# A Conceptual Framework for Food Loss and Waste in Agri-Food Supply Chains: Circular Economy Perspective


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**Abstract** The importance given to Circular Economy (CE) has further increased in the Agri-Food Supply Chain (AFSC) to combat the challenges of food loss and waste which could be caused by various reasons, such as poor stock management, economic behavior and also, the occurrence of COVID-19 outbreak. The transition from linear to circularity can also enable competitive sustainability from farm to fork in AFSC, which consists of different stages: farmers, food processors, food distributors, food retailers, consumers. Food loss mainly occurs in AFSC at near-farm stages (i.e., harvesting, processing) while food waste happens in AFSC at near-fork stages (i.e., retail, post-consumption). Thus, 6Rs (remanufacture, redesign, reduce, recycle, reuse, and recover) of CE principles can offer various benefits to close the loop of the wastages along with the AFSC. In this chapter, a conceptual framework for circularity in the AFSC is proposed considering the 6Rs. Furthermore, this framework also supports the Sustainable Development Goals. The applicability of the proposed framework is examined and discussed in the case of Turkey using SWOT Analysis. Key findings indicate that there is confusion about food loss and waste issues in Turkey. In addition, the solutions and developments for FLW problem are generally focused on food waste.

**Keywords** Circular economy · Agri-Food supply chain · Agri-Food · Circularity · Food loss and waste · SDGs · SWOT analysis

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## 1 Introduction

The unsustainability of the current food system is caused by the inefficiencies that lead to loss of productivity, energy, natural resources, biodiversity [31], and increase in Greenhouse Gas (GHG) emissions, resource scarcity, climate change, and so on. Also, these inefficiencies cost approximately trillions of dollars in a year according to the Food and Agricultural Organization of the United Nations (FAO) [31]. The mismanagement of natural resources and processes can be classified as one of the reasons that cause these inefficiencies [15].

Moreover, another challenge faced by food retailers worldwide is Food Loss and Waste (FLW) which is considered as a substantial contributor to the overall generation of waste all along the supply chain [8, 21]. Depending upon different estimations about FLW, almost 30–50% of food intended for human consumption is being lost or wasted at some points of Agri-Food Supply Chain (AFSC) [26, 31, 47], and result in serious sustainability issues in terms of economic, environmental, and social pillars of sustainability [16]. Also, corresponding to the latest emerging disease COVID-19, the amount of FLW generated in households, the associated economic cost of FLW generation increased by 12% and 11%, respectively [4]. For these purposes, the current economic model based on the take-make-dispose method has been highly criticized in terms of its unsustainability lately. Therefore, the transition process of the production systems into more sustainable approaches gained momentum [15] and the transition into Circular Economy (CE) can be proposed as a solution to these issues. CE can be defined as a renewable and regenerative system that aims to reduce waste by the effective and sustainable design of materials, products, processes, and business models [7, 31, 47]. Sustainable development goals (SDGs) are necessary to guarantee the wider usage of CE principles throughout the sector and economy [6, 34]

In 2015, the Sustainable Development Goals (SDGs) on sustainable agriculture and food waste were implemented as part of the 2030 Agenda [52]. The SDGs related to AFSC are SDG-2 “Zero Hunger”, SDG-6 “Clean Water and Sanitation”; SDG-7 “Affordable and Clean Energy”; SDG-8 “Decent Work and Economic Growth”; SDG-9 “Industry, Innovation and Infrastructure”; SDG-11 “Sustainable Cities and Communities”; SDG-12 “Responsible Consumption and Production”; SDG-13 “Climate Action”; and SDG-15 “Life on Land”. In order to meet SDGs, the implementation of CE principles in the AFSC is imperative to reduce FLW and land use; recovering natural capital, biodiversity, and eco-systemic assets; and improving soil quality [15].

There are several studies in the literature focused on FLW. This study differs from other studies by supporting the circular AFSC framework with SWOT analysis of Turkey. The main motivation is the applicability of the CE principles for FLW issue in Turkey’s case. In this context, SWOT analysis has been proposed for the adaptation of the CE principles (6Rs) into Turkey to reduce FLW. Thus, the objective of this chapter is to construct a SWOT analysis-based conceptual framework for the circularity of the AFSC because wastages are becoming a crucial problem of the AFSC in terms

of sustainability (economic, environmental and social) issues. FLW were examined as an important contributor to these critical problems in AFSCs. For this purpose, 6Rs (remanufacture, redesign, reduce, recycle, reuse, and recover) of CE principles have been examined in detail to close the loop to address the circularity function in the AFSC to eliminate the FLW. Also, the concept was supported by SDGs and a framework has been presented. The applicability of the proposed framework is investigated and discussed for the Turkey case with a SWOT analysis.

