

Review

Opportunities and Constraints for Creating Edible Cities and Accessing Wholesome Functional Foods in a Sustainable Way

Katarzyna Świader ^{1,*} , Dražena Čermak ², Danuta Gajewska ³ , Katarzyna Najman ¹ , Anna Piotrowska ¹ 
and Eliza Kostyra ¹ 

¹ Department of Functional and Organic Food, Institute of Human Nutrition Sciences, Warsaw University of Life Sciences (SGGW–WULS), 159C Nowoursynowska Street, 02-787 Warsaw, Poland

² Faculty of Food Technology and Biotechnology, University of Zagreb, Pierottijeva 6, 10000 Zagreb, Croatia

³ Department of Dietetics, Institute of Human Nutrition Sciences, Warsaw University of Life Sciences (SGGW–WULS), 159C Nowoursynowska Street, 02-787 Warsaw, Poland

* Correspondence: katarzyna_swiader@sggw.edu.pl; Tel.: +48-22-593-70-47

Abstract: Malnutrition, food security and food safety will remain major global issues as the world's population grows and the consequences of climate change prevail, so we need to rethink how we grow and source food to create sustainable systems for future generations. Edible cities, as innovative solutions to use public spaces for urban food production, can bridge this evident gap between the present and the future. The aim of this review was to analyze the opportunities and constraints for creating edible cities and accessing wholesome functional foods in a sustainable way and explore existing solutions that can be strengthened. We can grow food in urban environments using ideas such as controlled-environment farms (CEAs), home food gardens on balconies, roofs and terraces, underground farming and foraging. As citizens become more aware of complex foods with nutritional benefits, we should take this opportunity to teach them about edible wholesome functional foods and how they can be grown instead of using plants. There are still many constraints such as pollution, a lack of government support and the economic aspects of urban farms that need to be resolved in order for edible cities and access to functional foods in them to become the standard worldwide. The goal is worthwhile as citizens would benefit from climate control, reduced resource consumption, a safer food supply, improved mental and physical health, reduced malnutrition and nutritional deficiencies and connected communities that share knowledge and resources to further innovation and welfare.

Keywords: edible cities; functional food; malnutrition; opportunities; constraints; sustainability



Citation: Świader, K.; Čermak, D.; Gajewska, D.; Najman, K.; Piotrowska, A.; Kostyra, E. Opportunities and Constraints for Creating Edible Cities and Accessing Wholesome Functional Foods in a Sustainable Way. *Sustainability* **2023**, *15*, 8406. <https://doi.org/10.3390/su15108406>

Academic Editors: Luigi Aldieri and Colin A. Jones

Received: 31 March 2023

Revised: 14 May 2023

Accepted: 18 May 2023

Published: 22 May 2023



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1. Introduction

Today, most of the population growth is occurring in cities and especially cities in developing countries. The United Nations [1] have predicted that cities will be responsible for taking in all of the growing population in the next 40 years while also accepting the population from the rural areas. Estimates from 2018 stated that by 2050, about 50% of the world's population will be living in cities and requiring clean water, food, energy and many other things [1]. However, data from 2021 shows that this number has already been surpassed, with 56% of the world population living in cities. The number is currently expected to rise to 68% by 2050, which would account for new 2.2 billion urban residents [2]. Cities cover only 2–3% of the land area, but they are responsible for consuming roughly 75% of the world's energy while generating about 80% of the CO₂ emissions, massive amounts of waste and air pollution and vast water utilization [3].

As the population numbers rise, the agricultural sector is expected to produce larger quantities of food that is safe to consume and, at the same time, combat the environmental stressors of climate change and the loss of biodiversity [4]. In the process of building a modern city, many traditional and rural ties, such as localized food production, are

lost as the urban residents enjoy the benefits of a globalized food system. Cities spread and take over surrounding farmlands to accommodate newcomers as they migrate from rural to urban areas. This impacts the food systems to switch to producing food based on intensive agriculture and food products that are expected to have a longer shelf life. These globalized food systems are also responsible for the overproduction of food and changes in food choices leading to overweight, obesity and malnutrition, pollution of the natural environment such as air and water and decreasing biodiversity by favoring a small number of high-yield crops [4,5]. Our global food system is in need of a transformation to more sustainable practices.

