DESIGNING AN URBAN FOOD SYSTEM FOR ACHIEVING CIRCULAR ECONOMY TARGETS: A CONCEPTUAL MODEL

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ABSTRACT

In exploring the strategies for reaching sustainable development goals (SDGs), the importance of circular development has been greatly recognized in sustainable studies and practices. Regarding applying the circularity concept at city scales, the United Nations Economic Commission for Europe emphasizes that transitioning to a circular economy will help city leaders achieve SDGs and other global objectives of climate actions. The food sector is a significant contributor to climate change, biodiversity loss, and land degradation, which can all be resolved via circular economy solutions. There is an urgent need for our current dominant global food systems (FS) to change due to the multiple environmental influences across the whole food value chain (FVC). This calls for the implementation of circular economy principles in FS, especially for urban systems, which account for most of the world's food consumption, loss, and waste; and for most of the world's greenhouse gas emissions. Applying circular economy principles to each stage of FVC offers various opportunities to address FS issues as they enable each actor to identify the parts they can participate in FS transition. Secondly, circular economy strategies such as localizing food chains, food wastes reduction, and reusing raw materials offer solutions to FS sustainability, connecting FS sustainability transition with the transformation of industrial food metabolism from linear to circular. Since cities play a critical role in sustainable transitions from linear to circular, pursuing a circular urban food system (UFS) benefits circular urban metabolism too. To aid the implementation and promotion of circular economy in FS and cities, this study proposes a conceptual model of designing UFS for achieving circular economy targets.

Keywords: circular economy, food system, sustainability, conceptual model, food value chain.

1 INTRODUCTION

With the growing impacts of climate change and other global environmental challenges, the concept of circular economy (CE) as one of the practical strategies toward sustainable development has attracted considerable attention in recent years. It is believed that a circular economy can provide the solutions to current global environmental challenges through a systematic approach by the following three principles [1]:

1. Eliminate and/or design out waste and pollution;
2. Circulate products and materials/keep them in use at their highest value;
3. Regenerate natural system.

At the urban level, a circular city is seen as a promising way to transit from linear to circular urban metabolism. Promoting circular cities' implementation offers pathways to close material loops, reduce and recover material and resources, reduce greenhouse gas emissions and environmental impacts, protect, and improve biodiversity, and reduce social inequities in line with the SDGs [2].

Meanwhile, the food system (FS) discourse also received growing attention in the past ten years as food and agriculture are regarded as the cross-cutting elements for the United

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Nations 2030 Sustainable Development Goals (SDGs) [3]. FS plays a critical role in realizing multiple SDGs, such as SDG#1 no poverty, #2 zero hunger, #3 good health, well-being, etc. [4]. In general, current FS faces four critical issues [5]–[7]: production gap; triple burdens of malnutrition; inequity and inequality of FS outcomes; and Unsustainability of FS.

The first issue indicates that the current global agriculture and food system cannot produce enough food for the growing population. The second narrative has three sub-issues: over-nutrition or obesity, undernutrition, and micronutrient deficiencies [5]. The third issue implies that the current food system cannot create equal and equitable benefits for all, reflecting the underlying fact that 868 million people are starving. At the same time, one billion people are overweight globally, and the differences and imbalances between the global north and south regarding food security issues. The unsustainability of FS is the last narrative of FS failures, indicating one of FS's functions as a bridge that connects human beings and/or FS actors to the nature/biosphere, ecological and environmental systems, and the broad food environments. Moreover, Ericksen [8] argues that feedback loops exist between FS impacts and multiple global environmental changes (GEC). The outcomes and impacts of FS then promote or become triggers GECs. Meanwhile, GECs become risks or causes of FS issues.

Concerning those interactions and connections, it can be argued that FS issues and GECs can be solved simultaneously through a systematic and holistic approach. Applying the lens of circular economy strategies and food value chain (FVC) views will provide huge potential in solving urban FSs, promoting FS sustainability and urban sustainability, and eventually achieving circular urban metabolism. This study proposes a conceptual model of a circular urban food system (CUFS) to aid in implementing and promoting a circular economy in FS and cities. Modified 9R circular economy strategies are employed in the model respectively. They are refuse, rethink, reduce, reuse, refill, regift/ repurpose, recycling/recovery, rot, repeat. The objective of this study is to answer the following research questions:

1. How can CE principles be applied to urban FS through each stage of FVC?
2. How can such approaches address or reduce four narratives of FS failures?
3. How can these approaches be represented by a conceptual model (i.e., CUFS)?

