Circular Economy Solutions for the Agri-food Business

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Abstract: When we consider the long-term stability of the entire agri-food business, we are most likely at a major turning point. Recent significant disruptions in food supply chains have exposed the vulnerability of the global agri-food system, causing severe shocks to the world's food supply. The current agri-food supply chain is affected by different issues such as food loss and waste generation along the supply chain, and circular economy offers a potential solution to enhance and optimize the production and consumption process thereby achieving a sustainable paradigm shift. The article showcases several innovative solutions organized around thematic concepts.

Keywords: Circular economy, sustainability, food, agriculture, innovation

1 Introduction

In addition to the unexpected human tragedies, like the COVID-19 epidemic and the conflict in Ukraine, there are a few persistent dangers and concerns related to food and agriculture. For instance, the effects of climate change and extreme weather on ecology and the environment, crop production, agricultural resources, the supply chain, and market prices all pose a danger. For our current and future generations, pursuing a sustainable, circular route of food production and consumption is not only a viable solution but also an emerging one [1].

The circular economy concept gained momentum among scholars, industry, business and government as a more accurate concept, than green economy and green growth concepts, in dealing with environmental issues together with maintaining sustainable economic growth [2]. In particular, business enterprises started to redesign their business models based on circular economy principles, which ensures cost reductions in addition to material and energy savings [3].

According to Scott [4] , circular economy is a concept, whereas sustainability is a mechanism, which ensures the implementation of circular economy tools, projects, systems and models. However, the research, which highlighted the main differences

between circular economy and sustainability, states that the circular economy is a condition for achieving sustainability [5].

The most cited definition is from the Ellen MacArthur Foundation, which states that "circular economy is an industrial system that is restorative or regenerative by intention and design. It replaces the "end – of – life" concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models" [6, p. 6].

There are three main strategies, reduction, reuse and recycle [7]. By 2017 the number of "Rs" reached nine (Table 1) [8].

R1	Refuse	"Make product redundant by abandoning its function or by offering the same function by a radically different product or service"
R2	Rethink	"Make product use more intensive (e.g. through product-as-a-service, reuse and sharing models or by putting multi-functional products on the market"
R3	Reduce	"Increase efficiency in product manufacture or use by consuming fewer natural resources and materials. It includes the prevention of food waste along food value chains including in agricultural production, processing, manufacturing, distribution and consumption"
R4	Reuse	"Reuse of a product which is still in good condition and fulfils its original function (and is not waste) for the same purpose for which it was conceived"
R5	Repair	"Repair and maintenance of defective product so it can be used with its original function"
R6	Refurbish	"Restore an old product and bring it up to date (to specified quality level)"
R7	Remanufacture	"Use parts of a discarded product in a new product with the same function (and as-new-condition)"
R8	Repurpose	"Use a redundant product or its parts in a new product with different function"
R9	Recycle	"Recover materials from waste to be reprocessed into new products, materials or substances whether for the original or other purposes. This includes the reprocessing of organic material but does not include energy recovery and reprocessing into materials that are to be used as fuels or for backfilling operations"

Table 1.
Circular economy strategies
Source: Adopted from The EIB Circular Economy Guide [9, p. 14]

The current agri-food supply chain is affected by different issues such as food loss and waste generation along the supply chain, and circular economy offers a potential

solution to enhance and optimize the production and consumption process thereby achieving a sustainable paradigm shift. The agri-food sector is one of the main industries where action is needed to ensure the shift to a more sustainable developmental model in accordance with circular economy principles [10].

"There is a great potential through the decrease of operational costs (minimization of energy and water use, exploitation of waste, decrease in the use of raw materials, etc.), as well as through greening their brand and therefore achieving a greater share in the market." [11, p. 31]. Food companies can pursue multiple sustainability strategies thereby limiting food waste, environmental impacts of the food-packaging combination, and achieving recyclability and circularity.

2 Methodology

For research method literature review [12] and content analysis [13] was used which helped to close the knowledge gap about the origins and scope of circular economy concepts. With the aid of content analysis, researchers may methodically and relatively easily sort through massive amounts of data.

A tailored search plan was developed through relevant peer-reviewed articles from Google Scholar, EBSCO and Researchgate databases. The following search terms were utilized as well as keywords for each of the identified broader areas (Figure 1). The searches were run between January and February of 2024.

Figure 1

Word cloud for literature review

3 Innovative solutions

There are several innovative solutions available in the agri-food business that are aimed at sustainable production and consumption (Table 3).