There is a growing body of research on urban farming [6–8] and edible cities [9–11], but there is a lack of data about the usage of functional food of plant origin in the concept of edible cities that can give citizens better access to the valuable food. The aim of one semi-systematic review [12] was to identify evidence that answers specific research questions: (RQ1) What is the idea behind edible cities and what wholesome functional foods can be used there? (RQ2) What are the opportunities and constraints for creating edible cities and accessing wholesome functional foods in a sustainable way? (RQ3) What do we know about the solutions that already exist? The review focuses on functional foods of plant origin which make up the majority of foods in a planetary health diet, a form of a sustainable diet that integrates the needs of human health with the environmental impact of food production [13]. Another important segment is the convenience of growing food over keeping animals for food, since they require less space and resources to grow.

To evaluate these research questions and provide adequate answers, the Web of Science, Scopus, PubMed and Google Scholar databases were screened for articles published under different keywords in the topics or titles fields. To answer RQ1, the databases were screened for the following topics and titles: “edible city”, “urban agriculture”, “functional food”, “wholesome food”, “green tea”, “wheatgrass”, “ginko leaves”, “lemon balm”, “basil”, “aloe vera”, “olive”, “rosemary”, “oregano”, “parsley”, “rapeseed oil”, “avocado oil”, “black soybeans”, “adzuki beans”, “flax”, “chia”, “sunflower”, “fenugreek”, “oats”, “barley”, “date”, “plum”, “mulberry”, “fig”, “apple”, “chokeberry”, “pollen”, “edible flowers”, “garlic”, “ginseng”, “carrot”, “beetroot”, “reishi”, “cordyceps”, “champignon” and “shiitake”. To answer RQ2, the main keywords used were “sustainable agriculture”, “urban farm”, “urban farming”, “vertical farming”, “urban gardens”, “urban gardening”, “rooftop garden”, “urban foraging”, “urban malnutrition”, “climate change”, “urban pollution”, “soilless farming”, “edible schools”, “underground farm”, “aeroponics”, “hydroponics”, “aquaponics”, “controlled environment farm”, “agrivoltaics”, “balcony vegetables”, “balcony fruits”, “food safety”, “food security” and “government action”. In order to prepare the answer to RQ3, the databases were screened for research articles with keywords such as “edible city” and “solution” or “example”. Articles were eliminated if there was no access to the full document or if the title and abstract did not align with the topic of our research questions. Further elimination was based on reviews of the full text of the articles. Other articles were added using cross-references in the bibliography of the selected papers, and gray literature was added using cross-references in the research. It was important to include these findings as they provide insight into the newest advances and innovations that are not yet covered by traditional academic publishing databases.

2. The Idea behind Edible Cities and Wholesome Functional Foods That Can Be Used in Them

2.1. Understanding the Concept of Edible Cities

The concept of edible cities is covered in numerous research papers and has been mentioned in case studies from cities around the world. Even so, there has not been a clear, unified definition of what edible cities are, and many authors try to give their own view and include more factors that contribute to the concept of an edible city. The idea of an “edible city as nature-based solution (NbS) is to use public spaces for urban food production to generate multiple environmental, social and economic co-benefits” [11]. Moreover, it is

“understood as a local, action-based strategy targeting desirable goals relevant for sustainability transformation” [14]. “In terms of edible cities, the goals are to foster social cohesion and quality of life, human-food connection (HFC) and pro-environmental behavior” [11]. Edible cities include community gardens, which are defined as “a type of open space that is planted collectively with vegetables or flowers by local members” [15], but also green roofs, green walls, urban forests, domestic gardens and historic gardens [16]. Actions to create edible cities lead to the creation of edible landscapes, “a space greened by using edible plants and other landscape plants to create a multi-functional space” [17,18]. Edible cities are linked to continuously productive urban landscapes, and food production is an integral part of the city that empowers local communities to overcome social problems, create new businesses and jobs, generate economic growth and foster social cohesion [19]. Edible cities encourage citizens to co-create sustainable development pathways and proactively change the urban environments to their own benefit for a more connected urban lifestyle [19].