## 2 Food Loss and Waste in AFSC

Around one-third of the world's edible food is estimated to be lost, discarded, or wasted in global food supply chains [17]. Food loss and waste are different from each other due to the processes in which they occur. Food loss can be defined as food that is no longer suitable for human consumption due to reasons such as spoilage, spilling, bruising, and wilting, etc. in the process up to the retail process is called food loss [16]. Recently, the shutdown of coffee shops and restaurants led to a sharp decrease in demand for milk and dairy products during the pandemic, resulting in a significant food loss of up to 80% of the milk and dairy products produced [42]. Moreover, many dairy farmers in the UK have to dispose of thousands of liters of fresh milk because of the supply chain deterioration caused by COVID-19 [5]. Food waste can be defined as food that has good quality and suitable for human consumption but is not consumed and being discarded before and after the consumption [16]. In particular, animal-based products and meat have been associated with significant waste of resources [24] that also requires large quantities of agricultural land [19].

There are many underlying reasons behind the occurrence of FLW as presented in Fig. 1. For instance, poor harvesting techniques that are combined with insufficient harvesting equipment may cause crop/grain left behind in the field. Moreover, food products harvested at the wrong time may play a critical role since deformations such as blackening, rotting, and crushing in food items occur on over-maturing food and reduce the consumable of these items. Also, the usage of chemical substances for the

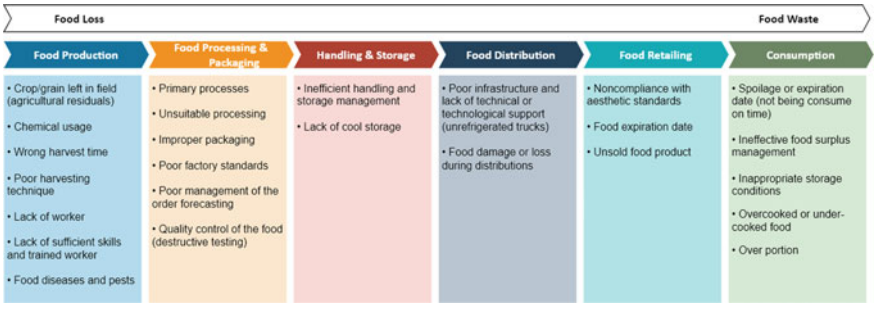


**Fig. 1** Underlying reasons for FLW at different stages of AFSC. *Source* Authors

production process of the food can pose a threat to food security and hygiene, and contamination by changing the structure of the food and affect the perishability of the food which is assumed as a low-quality food product by the consumer. Besides, an insufficient number of workers causes the product to remain in the field. Furthermore, improper harvesting and likewise loss occur when the area is harvested by workers without sufficient skills and training. According to the results of Gustavsson et al. [26] and Lipinski et al. [37], food processing and handling is the stage that has 24% of the global FLW occurred [44]. For instance, milling, cleaning, classifying, drying, winnowing and packaging, etc. are the most frequently used processes during food processing and packaging that cause FLW. In these food processing and packaging stages, FLW can occur in many ways such as damaged perishable foodstuff (e. g. seafood, fruits, and vegetables), spilled milk due to improper packaging [44]. Also, poor factory standards such as temperature, lighting, etc. can pose losses in food. Poor management of order forecasting is another crucial component that has serious effects on food losses because most used forecasting tools are generally not even close to optimal solutions and it ignores the risk of human error which unpredictable.

Another important stage that FLW occurs is the handling and storage process of food. Mismanagement of these processes can cause losses in this stage of the AFSC. Also, a lack of cool storage might be required for perishable foods such as seafood, milk, meat, etc. The lack of these systems leads to food loss as the product will spoil during the stock, and reprocessing of these products was very difficult. FLW can also occur in the food distribution stage which includes poor infrastructure and lack of technical or technological support such as improper coverage of the trucks, failure in cool storage conditions, packaging, insufficient ventilation, delays in transportation [44]. The reasons underneath food waste are determined as follows: noncompliance with aesthetic standards, food expiration date, and unsold food product. The non-compliance with aesthetic standards is usually caused by the insufficient packaging of the products or the deformation of the boxes or packages due to the impacts they are subjected to during distribution. Moreover, the food expiration date is a substantial component for the foodstuffs to be considered as waste. The close expiration dates of products often create a barrier to consumers from purchasing these products and cause products not to be sold.