Life-Cycle Assessment (LCA), Farm-to-Table Supply Chains, Closed-loop agricultural systems	Surplus ingredient utilization, Upcycling, Revalorization , Agropark, Environmental Biorefinery
Precision Agriculture, Smart Farming, Industry 4.0	Regenerative agriculture, No-Till Farming, Biodynamic farming, Integrated Aquaponic Systems
Seed exchange systems, Agricultural Cooperatives	Local Food Systems, Pocket Markets
Solar-Powered Farming Equipment, Solar thermal, photovoltaic modules, Biogas Plant	Circular Packaging Solutions, Reusable Container programs
Food Sharing Platforms, Food Banks, Social Eating Platforms, Food Alerting Platforms, Zero-Waste Restaurants, Social Supermarkets	Permaculture, Urban Vertical Farming, Homegardens, Community Supported Agriculture (CSA)

Table 3.
Possible Circular economy solutions grouped by concepts

3.1 Reduce

Precision Agriculture

Precision agriculture is a management approach that targets production variability with the goal of improving decision-making in agriculture. It involves using technologies such as soil sensing, satellite imagery, GPS, and GIS to measure and map soil variation, locate ground positions, and store ground information [14][15][16]. By efficiently matching resource inputs with crop needs, precision agriculture can improve crop production and reduce resource wastage. It can be used for various operations such as tillage, fertilizer application, sowing, irrigation, and spraying, allowing for more precise and intensive production [17]. Precision agriculture can also help synchronize nutrient supply with crop demand, such as variable application of nitrogen fertilizer, to improve fertilizer use efficiencies and reduce environmental impacts [18]. Overall, precision agriculture combines reactive approaches using yield maps and sensors with proactive approaches using simulation modeling to optimize land and crop management, contributing to the development of sustainable agricultural production systems.

Regenerative Agriculture

Regenerative agriculture is an approach that focuses on restoring and maintaining soil health, supporting biodiversity, and improving ecological and economic resilience [19]. However, there is currently no widely accepted definition of

regenerative agriculture, with various definitions based on processes or outcomes [20].

Biodynamic agriculture, which avoids the use of inorganic fertilizers and chemicals, is one of the tools of regenerative development [21]. Instead of using artificial chemical fertilizers and pesticides, biodynamic farming places an emphasis on increasing soil fertility through the addition of compost and animal and green manures, naturally managing pests, rotating crops, and diversifying livestock and crops [22].

Permaculture

Permaculture is a concept that originated in the 1970s and is centered around sustainable and resilient systems. It goes beyond just agriculture and can be applied to various domains such as the environment, social aspects, economy, and politics [23]. Permaculture is an interdisciplinary branch of science that addresses food security, energy, and environmental care. It involves designing sustainable human communities by combining traditional techniques with new knowledge and technologies in various fields [24]. “Permaculture is primarily a thinking tool for designing low carbon, highly productive systems" [25]. Research on permaculture provides answers on how to preserve the environment while simultaneously producing food, creating energy-efficient homes, and enhancing the functioning of urban communities [23].

Sustainable energy generation

Key energy-saving strategies in agriculture farming includes photovoltaic (PV) modules, solar thermal (T), energy-efficient pumping systems, various covering materials for improved thermal insulation, and energy generation from by-products. Anaerobic digestion is a process that recycles natural organic wastes and reduces the pollution that is typically associated with them while producing methane, a premium fuel and also residue rich in protein.

Shared resources in agricultural operations

Smaller farmers now have an alternative to leverage the efficiencies of large farms and stay competitive in an increasingly consolidated agricultural sector by utilizing machinery-sharing. Sharing can provide other benefits, including improved access to skilled labor, reduced risk, and idea sharing among peer groups of like-minded individuals [26].

Local Circular Food Systems

Local circular food systems are gaining recognition as a key strategy for achieving sustainable development goals and addressing the environmental impacts of the global food system. Implementing circularity at the city scale, particularly in urban food systems, is crucial due to their significant contribution to food consumption,

loss, waste, and greenhouse gas emissions. Designing urban food systems that embrace circular economy principles can contribute to the overall transition to circular urban metabolism. The implementation and promotion of circular economy in food systems and cities can be facilitated through the development of a conceptual model for designing urban food systems that align with circular economy targets [27][28][29].

Community Supported Agriculture (CSA)

Community Supported Agriculture (CSA) programs involve partnerships between consumers and farmers, where consumers pay in advance for farm products and farmers commit to supplying a sufficient quantity, quality, and variety of products throughout the season [30]. CSA programs are seen as a potential solution to challenges in the globalized food system and a way to promote agricultural and rural sustainability [31]. CSA aims to produce environmentally, socially, economically, and nutritionally sustainable food by sharing the risks and responsibilities of farming activities between producers and consumers [32]. CSA farms seek to create a direct relationship between farmers and those who eat their food, with farm members or shareholders purchasing shares and receiving weekly allotments of produce [33].

