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Enabling circularity for food safety: the rooftop farming model

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Abstract

Population growth, environmental change, urbanization, consumption patterns, waste, the global political climate, conflicts, and infectious diseases all exert a strain on global food security. Access to sufficient and nutritious food is becoming increasingly problematic, particularly for individuals living in less developed and developing countries. More individuals are becoming aware of the significance of developing a "Green Economy" approach to ensure global food security. A multifaceted strategy is required to ensure global food security. This study emphasizes the need for regional self-sufficiency for the transition to a green economy, and as a model proposal, it is suggested that it would be beneficial to encourage and develop farming operations on the roofs of residential, commercial, and public housing in urban regions. Rooftop farming, as one of the urban agriculture practices, can be utilized as a strategic instrument to achieve a variety of key aims, including enhancing the local economy, reducing inequality, internalizing responsible production and consumption by society, improving the quality of urban life, and more. Furthermore, because of the novel production processes seen in urban agriculture, circularity in production and consumption, a key component of the transition to a green economy, can be realized. "Self-sufficiency" is one of the concepts underlined in this study. The study also includes real-life cases highlighting the potential benefits of rooftop farming.

Keywords: Food security, Self-sufficiency, Circular economy, Urban Farming, Rooftop farming

INTRODUCTION

If the current situation continues, the world population is expected to reach 10 billion by 2050 (UN, 2017), and the urban population will also increase to 66% (WHO, 2016). Many reasons, such as the ever-increasing global food demand, the physical distance between production and consumption locations, intensive agriculture, and livestock farming shaped by gene technologies, synthetic fertilizers, and pesticides, will lead to further increasing pressure on the ecosystem (Boneta et al., 2019).

It can be said that agricultural land is declining, especially due to the increasing urbanization rate and increasing population, and traditional food production, which is largely based on agriculture and livestock farming, is no longer sustainable in terms of environmental costs in its current state. These developments also pose a food security problem. The situation has been exacerbated by COVID-19, which

has hampered the international food trade (Xi et al., 2022). In addition to population growth, the increasing demand for food due to protein-intensive and high-calorie diets is considered an important problem (Godfray et al., 2010). Due to these stated circumstances, the need to rethink food systems emerges. It is observed that the number of academic debates and research focusing on the green economy is increasing. It can be said that efforts to create an academic conceptual framework in this direction will not be meaningful on their own unless they are supported by practice. For this reason, innovative practices supported by innovative perspectives are needed.

In the literature, it is seen that recommendations for ensuring food security are concentrated on more efficient production or more limited consumption (Beltran-Peña et al., 2020). Examples; reducing meat consumption and preferring a diet based on plant-based consumption, lowering food waste, increasing yield in production in existing arable areas, ensuring efficiency in resource use in production, and using environment-friendly irrigation (Davis et al., 2014; Kummu et al., 2012; Garnett et al., 2013; Pretty, 2018; Springmann et al., 2018; Rosa et al., 2018).

The rate of urbanization has made it necessary for food production areas to be increasingly located near the main consumption centers (Gupta & Mehta, 2017). The approach of "food self-sufficiency", which refers to the ability to provide the necessary food within the city or country borders, has a long history (Ligutti & Rawe, 1940). It is aimed regionalizing food systems by increasing local food production and thus shortening supply chains (Zasada et al., 2019). The phenomenon of self-sufficiency in food has made urban agriculture practices more popular. Through urban agriculture, food crops are grown within the city boundaries, and urban dwellers have access to healthy, fresh produce (Hume et al., 2021). While urban households historically supplemented their foods from their gardens, in times of economic upswing (e.g. Industrial Revolution, post-World War II) has been experienced a shift from producing food at home to sourcing food products produced in different geographies from distribution channels (Burgin, 2018). Rooftop farming may be considered a model to meet food safety in a circular way (improve air quality, heat flow, and reduce corridors for local flora and fauna) (Skanavis et al., 2017). Gupta & Mehta (2017) state that rooftop farms can help achieve six important sustainable development goals of the United Nations. These are:

Food Security

According to the Food and Agriculture Organisation of the United Nations (FAO), which estimates that the global population will rise by one-third between 2009 and 2050, and already 9.3% of the world's population (approximately 689 million people) has problems accessing food (Manríquez-Altamirano et al., 2020). Climatic changes and the increase in the number and impact of natural events with destructive effects (droughts, floods, storms, etc.), plant and animal diseases, epidemics, and increases in the costs of production factors (water, electricity, fertilizers, pesticides, oil, etc.), the use of land for animal feed or bio-fuels instead of food, relatively small fluctuations in global supply or demand can lead to large fluctuations in international prices, speculative or manipulative price or supply interventions on foods, increasing urbanization rate, changing lifestyle and food consumption patterns, and increasing spoilage and wastage make access to food increasingly difficult (Wong et al, 2020; Misselhorn et al., 2012). It is also estimated that every one (^{0}C) degree increase in global warming will lead to a 10 per cent decrease in the suitable agricultural land (Despommier, 2013). These conditions have made 'food security' an issue that is being discussed, debated, and researched more and more every day. Financial, energy-based and food crises, as a result of globalization, have made the fragility and interrelatedness of lifestyles more salient (Kinda, 2021). Especially after the 2007-2008 food crisis, food security has become more questionable in some countries and food self-sufficiency has become an important goal of agricultural policies. Possible global food shortages are considered a national security issue (Clapp, 2017).

The fluctuations in world food markets, which started with the COVID-19 pandemic, led to a different level of concern with Russia's attack on Ukraine. Global epidemics, decreases and fluctuations in agricultural output depending on climatic change, the use of food as a political trump card in international relations and many similar factors have made the issue of food security more topical than ever (Clapp, 2017).

Food Self-sufficiency

Food self-sufficiency means the ability of a country to provide the food it needs through its domestic production (FAO, 1999). Food self-sufficiency was set by the first six members of the European Union as an objective of their agricultural policy in the 1950s and 1960s (Zobbe,

2001). However, towards the end of the 20th century, as globalization increased its influence, the approach of food self-sufficiency began to be disregarded.

Food security and food self-sufficiency are not the same concepts. Food security focuses on the accessibility of food regardless of its source. In this respect, it does not matter where the food is produced; it is sufficient for consumers to have access to food. However, the concept of food self-sufficiency focuses on reducing imports and supplying food requirements based on the geography of the country. There is no avoidance of food imports in food security (Wegren & Elvestad, 2018). Clapp (2017), defines food self-sufficiency on a national basis as a country's ability to produce at least as much food as it consumes. She has created the information in Table.1 by taking into account the categorization developed by FAO. In the table, the point at which food production equals food consumption is indicated by 100 and is expressed as the point where self-sufficiency begins.

Table 1. Food Self-sufficiency Situation of some Countries

	Food Self-sufficiency Ratio		
	<85%	=85-115%	>115%
Consumption equal to or above a balanced diet	Produce less food than they consume, and meet their food requirements. The hunger rate is < 5% e.g.: Japan, South Korea, Greece, Italy, Mexico, Kuwait	Produce food close to what they consume, and can meet their food requirements. The hunger rate is <5 % e.g.: South Africa, Brazil, Germany, Turkey, Austria Sweden,	Produce more food than they consume, and can easily meet their food requirements. The hunger rate is <5 % e.g.: Canada, Australia, Argentina, USA, Hungary, Kazakhstan, Russia,
Consumption below the balanced diet rate	Produce less food than they consume, and have a high hunger rate is >25% e.g.: Liberia, Zimbabwe, Namibia, Bolivia, Haiti, Mongolia, Yemen, Mozambique	Produce food close to what they consume, and have moderate (5-25%) and high (>25%) levels of hunger e.g.: India, Tanzania, China, Guinea, Cambodia, Malawi, Chad, Zambia	Produce more food than they consume, and have low to moderate levels of hunger (5-14.9%) e.g.: Guyana, Vietnam, Thailand, Paraguay

Source: Clapp (2017)

According to the table, countries such as Australia, Canada, Argentina, Russia, and the USA stand out in terms of self-sufficiency, and Liberia, Bolivia, Zimbabwe, Namibia, Yemen, Mongolia, Haiti, and Mozambique are the countries that are the farthest away from self-sufficiency. Even if a country has the necessary natural, financial and economic resources, vision, management skills, infrastructure and distribution systems, effective agricultural programs and policies to become fully self-sufficient, dynamics such as comparative advantage, political and economic relations between countries may prevent this. A country cannot be expected to isolate itself from global markets based on food self-sufficiency.