To address these questions, this study conducts literature reviews on urban food systems/FS, CE principles and applications on FS in Section 2. The conceptual model and explanations are presented in Section 3. Followed by a discussion and conclusion in Section 4.

2 LITERATURE REVIEW

2.1 Urban food systems (UFS)

It is assumed that UFS has the utmost potential in FS transition towards sustainability to resolve most FS issues and reduce the impacts of climate change due to several reasons. First, cities are the leading contributor to climate change and are influenced by climate change the most at the same time, implying that the role of cities/urban areas in climate change actions is irreplaceable as an inescapable part of the solution to this GEC. Additionally, FS is also one of the main contributors to GHGs and are impacted by climate change greatly; indicating that FSs play an imperative role in developing climate change strategies. Lastly, since most of the world's population lives in cities, most of the world's food is also consumed in urban areas, tightly connecting the two critical actors of climate action. In short, it can be argued that FS of the cities or UFS holds the key to one of the most promising pathways for slowing or even reversing climate change impacts.

Speaking of UFS and FS definitions, there is no comprehensive, compact, and precise definition of UFS and no unified definition of FS in the literature. According to the Oxford Martin Programme on the Future of Food [12], FS can be considered a complex web of activities, including food production, processing, transport, and consumption. While the FS approach has been widely applied to identify, analyze, and assess the interactions, feedback, and impacts of FS actors and activities [12] and for examining the issue of GECs and food security, too [8]. On the other hand, Vieira et al. [13] define UFS as FS that encompasses activities and actors relating to cities' food supply and their interactions with the surrounding natural and built environments, socio-economic dynamics, and governance. With the growing recognition of the importance of FS in climate change and sustainable development around the world, other different types of FS have been introduced into academia and policymaking, such as sustainable food systems [14], [15], city region food system [16], [17], resilient food system [18], etc.

2.2 Circular economy principles and food system

CE principles originate from industrial ecology, which aims to close the loop of resource, material, and energy flows at the smallest possible cycles and decreases resource and energy inputs and waste outputs through reusing and recycling strategies [31]. In a recent article on CE and sustainability [33], several CE definitions are illustrated with a focus on different aspects of materials preservation and economic development. For instance, they define CE as "a regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops, this can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling" [34], highlighting the key features of "restorative and regenerative" [35]. While some authors defined a circular city as "is a city that practices CE principles to close resource loops, in partnership with the city's stakeholders (citizens, community, business and knowledge stakeholders), to realize its vision of a future proof city". In speaking of FS, a circular FS means it "prioritize regenerative production, favour reuse and sharing practices, reduce resource inputs and pollution and ensure resource recovery for future uses" [21].

According to ICLEI [21], there is an urgent need for our current dominant global FS to change due to the numerous environmental effects across the whole food value chain (FVC), including the following; 1. Clearing land and changing natural ecosystems for agricultural and food production remains the top cause of habitat and biodiversity loss; Agriculture occupies about 70% of global freshwater usage; Food and beverage occupy about 40% of all plastic packaging; Over 60% of the people's calories source come from only 4 crops (i.e., maize, rice, wheat, and potatoes), and monoculture of food reduce FS resilience dramatically.

Over of the 98% nutrients in food by-products and human waste generated in cities are directly landfilled, incinerated, or discarded without reusing or recycling;32% of all food loss and wastes happen in the stage of primary production; and 44% of all food loss and wastes occur in the stage of storage and processing, usually caused by insufficient cold chain.