The consumption stage of the food, which is also known as post-consumer, is among the stages food waste occur. Principally, not being consumed on time is one of the main reasons result in food waste which leads to spoilage and expiry date of the product. Also, ineffective food surplus management causes food waste because food surplus means a removal of the intentionally abandoned edible food, that is appropriate for human consumption, from the sale or otherwise some failures at the consumption stage due to several reasons [31]. In addition, overcooking and undercooking the food is another way that affects the quality of the food and therefore the food is not consumed and becomes a waste. Over portion can be considered as a contributor to food waste as it causes food waste due to leaving leftovers.

## 3 Circular Applications for SDGs in AFSC

SDGs were launched in 2015 to be a "blueprint to achieve a better and more sustainable future for all" as a part of the 2030 Agenda [52]. The concept consists of 17 interlinked global goals. However, the 9 interlinked global goals with a potential for circular AFSC were determined by evaluating [18], which highlighted the SDGs related to AFSC, and Schroeder et al. [45], which studied the relevance of CE principles to SDGs. The interlinked global goals are demonstrated in Fig. 2.

The principles of CE are imperative along the AFSC to achieve SDGs. CE principles can be implemented as a "toolbox" to accomplish a large range of SDGs [45]. Accordingly, FLW is also seen as the key to achieving SDGs within the scope of the farm to fork policy [11]. Thus, the main consideration of this framework is adjusting FLW flow under a circular approach with 6Rs to accomplish SDGs. The framework of circularity in AFSC is displayed in Fig. 3. Considering SDG-13, "Climate Action", the Agri-Food sector is recognized as a major sector in the production of GHG emissions, as it contains about 24% of global GHG emissions [30, 46]. Minimizing the utilization of natural resources would help reduce GHGs caused by FLW, among other pollutants [36]. Thus, CE activities such as chemical leasing and nutrient recycling in agriculture could decrease global carbon dioxide equivalent ($CO_2$-eq.) amount by up to 7.5 billion tones [13].

As the supplying process is performed through resources which are solar, water, soil, and nutrients; food production initiates three categories which are crop production, livestock, and aquaculture. Agricultural water use primarily includes this process to harvest for crop production and numerous other requirements of livestock systems, such as the need for animal water, washing facilities, etc. [3]. Commonly, primary or secondary processes of AFSC create wastewater that can be reused for


**Fig. 2** The interlinked global goals with a potential for circular AFSC. *Source* [52]


**Fig. 3** Framework of circularity in AFSC. *Source* Authors

crop production improve soil [54] after eliminating any existing pathogens [29]. In this way, following the SDG-6, a large percentage of the irrigation needs will be met by a circular approach [43]. CE practices can assist expand accessibility to clean drinking water and equitable sanitation, decrease toxicity and enhance the quality of water. These practices include such as small-scale water purification, sustainable sanitation, wastewater treatment, water reuse and recycling, nutrient recovery, biogas systems, etc. [45].

CE is considered an important element for the transformation to systems of sustainable consumption and production [53]. Moreover, SDG-12 is defined as "By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses." [25]. Less organic assets and components are used in food production by applying to reduce from 6Rs. Also, waste from consumption can be re-included in the production, processing, and packaging processes of the chain by going through remanufacture, recycle, recover, reuse, and redesign processes. Food waste has direct implications for multiple interrelated environmental impacts associated with the use of fertile soils, fresh water, fertilizers, energy, and the release of greenhouse gases for producing food [16, 24, 40]. For the inevitable FLW, the best option is its reuse, primarily for human consumption, and secondly for animal feed [46].

Food waste occurs at the end of the AFSC originating at the retail while food losses occur in the production, post-harvest, and processing stages [9]. Food waste is divided into two as edible and nonedible. Edible food is sent to animal houses for animal feeding which is an option for FLW [46], and food banks according to their types, which corresponds to SDG-2 "Zero Hunger" [25]. Nonedible food, waste from food banks and animal houses, and food loss are recruited into the loop as fertilizer, animal feed, and biomass through the formation process to provide clean and more efficient encouraging growth and helping the environment as in SDG-7. Also, when we refer to SDG-11 as "By 2030, reduce the adverse per capita environmental impact

of cities, including by paying special attention to air quality and municipal and other waste management" [25], food waste includes urban waste.