In practice, very few countries are able to achieve food self-sufficiency (Wegren & Elvestad, 2018). The traditional meaning of food security favors interaction between markets. Increased trade volume is thought to be in favor of food security (Dithmer & Abdulai, 2017). In a sense, food self-sufficiency is contrary to the spirit of globalization. Because it will lead to a decrease in the integration between countries and foreign trade volume. Since a country with a food surplus cannot export the surplus, the excess supply will lower domestic prices, which may lead to production cuts. However, instability in commodity prices due to economic, political, or climatic factors enables countries to put food self-sufficiency on the agenda as a protective measure. They develop various strategies to increase self-sufficiency to be minimally affected by the anomalies brought about by unpredictability. These can take the form of increasing domestic food production, expanding the modes of production, improving the distribution of domestically produced food, improving food production technologies, reducing food loss, waste, and hoarding, and even aligning domestic consumption levels with supply (Gráda, 2009).

Innovative Approaches for Food Safety

The world's population is increasing day by day. In 1950, the population was approximately 2.5 billion and reached approximately 6.08 billion in 2000. As of 2021, approximately 7.9 billion people live in the world, and with the same growth rate, it is estimated to be 9.7 billion in 2050, and 10.4 billion in 2080. Similarly, the rate of urbanization is also increasing. The global urbanization

rate of 50% in 2009 is expected to increase to 68% in 2050 (UN, 2018). The increasing population and urbanization rate create significant pressure on nature (Deelstra and Girardet, 1999). The current economy and development model have come under increasing scrutiny as the effects of climate change have become more apparent, and efforts to adopt an environmentally friendly growth model have increased (UNEP, 2009). The abandonment of the linear economy model and the transition to an environmentally friendly circular economy have been discussed more and more in recent years. The green economy approach can be considered an important political tool to ensure food security. Through various innovative tools and strategies to be developed within this approach, global monitoring, strategy development, and management capacity can be established.

Urban Agriculture

When the history of humanity is taken into account, it is seen that there have been some breaking points where paradigmatic changes in production and consumption patterns have occurred. With the Industrial Revolution, a new phase was entered in production technologies, and logistics facilities were carried to a higher level than ever before. Similarly, after the two world wars, war technologies evolved into production technologies. These revolutionary developments in production and distribution have undoubtedly increased consumption opportunities and facilitated consumer access to goods and services. This has resulted in radical transformations in consumption patterns. Until the Industrial Revolution, consumption was limited to local production possibilities. Goods and services produced in geographically close neighborhoods were purchased, and agricultural and animal production was processed to be consumed within the year with storage techniques such as drying, salting, canning, etc. The family's main source of nutrition was the small gardens and fields near the house. Surplus food was distributed or exchanged among neighbors, friends, and/or relatives. In short, the physical distance between the places of production and consumption was quite short. With the transition to modern times, especially in industrialized countries, the role of local production in meeting the family's food needs has declined significantly. Grapes started to come from Chile, computers from Taiwan, and bottled drinking water traveled thousands of kilometers (Unmüßig et al., 2012). Increasing urbanization has been a major accelerator. However, situations that pose a threat to food access (such as economic and financial crises and wars) have once again highlighted the importance of micro-scale agricultural activities. For example, during World War I (1917-1918), 'amateur gardeners' played an important role in overcoming food shortages (Cole, 1993). Moreover, during extraordinary periods such as the Great Depression and the Second World War, home gardens were able to produce more than 40 per cent of fresh food in the USA (Burgin, 2018). More than %50 human being currently live in urban areas. This rate is estimated to reach 70 per cent in 2050 (%66 for least developed regions and %86 for the most developed regions) (Parfitt et al., 2010). The fact that cities are responsible for using %75 of the global resources (TFPC 1999), however, they only account for 2 per cent of the global surface area, makes it necessary to position cities in a critical position for food security (Kumar et al., 2019). Globalization and increasing urbanization have caused the food supply chain in the world to spread over long distances. The place of production is separated from where the products are consumed, leading to long transport distances and associated environmental impacts (Grewal & Grewal, 2012). The continuous development of infrastructure in cities also leads to increased demand for energy, water, food, and other resources. The intensity and impacts of many environmental problems such as decreasing availability of natural ecosystems, poor air quality, polluted water, the urban heat island effect, and the loss of natural habitats have become serious (Goldstein et al., 2016). It is estimated that food production in the world will decrease by more than 50% and the population will reach 9 billion by 2050 due to climate change (Kumar et al., 2019). All these changes, trends, and forecasts indicate that there will be more pressure on food security (Corbould 2013; Buehler & Junge, 2016; Shrestha et al., 2020) and a need for a sustainable food supply in cities (Lawrence et al., 2022). A food security problem is of great concern globally due to the intense environmental impacts of urban populations, limited agricultural land resources, and the fact that traditional agricultural production can technically be increased to a certain extent, consumption patterns are no longer sustainable, there is widespread waste, and traditional and industrial agriculture are becoming increasingly difficult. Worsening global warming and climate change will make traditional agricultural activities more difficult, risky, and uncertain. Therefore, innovative strategies are needed to increase the production of food crops without any detrimental impact on the environment (Grard et al., 2015). Discussions on urban metabolism are becoming increasingly important (Meerow et al., 2016), and resource flows, food security, and regional self-sufficiency are receiving increasing attention (Zasada et al., 2019).