ICLEI [21] argues that the food sector is recognized as a significant contributor to climate change and biodiversity loss, while these two issues can be resolved via CE solutions. When applying circular economy principles to each stage of the food value chain (FVC), they offer various opportunities to address FS issues. They enable each actor to identify the parts that they can participate in transforming the FS [21]. Furthermore, Jurgilevich et al. [31] also argue that CE, such as supporting local food chains with food wastes reduction, closing the nutrient loops, and developing policies for recovering and reusing essential raw materials, will offer solutions in moving toward a sustainable FS. By applying CE principles to the food system, natural systems will be supported by food while localizing food production and clearing food waste [21].

On the other hand, food is perceived as an interconnected urban infrastructure with the growing recognition of its central role in our survival in the urban context and well-being, sustainability, and prosperity for all [29]. However, in recent years, urban FS has been increasingly recognized as not sustainable, equitable, or resilient [28]. Regarding CE principles, it can be argued that pursuing a circular UFS promotes the overall FS sustainability and benefits circular urban metabolism. Moreover, one of four guiding principles from the FAO framework for the Urban Food Agenda is "resilience and sustainability by supporting the principles of a circular bioeconomy…and reshaping development pathways by taking account climate risks and vulnerabilities in urban food system planning" [32]; implying the vital role of utilizing circular principles as a powerful strategy in promoting urban FS transitions towards resilience, inclusiveness, and sustainability.

3 RESULTS AND ANALYSES: CIRCULAR URBAN FOOD SYSTEM MODEL

The following conceptual model (Fig. 1) is intended to be used to illustrate possible pathways of applying CE principles on each stage of FVC, to offer potential strategies to deal with issues of urban FS (i.e., four narratives) and improve its resilience, inclusiveness, greenness, circularity, and sustainability. This model is inspired by and builds upon various models and approaches, including Food System Framework [8], City Region Food System Assessment by FAO and RUAF [17], Ellen MacArthur Foundation's City Self-Assessment Tool [20], ICLEI's Circular Development [21], Food Environment Framework [23], Ellen MacArthur Foundation's Cities and the Circular Economy for Food [38]. The model consists of three belts (Section 3.1) and one core (Section 3.2). Detailed illustration and related key strategies are discussed in the following sections.

3.1 The triple belt of circular urban food system (CUFS)

According to FAO [39], a food value chain (FVC) "consists of all the stakeholders who participate in the coordinated production and value-adding activities that are needed to make food products". It has been divided into several stages regarding specific contexts and/or issues. For instance, in a conceptual framework for understanding the impacts of agriculture and food system policies on nutrition and health, Kanter et al. [40] evaluate FS through seven stages of FVC, including the origin of source, production, processing, distributing, storage, marketing, and consumption. While in another conceptual framework of food systems for children and adolescents, Raza et al. [41] employed disposing and wastes stage of FVC but no storage as follows: farm level, post-harvest, processing and packaging, transportation, trade, preparation, and disposing/wastes. Some only cover five stages of FVC when constructing a food supply system respectively, they are agricultural production; food storage, transportation, and trade; food processing and transformation; food retail and provisioning; and food consumption [30].

3.1.1 The belt of food value chain (FVC)

To demonstrate a complete picture and holistic view of the CUFS, the first belt is designed to cover the following seven stages of FVC (see Fig. 2).