3.2 Reuse

Food Sharing Models

Food sharing platforms have emerged as potential solutions to address food loss and waste, as well as promote sustainability in food systems. These platforms aim to reduce food waste and incorporate sustainable objectives in their mission [34].

Three types of models have became popular:

- “the sharing for money model, which is primarily a B2C for-profit model to reduce waste and, at the same time, generate revenue (social supermarkets,)

- the sharing for charity model in which food is collected and given to non-profit organizations (e.g. food banks);

- the sharing for the community model which is a P2P model where food is shared amongst consumers” [35].

Opportunities brought about by digital technology and the sharing economy phenomenon have recently increased the number of web platforms and food sharing apps being developed by new and existing entities that operate exclusively online, as well as by existing organizations [35].

However, the adoption of digitally mediated meal sharing in everyday food provisioning practices is influenced by factors such as convenience, affective engagement, and coordination with other practices [36]. Complaints within food

sharing platforms can deter participation, and analyzing these complaints using machine learning can provide insights into user dissatisfaction [37]. To assess the sustainability impacts of food sharing initiatives, an online sustainability impact assessment (SIA) tool called The Toolshed has been developed, which allows initiatives to evaluate and communicate their sustainability impacts [38].

These initiatives, while having positive social and environmental effects, are not immune to criticism because there isn't a dominant player and there is a high degree of user fragmentation among the platforms that are currently in use.

Surplus ingredient utilization

Surplus ingredient utilization is a topic that has gained attention in various fields. Researchers have focused on developing economically viable bioprocesses to convert waste and surplus materials into valuable products such as biosurfactants [39]. In the agricultural sector, there is a need for efficient management of agri-food surplus, waste, and loss (SWL) to prevent the loss of valuable compounds and promote a circular economy [40]. Pulse processing byproducts have also been explored as a potential source of functional bioactive components, and various extraction techniques have been studied for their recovery [41]. Additionally, there is potential for consumer acceptance and preference for value-added surplus products made from ingredients that would otherwise go to waste [42]. In the context of a sintering kiln, surplus heat utilization devices have been developed to collect and utilize surplus heat, resulting in energy savings and improved product quality [43].

Reusing food leftovers for new products while preserving their nutritional and commercial value is known as upcycling. Future obstacles to the reuse of side streams include securing consumer acceptance and maintaining food safety.

Circular Packaging Solutions

Circular packaging solutions aim to reduce negative environmental impacts and promote sustainable consumption. These solutions involve the application of circular economy principles to packaging design, including strategies such as refuse, reduce, reuse, and recycle. Research has focused on developing practical design guidance and considerations for circular packaging design solutions, addressing concepts, material selection, design process, and manufacture [44]. Advances have been made in the development of biobased packaging materials, including new materials, modification techniques, and end-of-life scenarios. End-of-life factors such as sorting systems, composting options, and recycling and upcycling possibilities have also been explored [45]. Implementing sustainable food packaging solutions within circular food supply chains is crucial for protecting customers and ensuring food quality and safety [46]. The implementation and management of circular supply chain management can guide efforts in innovative

logistics packaging management, such as sustainable wooden packaging logistics [47].

3.3 Outlook

Despite the fact that circular economy is a predominant concept and many studies call for shifting from linear to the circular economy, there are still superficial transitioning practices. According to the World Business Council the circular economy transition today is up to 8.6% and there is an urgent requirement to accelerate the transition [48]. The CEPS framework research claims that the linear economy practices are still dominating in production cycles [49]. One of the reasons is that linear economy is still effective in providing economic growth, despite being a reason for our current environmental and social issues [50]. Furthermore, the authors assume that linear economy can possibly remain till the time when there is a dignified alternative "green" model for it, which functions as the old one with providing the same economic benefit and does not demonstrate any errors in the deployment [50]. An additional reason of slowing circular economy transition is consumers' behavior. According to Planning [51], consumers would rather own a product for an extended period of time than reuse it, even if doing so would cost them less. This preference is attributed to the fact that consumers are habitually irrational rather than rational, and that their behavior is shaped by routines and habits.

Conclusions

The apparent short-term strategy to minimize interruption to global supply networks is to try to limit consumption and identify alternate sources of raw materials and crops. The current crisis does, however, also emphasize how heavily most nations' food systems rely on imported inputs, including fossil fuels, fertilizers, and feed. This underlines the necessity of radically changing agriculture and food systems in order to move toward sustainability. Although the benefits of novel food production methods like hydroponics and aquaponics, short supply chains, and circular economies will probably not be seen for some time, efforts should be made to support them.

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