Urban Agriculture Concept

Urban agriculture has a long history. Examples of urban agriculture, which developed as a measure against the food security problem of cities that emerged with the establishment of cities, date back to Ancient Egyptian societies and examples can be found throughout history until after the world wars (Calvet-Mir and March, 2019). The fight against climate change, the search for alternatives to traditional commercial agriculture that have a larger carbon footprint, the adoption of

sustainable agricultural methods, and the aim of reducing and overcoming environmental depression, economic bottlenecks, and social problems as well as meeting the needs and demands of people are important motivators for urban agriculture (Wong et al., 2020; Yusoff et al., 2017). There are the following definitions of urban agriculture in the literature:

> "Raising food crops and livestock in an urban environment to feed the local population" (Pfeiffer et al., 2014:1),
>
> "An urban design solution to the environmental impacts of urban food needs" (Goldstein et al., 2016:984),
>
> "Food or animal cultivation or processes carried out in urban areas or around urban centers to generate income" (Yusoff et al., 2017:272).

Urban agriculture, which is considered a complement to rural agriculture, includes different scales from commercial agricultural facilities to household-level production (van Veenhuizen, 2014) and is widely practiced by society in areas of rapid urbanization, cities, and towns (Yusoff et al., 2017). It is estimated that urban agriculture provides about %15-20 of the world's food supply (Gerster-Bentaya, 2013; Nadal et al., 2017). Urban agriculture activities can be carried out in small-intensive urban farms where traditional agriculture is practiced, in public spaces such as schools, in the gardens and/or roofs of residences and businesses, on balconies and windowsills (Burgin, 2018; Schupp & Sharp, 2012). The term Zero-Field Farming (ZFarming) is used for urban farming activities that do not use agricultural land or open space (Buehler & Junge, 2016). However, there is currently no taxonomy to categorize urban agriculture practices (Goldstein et al., 2016).

Benefits of Urban Agriculture

Urban agriculture has become an area of increasing interest. This is based on increasing urban food demand, global and local environmental impacts, and growing concerns about food security (Sanyé-Mengual et al., 2018). Urban agriculture, which can be realized in different urban settings and in different forms, contributes positively to the economic, social, and environmental sustainability of cities (Ackerman, 2011). There are many studies in the literature on the potential benefits of urban agriculture. For example, Goldstein et al. (2016) grouped these benefits into three categories: supply chain efficiency, urban symbiosis; on-site environmental benefits. The proximity to urban processes makes urban agriculture a viable practice to increase food security by reducing the environmental impact of long transportation distances in the conventional food cycle (Buehler & Junge, 2016). Because of its proximity to other urban processes, it can contribute to closing the urban metabolism cycle and achieving sustainability goals by reusing urban waste products as agricultural inputs (Hume et al., 2021). Crop planning that takes into account the region's consumption preferences, demand volumes, and fluctuations, and high-yielding food crops can enable environmentally and cost-effective, efficient production and consumption, and can be useful to avoid waste (Sanyé-Mengual et al., 2016). For example, in conventional food production, the average distance of arrival is estimated to be 2800 km on average (Peters et al., 2009). In addition to the environmental destruction caused by this transport, it also causes waste due to the loss of freshness and spoilage of food products. According to Peters et al. (2009), the distance traveled by food can be reduced to 49 km by reorganizing the food system.

In the literature, the benefits of urban agriculture are generally expressed under the headings of environment, economy, and social (e.g. Hui, 2011; Noseir, 2014), but some studies (e.g. Yusoff et al., 2017) also include a fourth category called health and nutrition. In this study, as a result of the literature review, Table 2, which includes the benefit categories of 'environment, economy, social structure, health and nutrition, education, and motivation', was created and shown below.