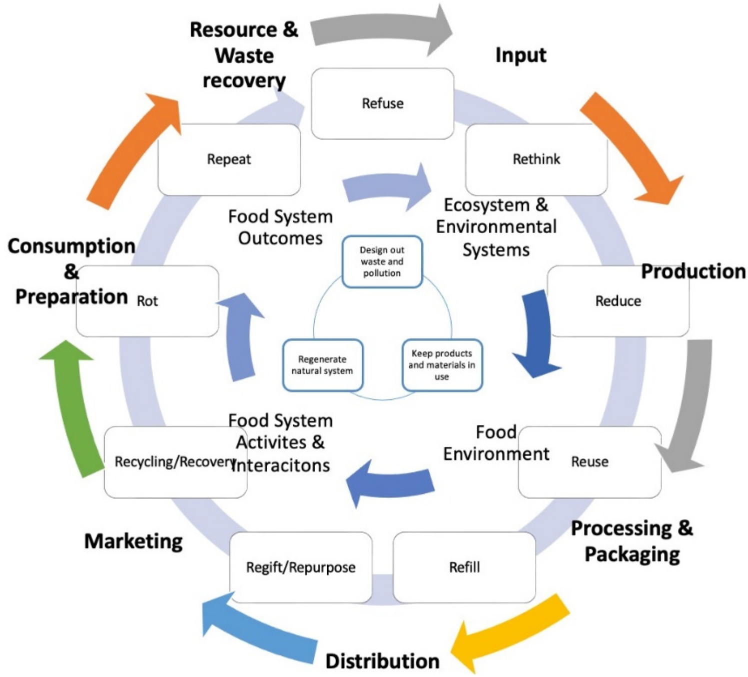

Figure 1: A conceptual model for a circular urban food system.

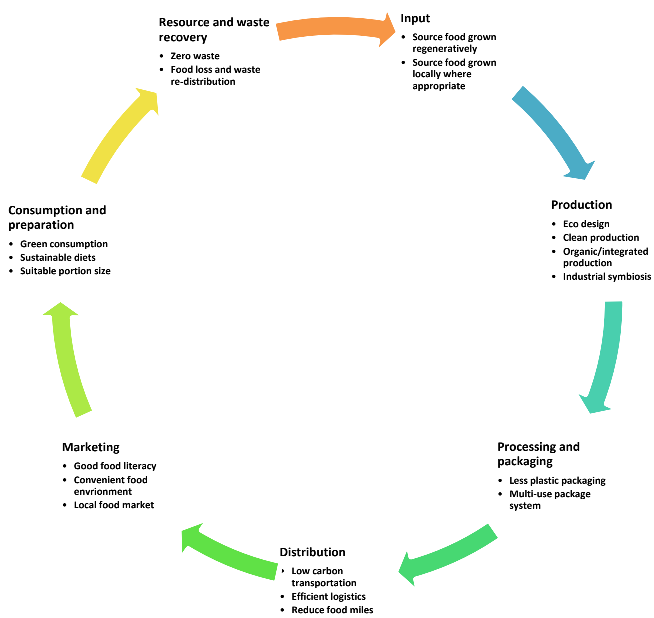

Figure 2: The belt of food value chain.

The second belt is to help identify the scope and coverage of the CUFS, it is suggested seven stages of FVC from cradle to cradle should be considered in constructing CE strategies regarding to the complex UFS issues (see Table 1).

Table 1: Seven stages of FVC.

	Elements/actors
Input	Land use, climate and weather, biosphere/ecological and environmental inputs, Ecosystem services
Production	Crop production, orchard production, livestock husbandry, forestry, managed fisheries (aquaculture)
Processing and packaging	Industrial food processing and packaging, home or warehouse processing and packaging
Distribution	Importers, exporters, brokers, wholesalers
Marketing	Retailers, local food markets, second-hand markets, sharing and exchange platform, food services and advertising, restaurants
Consumption and preparation	Catering, restaurants, home cooking
Resource and waste recovery	Source reduction, feed hungry people, feed animals, industrial uses, composting, landfill/incarnation

3.1.2 The belt of circularity

The CE consists of 12 different functions or activities. Circular Economy Asia [42] called them the "Circular Rs", including refuse, rethink, reduce, redesign, return, reuse, repair, refurbish, remanufacture, repurpose, renovate, recyclable resources, and recover. The Circular Rs are seen as standalone activities, even though they are already practiced in the linear economy [42]. Moreover, only very few can practice all the 12 Rs. For instance, in the CE business models illustrated by European Investment Bank [43], only 5Rs are considered: repair, reuse, refurbish, remanufacture, and recycle. While the Circulars City action framework proposed by ICLEI [21], utilizes a different set of 5Rs for its strategic directions, involving rethink, regenerate, reuse, reduce, and recover.

Since some of the 12 Rs are only suitable and essential to industry and business sectors, this study selects the following 9 Rs, which are the most applicable and practical for UFS to realize circularity along the whole FVC (see Fig. 3).

The second belt is to help identify the strategies for assisting CEUFS. It is suggested the nine Rs should be considered in promoting a circular economy towards sustainable transitions of FS (see Table 2).