Considering SDG-8, CE approaches also could bring important benefits of cost savings, job creation, innovation, productivity, and resource efficiency in both developed and developing countries [45]. In the modest scenario, European CE job opportunities vary from 634,769; in the optimistic scenario, 747,829 by 2025 [12]. Also, new skilled jobs could be created in recycling up to 85% and remanufacturing up to 50% by 2030 in the UK [38]. The definition of the target SDG-9 is "Develop quality, reliable, sustainable, and resilient infrastructure, including regional and trans-border infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all" [25]. Accordingly, the concept of CE is "restorative and regenerative by design" [14]. CE applications redesign this industry to new and more innovative infrastructures such as renewable energy, circular water, and waste/resource management, reverse logistics, support for research, and innovation to make AFSCs more resilient and sustainable. CE practices strive to restore natural capital by utilizing sustainable and regenerative agriculture and agroforestry applications that encompass and guard biodiversity and restoring biological material to soils as nutrients that are crucial for healing terrestrial ecosystems [45]. This situation corresponds to the definition of SDG-15 "Life on Land".

## 4 Case Focus: Turkey

In this section, SWOT analysis, which is a strategic planning technique, is used to identify strengths, weaknesses, opportunities, and threats of Turkey related to circular AFSC in terms of SDGs considering Fig. 3. The SWOT matrix is shown in Fig. 4.

Turkey is a large country with the population which is more than 83 million at the beginning of 2021 [51]. Considering SDG-8, the share of agricultural employment in total employment is about 20% and Turkey ranks 12th in the world with this rate [32]. While the population of the village decreased by 11.4% between 2013 and 2020 [51], current records showing that the migration from the city to the village increased with the occurrence of the COVID-19 outbreak.

The food industry is the major sector in Turkey [33] with 7% of GDP contribution [49]. Also, agricultural production and the food industry play important roles in the economy as 30. 8% of Turkey's land is used for agricultural purposes [1]. Moreover, Turkey ranks as a significant producer and exporter of fruits, vegetables, and nuts [39]. Food supply is therefore not one of Turkey's main problems, however, the large quantity of municipal solid waste produced is a concern as FLW has not been controlled [44]. However, the lacks of the infrastructure of land consolidation and irrigation in Turkey cause high cost as well as the increase in the amount of fuel that the farmers use [10]. When the concentration is on SDG-9 and SDG-11, policy recommendations were presented for the effective implementation of support, incentives, rewards, and sanctions for a sustainable land and irrigation management [32] which corresponds to the definition of SDG-6.


**Fig. 4** SWOT analysis of Turkey related to circular AFSCs in terms of SDGs

Turkey has greatly expanded its poultry production, particularly in the last 20 years, built contemporary facilities using emerging technologies, and has become one of the world's leading producers and exporters of poultry meat [35]. Besides, Turkey has become the second country after France with 14.1 million head of cattle among the countries of the European Union in 2016 [32].

One of the most important industries for Turkey's exports is aquaculture. In tandem with the advances in the cultivation of aquaculture and the export of processing technologies for aquatic products in Turkey, there is also a major growth in the production and export of aquatic products [32]. Thus, aquaculture accounts for approximately 20% of the world's animal protein intake, actively participating in global food security and human nutrition [39]. In addition, eco-friendly production techniques are in the process of increasing traceability in aquaculture products [32].

However, the majority of the Agri-Food industry in Turkey consists of small and medium-sized companies and, in this situation, the transformation of the technical system and the efficiency and capability of production are also adversely affected [27, 35]. Also, Turkey, as a developing country, in the future will be increasingly important in the agricultural and food sectors due to its agro-strategic location that allows easy access to major markets [32]. However, the political challenges and uncertainty observed in recent years have adversely affected the sector's export capability [35].

The agriculture sector includes emissions from enteric fermentation, manure management, rice cultivation, agricultural soils, field burning of agricultural residues,

and urea application. In 2017, the agriculture sector accounted for 11.9% of total emissions in Turkey which does not cause a significant amount considering the climate action, namely SDG-13. However, enteric fermentation is by far the largest source of GHG emissions of agriculture in Turkey. Enteric fermentation and agricultural soils dominate the trends in this sector [50].