In addition to the benefits mentioned above, there are also some difficulties in the implementation of urban agriculture. High investment costs, the need for structurally sound multi-story buildings, the need for technical knowledge for soilless agriculture applications (such as aquaponics, hydroponics, and aeroponics), and the need for artificial light during periods of lack of sunlight can be given as examples of these difficulties. There is also a misperception that urban agriculture is "unnatural" (Specht and Sanyé-Mengual, 2017), especially for systems that move away from traditional agriculture (e.g. soilless agriculture). This may slow down the acceptance and popularization of such systems.

Types of Urban Agriculture

Although there is no clear taxonomy in the literature, different types of urban agriculture can be mentioned, ranging from family and community gardens to commercial ventures (Opitz et al., 2016). For example, Yusoff et al. (2017) identified three types of urban agriculture: community farming, vertical farming, and rooftop farming. Each approach has similar practices and objectives but also has some distinctive characteristics. Urban farming types are differentiated according to the purpose(s) of the establishment (food security, contribution to the family budget, local development, education, R&D, social motivation, aesthetics, etc.), scale, and level of technology utilization. These activities can be carried out both indoors and outdoors. There are urban agriculture types known as vertical agriculture, greenhouse agriculture, container agriculture, roof agriculture, reserved area agriculture, and warehouse agriculture. The applications can be soil-based, as in

Table 2. Benefits of Urban Agriculture in the Literature

Benefit category	Description of benefit	Author(s)
Environmental	Reducing water use, eliminating or minimizing the need for pesticides and fertilizers thanks to soilless/closed field applications	Ercilla-Montserrat et. al. (2018)
	Reducing the burden on agricultural land and new landscape opportunities	Thomaier et. al. (2015)
	Development of environmental management skills	Lydecker & Drechsel (2010), Lanarc-Golder (2013)
	Increasing urban biodiversity	Howe & Wheeler (1999), McClintock (2010), Arosemena and Hammond (2012), Guitart et. al. (2012), Smith et. al. (2013), Sanyé-Mengual et. al. (2013)
	Saving up to 95% in water use thanks to aeroponic and hydroponic methods	Kalantari et. al. (2018), Perez (2014)
	Can help remove potentially hazardous wastewater	Möller Voss (2013)
	Reducing urban heat island effects	Chen & Wong (2005), Grewal & Grewal (2012), Haberman et. al. (2014), Johnson et. al. (2015), Hussain et. al. (2020)
	Can help manage municipal waste for food production	Shrestha et. al. (2020))
	Prevents overuse of natural resources and high waste production	Deelstra & Girardet (1999).
	Wastewater (recycling of rainwater and domestic wastewater) and organic solid waste can be turned into resources for the cultivation of crops	Hussain et. al. (2020)
	Potential to integrate the requirements of agricultural production into the flow of resources in the city (supporting the circular economy)	Xi et. al. (2022).
	Contributes to reducing the environmental impact of consumption by providing food from remote farms without the need for transport	Puri & Caplow (2009)
Economic	Utilization of idle areas for agricultural purposes and bringing them into the economy	van Veenhuizen (2006)
	Ability to reduce food waste throughout the supply chain	Despommier (2013)
	Growing fresh produce all year	Despommier (2013)
	It also can attract new investment opportunities	Toledano (2019)
	It can produce a much larger amount of food per square meter compared to traditional forms of agriculture	Kalantari et. al. (2018)
	Can grow a variety of crops at any time throughout the year	Platt (2007), Sivamani et. al. (2014)
	Shortening urban agri-food supply chains	Van der Schans & Wiskerke (2012)
	High-quality niche products can be sold at high prices	Hinrichs (2000)
	Development of local and environmentally friendly economies	Howe & Wheeler (1999), McClintock (2010), Arosemena and Hammond (2012), Guitart et. al. (2012), Smith et. al. (2013), Sanyé-Mengual et. al. (2013, 2015), Altieri et. al. (1999), Bon et. al. (2010), Kortright & Wakefield, (2011), Nadal (2015), Manríquez-Altamirano et. al. (2020)
	Reduced food costs by saving on transport, storage, and product loss due to local production of food	Puri & Caplow (2009), Manríquez-Altamirano et. al. (2020), Goldstein et. al. (2016)
	Local job creation	Manríquez-Altamirano et. al. (2020)
	From an economic point of view, urban agriculture also has a positive impact on job creation	Surls et. al., 2015

Table 2. Benefits of Urban Agriculture in the Literature (continued)