3.1.3 The belt of food system interactions

The third belt is to help identify CE interventions of UFS at different scales. In detail, it has the following four elements (see Fig. 4 and Table 3).

3.2 The Core of CUFS

Since circularity is the main objective of our model, the core of CUFS, as illustrated in Fig. 5, is the three principles of CE [1], [38]: Design out waste and pollution; keep products and materials in use; and regenerate the natural system. For executing those three principles,

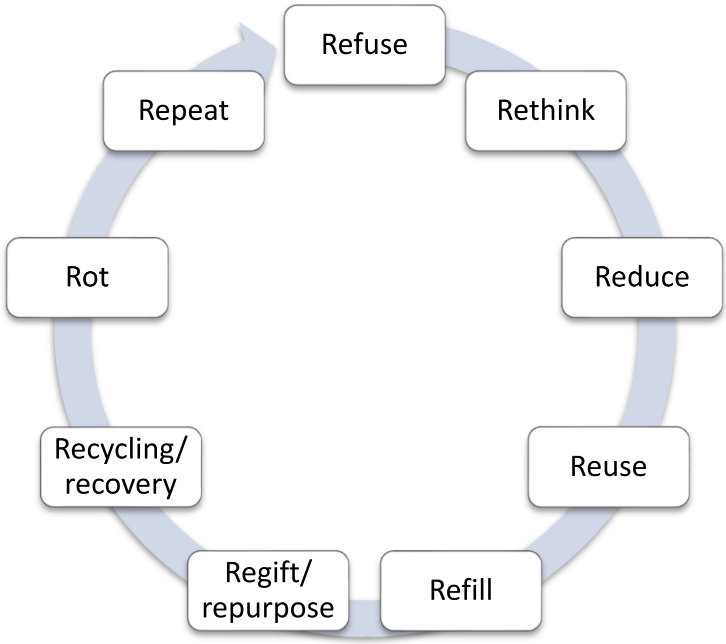

Figure 3: The belt of circularity.

Table 2: Nine Rs of CUFS.

	Descriptions/approaches
Refuse	Refuse to use unsustainable energy, materials, products, and process or there is a better alternative exists in terms of its greenness/eco-friendliness, eco-efficiency, footprints, and sustainability
Rethink	Redesign the UFS and FVC towards circular metabolism in a regenerative way
Reduce	Optimise the system and increase efficiency; reduce the consumption of energy, natural resources and material, food loss and wastes, resource and carbon footprint
Reuse	Design for extended use and reusable parts of products; improve people awareness
Refill	Design refillable products and packages; facilitate related infrastructures and regulation (e.g., water refilling station)
Regift	Facilitate second-hand markets and sharing and exchange platforms; Use a redundant product or its parts in a new product with a different function
Recycle	Recover materials from waste to be reprocessed into new things, improve the utility rate, promote upcycling, and minimize downcycling
Rot	Leverage microbial processes to turn food waste into municipal compost; biofertilizer and bioenergy
Repeat	Repeat the 9Rs cycle to promote CE strategies

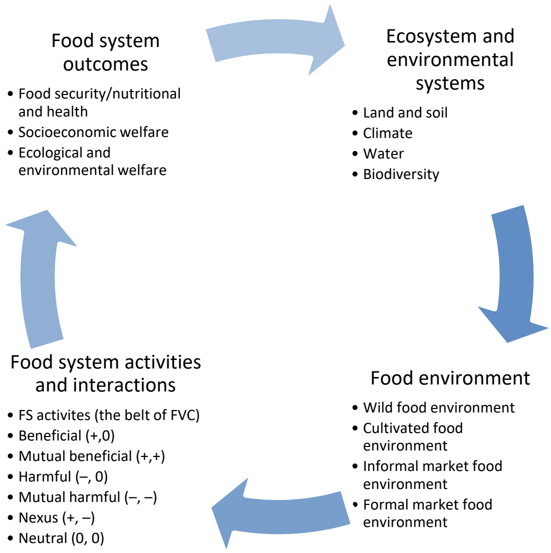

Figure 4: The belt of food system interactions. *(Source: Ericksen [8], Turner et al. [22], Ahmed et al. [23], and the authors, 2022.)*

Table 3: Four scales of FS interactions.