FAO [16] highlights that the amount of food wasted in Turkey are 26 million tons. 53% of fruit and vegetables are wasted until they reach the consumer from the field. Various applications to prevent FLW have been launched in Turkey. For instance, tax reductions are applied on goods for donations made to food banks [23]. Accordingly focusing on SDG-2, the retailer METRO in Turkey, performed the food donations of 164 tons (350 thousand meals) edible product (should be withdrawn from the shelves but have not passed the expiration date) in 2019 [41]. 15% of the food waste generated was also given to animal houses. For SDG-7, the company also aims to turn nonedible foods into fertilizers by sending them to the formation process which will provide a significant return to Turkey since 9.15 million tons were imported for animal feed [48]. Also, according to TGDF [48], natural gas, which is obtained from organic waste, is estimated to meet 6% of Turkey's energy needs by the definition of SDG-15 and SDG-12. In addition, AA [2] reduced food waste by 50% by donating 1,896 tons of food to feed street and forest animals, while delivering more than 4 million meals to the people who need it.

In this context, Migros and Animal Rights Federation in Turkey (HAYTAP) are conducting projects for shelter, street, and forest animals, setting out to protect the right to life of species, which is one of the basic principles of the concept of sustainability [28]. Within the scope of this project, which started in Istanbul and reached 205 stores in 24 provinces, food products such as fruits, vegetables, meat, charcuterie, and dry food that will be removed from the shelf due to the expiration date are delivered to HAYTAP volunteers. Furthermore, these products are subjected to sorting, cooking, and cleaning processes and are used for feeding shelter, street, and forest animals [28]. Moreover, the national "Protect Food" initiative was initiated by the FAO and the Ministry of Agriculture and Forestry to increase public awareness of the FLW and to unite all AFSC members [20]. Furthermore, logistics support and finance are provided by Fairy company to increase the food donation and distribution capacity of the Food Rescue Association in the regions of the Aegean and Mediterranean where food rescue activities cannot yet be carried out and those in need cannot benefit from food banks [22].

## 5 Discussion

In this work, a conceptual framework for FLW is proposed in Sect. 3. In addition, a SWOT analysis is performed for Turkey considering this framework. Through this analysis, it can be obtained that there is awareness about FLW. However, there is also confusion about the difference between food loss and waste considering the circular applications for FLW in Turkey. With this understanding, some projects are

focusing on the consumption stage but somehow aim to solve food loss. Solving this confusion is important for the applicability of the CE principles for the FLW issue since FLW is also seen as the key to achieving SDGs within the scope of the farm to fork policy.

Furthermore, Turkey mainly concentrates on food waste which occurs in the retail and consumption processes. However, there are no sufficient practices for food loss which is in the process up to the retail process. Thus, it is necessary to redesign FLW approaches to gain circular features in AFSC in terms of SDGs.

## 6 Conclusion

The redesign from linear to circular in AFSC will ensure successful sustainability from farm to fork. The emerging points in AFSC have also been highlighted by distinguishing the definitions of food loss and food waste. According to these definitions, this chapter proposed a conceptual framework for circularity (6Rs) in AFSC considering FLW to accomplish SDGs. To make AFSCs more robust and competitive, CE applications are evolving this sector into modern and more advanced infrastructures, such as clean energies, green water, and waste/resource management, reverse logistics, research support. Besides, a SWOT analysis is provided for Turkey related to circular AFSCs in terms of SDGs. Key results showed that there is misunderstanding in Turkey about food loss and waste problems. In addition, FLW problem solutions and innovations are usually based on food waste. Although Turkey is very rich in terms of biodiversity, also it has a dense population. This dense population increases the FLW level. Furthermore, the lockdown and travel restrictions caused by the COVID-19 outbreak affect greatly agri-culture and the food sector in many ways such as reducing the food sales to dining restaurants and hotels in the tourism in Turkey. However, circular steps have been taken and should be expected to provide results on FLW. The limitations of the study are the number of CE principles (6Rs) used during this framework. In this context, CE principles can be extended to offer a more precise solution to the FLW issue and eliminate the environmental effects. Furthermore, packaging processes, which have various processes depending on the characteristics of the food, are not included in this study because it requires a more specific focus on the reasons underneath FLW resulting from the packaging process. For further studies, the packaging process can be examined in more detail as an indicator of FLW.

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