Benefit category	Description of benefit	Author(s)
Social	Urban revitalization through increasing green areas for recreation purposes	Wackernagel & Rees (1996), Yusoff et. al. (2017)
	Establishing economic confidence in society	Giedych (2015), Lyson et. al. (1995), Yusoff et. al. (2017)
	Helps reduce the problem of food shortages and limited space for agriculture	Giedych (2013), Smith (2005), Yusoff et. al. (2017)
	Improving food safety	Kalantari et. al. (2018), Carney 2011, Goldstein et. al. (2016), Badami & Ramankutty (2015), Maxwell (2003)
	It can build a strong and vibrant partnership and enhance social cohesion	Yusoff et. al. (2017)
	Increased social interactions, contribution to social and cultural integration, social development	Boneta et. al. (2019), Feenstra (1997), Sharp et. al. (2002), Lachowycz & Jones (2011), Yusoff et. al. (2017)
	Can support the low-income group of society	Shrestha et. al. (2020)
	Increased social well-being, sense of community cohesion, and political participation	Armstrong (2000), Hale et. al. (2011), Morgan (2015)
	Social welfare and social resilience	Yusoff et. al. (2017), Morgan (2015), Mok et. al. (2014), Tornaghi (2014)
Health and Nutrition	Healthier nutrition	Kumar (2015), Yusoff et. al. (2017)
	Increasing green spaces can support public health	Shrestha et. al. (2020)
	Increased organic fruit and vegetable consumption and exercise	Mansfield & Mendes (2013), Taylor & Lovell (2012), Wood et. al. (2020)
Education	Bringing urban people back to nature, opening minds to global issues, and educating children about the natural life cycle of the landscape environment	Cabannes (2006), Yusoff et. al. (2017)
	Green training opportunities	Yusoff et. al. (2017)
Motivation	Promote individual food production	Block et. al. (2012), Vogl et. al. 2004, Ercilla-Montserrat et. al. (2019)
	Awareness of climate change prevention	Lwasa et. al. 2014
	Promote sociocultural relations	Calvet-Mir et. al. (2016), Zasada 2011
	Promoting the participation of young people and voluntary workers and skills development for job training programs	Pfeiffer et. al. (2014), Wood et. al. (2020)
	Ideas for beautifying the environment	Okvat & Zautra (2011)
	Leisure activities and exercise	Lachowycz & Jones (2011)
	Development of aesthetic values	Yusoff et. al. (2017)
	Urban self-efficacy, well-being, self-satisfaction, lifestyle, and urban sustainability	Hamilton et. al. (2014), Specht et. al. (2016), Mok et. al. (2014)

traditional agriculture, or in the form of hydroponics, aquaponics, or aeroponics, which are becoming increasingly widespread and use much less water. High-rise commercial and residential buildings and buildings belonging to government institutions can be used for these purposes (Xi et al., 2021). In Almeria (Spain), the largest vegetable producer in Southern Europe, soilless food production is carried out in greenhouses, and most of the vegetables sold in the market are produced using soilless techniques (Specht and Sanyé-Mengual, 2017). Urban agriculture practices vary in all corners of urban environments and ecosystems. Many studies have reported that urban agriculture is practiced on floors, balconies, roofs, and walls of buildings (Hui, 2011).

Roof Farming as Urban Agriculture Practice and Examples

Rooftop farming has become one of the most popular urban agriculture practices in the last 20 years. Rooftop farming practices are sprouting up around cities (Mok et al., 2013). Rooftop farming is the establishment of an ecosystem on the roof of any building, regardless of its intended use (residential, commercial or public), using different methods. In addition to plant products, livestock production (such as poultry, and bee breeding) can also be carried out. Rooftops can be used open and/or closed

and can be established and operated with or without soil. Even the most primitive planting of perennial plants or herbs in pots or large planting beds can become an important food source when economies of scale are achieved. In developed countries, especially shopping malls and large roofs of production facilities in organized industrial zones can be used to provide economies of scale. Real-life examples of rooftop farms that can offer many concrete outputs such as reducing the potential of cities to create heat islands, reducing energy costs by providing insulation of buildings, ensuring circularity by using rainwater and waste food for production purposes, a rich landscape visuality, developing the local economy, reducing the environmental pressure caused by supply from long distances thanks to local consumption, social integration are given below.