	Elements/actors
Ecosystem and environmental systems	Land use, climate and weather, biosphere/ecological and environmental inputs, ecosystem services (inputs of FVC)
Food Environment (FE)	Wild FE; cultivated FE; informal market FE; formal market FE
Food system activities and interactions	FVC activities (the belt of FVC); interactions: beneficial (+, 0), mutual-beneficial (+, +), harmful (–, 0), mutual-harmful (–,–), nexus (+,–), none (0, 0)
Food system outcomes/healthy and sustainable diets	Food security/nutritional and health; socioeconomic welfare; ecological and environmental welfare

the following seven themes are suggested to guide practical approaches and form a CUFS regarding the scopes and strategies from the belt of FVC (Section 3.1.1) and the belt of circularity (Section 3.1.2): eco-design; clean production; green consumption; zero waste management; equitable and equal benefits; inclusive and regenerative solution; and resilience capacity building.

It is argued that all these three core principles of CE are driven by design [1]. By considering pollution and waste are design defects [1], it's feasible to eliminate and/or avoid them at the beginning. Secondly, there are two main ways to keep products and materials in use: design the products reusable and refillable and use the materials in a circular loop.

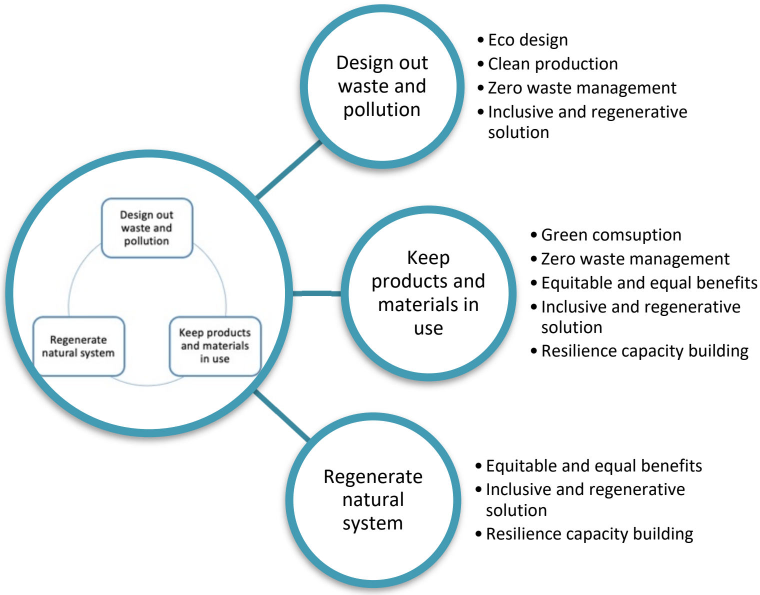

Figure 5: The core of circular urban food system. *(Source: Ellen Macarthur Foundation [1] and the authors, 2022.)*

Detailed strategies can be found in the belt of circularity (Section 3.1.2). Lastly, regenerating the natural system is the most crucial baseline of CUFS. ICLEI [21] interprets it as "harmonize with nature", highlighting the underlying basic rule of this principle is to ensure all infrastructure and interactions of producing and consumption stages benefits local resource and nutrient cycles while in deference to the natural ecosystems' regeneration rates.

4 DISCUSSION

This section discusses the results and considers to what extent the research questions have been answered in Sections 4.1–4.3.

4.1 Research Question: How can CE principles be applied to urban FS through each stage of FVC?

The three core principles of CE [1], [38] illustrated in Section 3.3 are the fundamental basis for the CE principles of Rs [21], [42], [43]. It can be argued that the Rs principles encompass the three cores while the three cores are also integral to the Rs principles. For better visualization and more comprehensive reflection, the 9Rs principles/strategies are used to show the application coverage along the FVC in Table 3. The applications of three cores can be found in Fig. 5 in Section 3.2.

