proposed by [17] can be used for the analysis and the assessment of alternative strategies towards resource efficiency enhancement.

The food sector, with a starting point on agriculture and across the whole supply chain, is accountable for a percentage of about 20 to 35% according to the total global energy use during the course of its entire life cycle. While the largest amount is considered to be during agricultural production, food processing is accountable for a large amount as well [24].

There are three types of energy indices that are extensively utilized [8].

Cumulative Energy Demand encompasses all energy from raw material extraction, manufacturing, and ultimate disposal and is used to define the total amount of energy necessary to generate a product (or a service) during its entire life cycle. The Embodied Energy Index, which is a measure of the amount of energy integrated in a product and is a dependable instrument to explain the inefficiencies caused by energy consumption, is used to characterize all essential energy flows utilized to make a product or a service. Finally, Energy Analysis centers on a specific work and defines the maximum quantity that a system, a matter flow, or energy may create as it approaches equilibrium with the environment.

Energy efficiency is used as a link between energy performance and environmental impact with costs, and is an indicator that expresses the sustainability of a system and provides information such as cost of energy and loss of productivity [2].(

An energy flow measurement, in the cases of bio-based produced energy or biofuels could have a very important application. Because energy losses are difficult to quantify, especially in complicated operations, relationship equations or measured data from the literature can be quite valuable in some circumstances [24].

Consumption and Land Use indices are commonly utilized [8]. The Ecological Footprint, which is used to calculate the planet’s biological capacity as a result of human activity or population, specifies the acreage necessary, including demand for food, crops, timber, energy, infrastructural space, and the area required to absorb carbon emissions emitted. The Sustainable Process is another index that evaluates the required area to support human activities over their whole life cycle. Such measurements support decision-making and forecasting since for example, the case of the rising trend of energy consumption that was noticed between 1990 to 2010 and that raised concerns due to the increased energy and fossil resources demand [5].

It is also worth noting that calculating the land, water, or sea area necessary to supply a person's food, shelter, mobility, commodities, and services in a given region is the first step in estimating their environmental footprint. [3].

A Life Cycle Assessment (LCA) includes Single or Multiple indicator-based assessments. In the first category of single indicator assessments, the Carbon Footprint is an environmental performance indicator that measures the impact of human activities and the resulting GreenHouse Gas emissions on global climate and is measured in carbon dioxide equivalents. (CO_2 eq). It addresses all GHGs (contribution (CO, CH_4, N_2O, HFCs, PFCs, SF_6) assessed on an equivalent based to their contribution [3]. The Swiss Federal Institute of Technology has established an indicator called the Ecosystem Damage Potential, which is intended to assess the ecosystem's affects as a result of land use and change.

An Environmental Performance Strategy Map is a depiction with a transversal cost-dimension that depicts five footprints (water, carbon, energy, emissions, and work environment) in a web graph (Elia et al., 2017) [8].

LCA is a broadly used multiple indicator that has been used for several years now in order to assess the environmental impact at a macro, meso, and micro level. The ISO 14040 family has standardized it as a technique, and producing LCA involves a large quantity of data that is not always accessible, increasing the uncertainty of the conclusions. Furthermore, it takes longer than other approaches, and outcomes' communication need an experienced audience [3]. Social LCA (S-LCA) uses a similar cradle–to–grave approach to environmental LCA, but it focuses on social issues linked to the quality of life and welfare of all categories of stakeholders participating in the processes under examination (Oliveira et al., 2021) [22]. A fresh interpretation of society life cycle costing is also possible using the S-LCA model method where societal hazards are valued [25].

In their study, [20]attempted to adapt the LCA to broader spectrum that of the social and organizational level proposing the new SOLCA. The frameworks of the current S-LCA and O-LCA have the potential to be applied, but additional obstacles emerge, such as data collecting in complex organizations with several sites or the difficulty of disseminating or aggregating social characteristics inside an organization.

Through a LCA, the obtained energy quantification during food production and consumption could be the key to identify intensive activities, and revaluate these processes in order to make significant reductions [18]. Currently, the majority of research is concentrated on product evaluations, followed by sector and process evaluations [1].

The model of circular economy finds application in all three pillars of sustainable development and the micro (i.e resources, processes, products) meso (i.e. supply chain, industrial parks) and macro (i.e. national, global economy) level. The identification of the process and the extent it impacts all three levels is the starting point for an integrated assessment framework. [22].

Reporting methods such as the Global Reporting Initiative [13]. and the development of certifications and certification bodies such as B Corp related to circular economy can accelerate the transition towards its application [23].

CONCLUSIONS

At the moment most of the developed measuring methods have been optimized on the widely used linear model and the limitations of application to circularity and feedback loops is obvious. Several approaches on the application of the circular economy model have been made but the transition has not yet completed.

The circular economy model has been strongly proposed as strategy to tackle the unsustainable use of resources. The evolution and expansion of application of the measuring indices and the process behind them, has been an alert for business to the realization of resource efficiency.

The practical importance of reporting and being a certified organization could provide better circular economy based management and compel an alteration that in the long term brings results to the environmental and sustainability management as well. An alignment of businesses processes with environmental and social needs is of prime importance.

A combination of these methods or assessments holds potential for further research on measurements since any economic system has an underlying physical structure while at the same time gives a holistic view on both financial and material flows to optimize procedures on the three pillars of sustainable development.

ACKNOWLEDGEMENTS

We acknowledge support of this work by the project "SMART AGRICULTURE AND CIRCULAR BIO-ECONOMY – SmartBIC." (MIS MIS5047106) which is implemented under the Action "Reinforcement of the Research and Innovation Infrastructure", funded by the Operational Programme "Competitiveness, Entrepreneurship and Innovation" (NSRF 2014-2020) and co-financed by Greece and the European Union (European Regional Development Fund).

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