"FOOD from the SKY"

Thornton Budgens supermarket in North London has created a rooftop permaculture garden of organic fruit, vegetables, and herbs with the "Food From The Sky" project. The aim of the project is summarized as increasing the food security of the community and proving that food products can be grown in cities and sold efficiently locally without waste. Starting in 2010 with 10 tons of compost and 300 recycling bins, the project collects enough produce to be sold every Friday with the support of more than 20 volunteers.

"Trent Rooftop Garden"

Trent University in Canada has an (educational purpose) rooftop garden. The garden provides food for the university restaurant. The Rooftop Garden was first established in 1996 as a laboratory on the roof of Trent's Environmental Science Complex. The project leader, Professor Tom Hutchinson, was fascinated by the food-producing capacity of urban areas and established this agroecosystem. In addition to being a research space, it contributes to the education of students. Despite its small size, about 500 kg of crops are harvested annually in this area.

"Rooftop Garden for Hotels"

A 4,000-square meter rooftop garden has been installed on the 14th-floor roof of the Fairmont Royal York hotel in Toronto, Canada. The freshly harvested herbs are used in approximately 6000 meals a day served at the hotel during the summer months. In addition to herbs, tomatoes, beans, and various fruits are also grown.

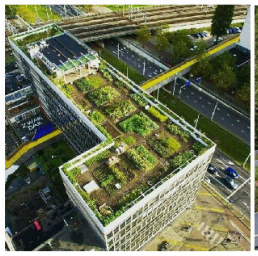
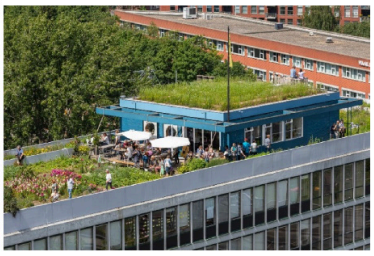
"Rooftop Garden for Hotels"

"Eagle Street Rooftop Farm"

Rooftop Farm is an internationally renowned, commercially operated 6,000-square meters rooftop farm producing organic vegetables on top of a warehouse in Brooklyn, New York. Offering seasonal produce, the farm's customers are restaurants in the area. The farm offers apprenticeship programs throughout the season and volunteer opportunities.


"Brooklyn Grange"

Brooklyn Grange was founded in 2010 and builds green spaces and hosts educational programs and events. It promotes sustainable urban living by expanding access to locally grown produce. The 5.6-acre rooftop farm is spread over three rooftops and produces around 50 tons of organic food per year. Their produce is sold at farmers' markets and through retailers. In addition, more than 30% of their harvest is sent free of charge to community members with limited access to wealth. They also run workshops that have helped educate thousands of students.

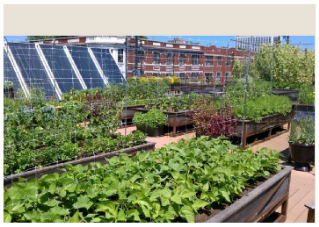
"Dakakker"

DakAkker is a 1000 m2 rooftop farm located on top of an apartment building in Rotterdam. The largest open-air rooftop farm in Holland (and one of the largest in Europe). DakAkker was established as an example of utilizing old buildings to provide alternative food sources within the city (Milanovic et al., 2018). It produces fruit and vegetables for sale to local restaurants, grows edible flowers, and has six beehives.


"Rooftop Farms for Restaurants"

Rosemary's restaurant in New York uses the products grown in the garden on the roof of the establishment in its kitchen.

There are many examples of restaurants with this concept in developed metropolises. Uncommon Ground, a restaurant in Chicago, likewise offers local food produced on its roof to its customers. So much so that it has received the title of the country's first certified organic rooftop farm. All of the perennial vegetables and herbs that are grown on the roof are included in the menu.

"Lufa Farms"

Lufa Farms in Montreal, Canada, produces 40 crops throughout the year, using cost-effective hydroponic methods. It provides food for 0.2% of Montreal's population. It is estimated that only 14 such greenhouses on the roofs of shopping centers would be sufficient to feed Montreal (Maughan, 2015). With a vision to create a better food system that includes local agriculture of all shapes and sizes on rooftop farms, the business delivers thousands of food baskets of rooftop-grown vegetables directly to thousands of customers every day.


"Gotham Greens"

This business was established in New York in 2009 and works in urban agriculture. Lettuces, herbs, and sauces grown throughout the year are distributed fresh locally. One of its facilities (established in Chicago in 2015) is the world's largest rooftop greenhouse (about seven thousand square meters). According to the enterprise, which defines itself as farmers living in apartments, they see green fields where others see gray. This business strives to help put better food on tables through environmental, educational, and community initiatives by partnering with local schools, community leaders, and non-profit organizations.