Rethink, reduce, and repeat can be applied to every stage of FVC. Concerning the basis of three core CE principles, the main idea of rethinking is to redesign [1]. Thus, it can be applied by redesigning the products, UFS, incentives, and policies. All the material and energy can be reduced at each stage if using appropriate technologies and techniques for the reducing strategy. For instance, they reduce the carbon footprint by promoting renewable energy in food practices, minimizing non-recyclable packages, reducing food miles by localizing food sources, etc. Similarly, refuse, reuse, refill and regift can be applied to most FVC stages, except the waste/disposal stage, subject to the rot strategy. Detailed options can be found in Section 3.1.2, the Belt of Circularity. In a word, CE principles can be applied to each stage of FVC in UFS primarily by design with the aid of institutional and political support. Approaches built upon these seven themes are suggested: eco-design, clean production, green consumption, zero waste management, equitable and equal benefits, inclusive and regenerative solution, and resilience capacity building (see Fig. 5).

4.2 Research Question: How can such approaches address or reduce four narratives of FS failures?

Since CE approaches aim to keep material and sources in use while reducing extra waste, it will boost productivity and efficiency, hence reducing the production gap and FS unsustainability. Only a few approaches can reduce the triple burdens of malnutrition for the triple burdens of malnutrition. For instance, provide a better food environment and smaller portions, increase food literacy and labelling, promote food sharing platforms, etc. Such approaches can encourage people with higher food security levels to eat less. In contrast, re-distribute and/sharing excessive food with the hunger may reduce the number of people suffering from obesity and hunger at some level. Additionally, reducing monoculture of food sources, favour local food, and education for improving food literacy can reduce the incidences of micronutrients deficiencies. Moreover, a repurposing strategy like food sharing can also benefit from lowering the third FS narrative – inequity and inequality. Since part of their root cause is uneven distribution and shortages of resources and materials, CE approaches offer opportunities to address the causes of FS inequity and inequality.

Lastly, the unsustainability of FS directly links to the environmental impacts of the current linear FS and/or FVC. Besides improving the efficiency and utilization rate, CUFS is also dedicated to respecting local natural ecosystems' regeneration rate [21], contributing to a long-lasting balance between FS activities and natural environments. Moreover, CUFS' themes like eco-design, clean production, green consumption, zero waste management, and resilience capacity building can contribute to environmental sustainability directly. The other two themes, including equitable and equal benefits and inclusive and regenerative solutions, can promote social and institutional sustainability. And undoubtedly, CUFS has absolute advantages in terms of economic sustainability.

4.3 Research Question: How can these approaches be represented by a conceptual model (i.e., CUFS)?

CUFS consists of 3 belts and one core part to represent this conceptual model's scopes, strategies, scales, and subjects. The Belt of FVC (Section 3.1.1 and Fig. 2) indicates seven detailed stages covering the whole lifecycle of any food and/or food products to determine the scope of different contexts of issues. The Belt of Circularity (Section 3.1.2 and Fig. 3) represents 9 CE strategies that can be applied to multiple stages of FVC. The third Belt of Food System Interactions (Section 3.1.3 and Fig. 4) is designed to help define specific scales for different scenarios and situations, involving four main parts from the wider outside biosphere to abstract outcomes or individual activities. The core of CUFS (Section 3.2 and Fig. 5) is based on three core CE principles, aiming at providing guides to set specific subjects to each design of CUFS with seven proposed themes.

5 CONCLUSION

Current research on UFS with CE is minimal. The urgent need to resolve GECs, such as mitigating climate change impacts, food system issues, and rapid urbanization, enhancing the resilience, circularity, inclusiveness, and sustainability of the urban food system, brings a silver lining to address some of these GECs. With three core principles and 9 Rs strategies of CE, this study illustrates a conceptual model of CUFS. It provides potential pathways for developing such a system and offers optimal options for implementing CE interventions to boost the overall urban metabolism and urban sustainability. This study is limited by time, data scarcity, lack of literature, and case studies. Future directions may include indicator development for this conceptual model, case studies, circular cities, and CUFS, examining technological barriers of CUFS, roles of agroecology and/or urban agriculture in developing CUFS, trade-offs between circularity and efficiency, and so on.

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