CONCLUSION

Global food security is under increasing pressure from population growth, climate and other environmental changes, urbanization, consumption patterns, wasta, the global political climate and conflicts, and infectious diseases. Increasing challenges to equitable food access hinder access to adequate and nutritious food, especially for people in less developed and developing countries. The need to develop a "Green Economy" approach to global food security is increasingly recognized. A multifaceted approach is needed to ensure global food security (Misselhorn et al., 2012). This is because the food security problem is multi-scale and cross-sectoral in nature. Addressing this problem requires various actors to work to ensure continuous improvements in human development and reduce pressure on the environment. In this context, especially in recent years, innovative business models have been sought to ensure food security through the green economy phenomenon. In addition, a green economy should be compatible with natural cycles and obtain and process food from regional ecosystems (Unmüßig et al., 2012).

In this study, the importance of regional self-sufficiency for the transition to a green economy is tried to be emphasized and as a model suggestion, it is tried to be expressed that it would be useful to encourage and expand farming activities on the roofs of residential, commercial, and public housing in urban areas. When we look at the past, we see that urban agriculture has been used especially in periods of high social stress. World wars are good examples of this (Mok et al., 2014). The COVID-19 pandemic has also highlighted the current food insecurity problems and once again emphasized the importance of local food production (Lal, 2020). Urban agriculture has become more important than ever before with the addition of factors such as bottlenecks in traditional agriculture due to global warming, the environmental burden caused by global food mobility, and the use of food as a political tool in international relations (Hume et al., 2021).

Urban agriculture has the potential to ensure food security (Nogeire-Mcrae et al. 2018). It can overcome many challenges facing traditional agriculture, such as climate change, loss of arable land, rapid population growth and urbanization, depletion of water resources, and soil pollution due to chemical pesticides and fertilizers (Kozai et al., 2016). In addition, thanks to the innovative production approach witnessed in urban agriculture, circularity in production and consumption, which is an important element of the transition to a green economy, can also be achieved. One of the concepts particularly emphasized in this study is "self-sufficiency". This self-sufficiency is an important approach to food security. Increasing localization in food production can provide economic independence and regional development (Calvet-Mir et al., 2012). In addition to ensuring food security, the proposed rooftop farming model can also help reduce the footprint of food production (use of rainwater, reuse of food waste in production processes, up to 95% less water use, no need for fertilizers and pesticides used in traditional agriculture, etc.), community education and participation, and strengthen ties between communities (Yusoff et al., 2017). Real examples of these potential contributions of rooftop farming were also included in the study. The introduction to the study also includes Gupta & Mehta's (2017) view that rooftop farms can help achieve six key sustainable development goals (SDGs). These are zero hunger, health and quality of life, industry, innovation, and infrastructure, sustainable cities and communities, climate action, and life on land. However, following a literature review and case studies, it is recognized that rooftop farming is also an opportunity to help achieve the other four SDGs. These are:

In summary, the systematic spread of rooftop farming as one of the urban agriculture practices in cities can be used as a strategic tool for the realization of many critical situations such as strengthening the local economy, reducing inequalities, internalizing responsible production and consumption by society, increasing the quality of urban life, and ensuring food security. Especially in the first quarter of the 21st century, when research and discussions are intensifying for the transition to a green economy, rooftop farming can make a difference as a multidimensional practice based on circularity instead of a linear economy.

The role of central and local governments in the process (policy development, planning, promotion, providing financial incentives, organizing trainings, etc.) is also critical for success. It is believed that rooftop farming will provide significant improvements in terms of sustainability with a systematic approach in which geographical information systems are actively used, location-dependent food types are identified and local distribution is planned with knowledge-based modern technologies.

In this context, new academic discussions and research are a must. With the increase in the number of empirical

studies centered on rooftop agriculture in the literature, it is clear that this strategic approach will find more application areas. Academic research should first focus on calculating the potential of rooftop agriculture for different geographical locations and then analyze techniques to increase the productivity of rooftop agriculture and improve the distribution channels of urban agriculture.

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interest

The author declare that for this research article, he has no actual, potential, or perceived conflict of interest.

Author contribution

The author read and approved the final manuscript. The author verify that the Text, Figures, and Tables are original and that they have not been published before.

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