Edible cities are closely tied to urban agriculture, as one does not exist without the other, and urban agriculture is an essential contributor to food production in edible cities, as seen in Figure 1. As urban agriculture developed, different definitions were proposed to include the innovation and social impacts of it. “Urban and peri-urban agriculture (UPA) can be defined as the growing of plants and the raising of animals within and around cities. Urban and peri-urban agriculture provides food products from different types of crops (grains, root crops, vegetables, mushrooms, fruits), animals (poultry, rabbits, goats, sheep, cattle, pigs, guinea pigs, fish, etc.) as well as non-food products (e.g., aromatic and medicinal herbs, ornamental plants, tree products). UPA includes trees managed for producing fruit and fuelwood, as well as tree systems integrated and managed with crops (agroforestry) and small-scale aquaculture” [20]. “Urban agriculture is an industry located within (intra-urban) and on the fringe (peri-urban) of a town, a city or a metropolis, which grows and raises, processes and distributes a diversity of food and non-food products, (re-)using largely human and material resources, products and services largely to that urban area” [21]. “Urban food gardening encompasses agricultural activities with generally low economic dependency on the material outputs while using food production for achieving other, mostly social, goals” [22].

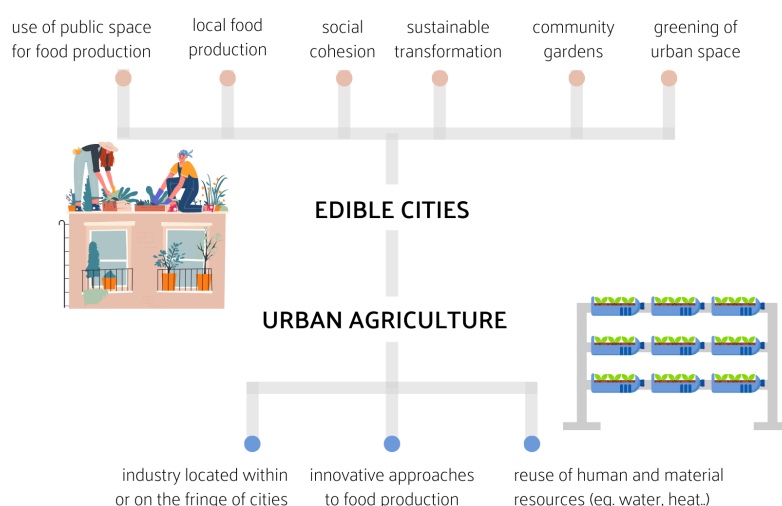


Figure 1. The concept of edible cities is closely linked to urban agriculture.

Urban agriculture can bring potential risks, but stakeholders overcome them by creating a new market structure and ensuring a socially accepted development of this new form.

“A food system gathers all the elements: people, environment, infrastructures, inputs, processes, institutions and activities that relate to the production, processing distribution, preparation and consumption of food, and the outputs of these activities, including socio-economic and environmental outcomes” [3], and urban food systems can be stud-

ied through four different aspects: social relevance, environmental relevance, economic relevance and spatial relevance which are presented in Figure 2 [3].

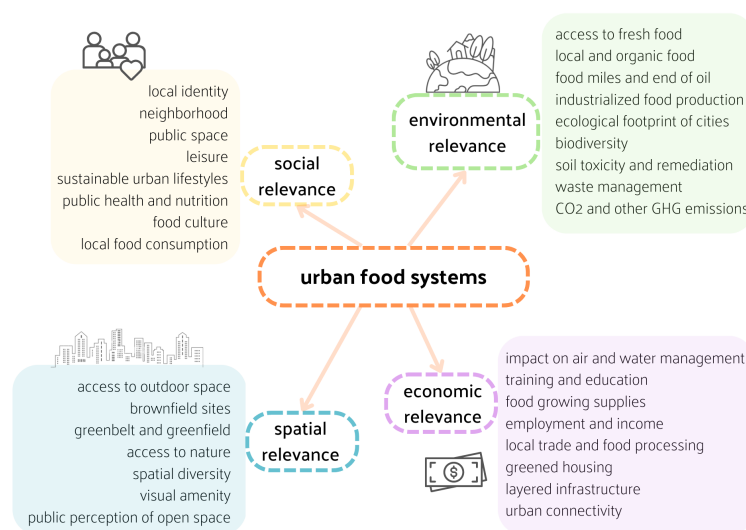


Figure 2. Urban food system [3].

2.2. What Wholesome Functional Foods Can Be Utilized

United Nations are working toward protecting the environment but at the same time improving nutrition through access to food and have developed seven of the biggest priorities: (1) ending hunger and improving diets by improving conditions to grow food and encouraging agricultural advancements; (2) de-risking food systems from price spikes and food-borne illness outbreaks; (3) protecting equality and rights that affect people's access to food, such as gender, ethnicity and age; (4) boosting bioscience to restore soils, breed and recarbonize the soil more efficiently; (5) protecting resources by offering sustainable solutions for agricultural problems such as irrigation, fertilization, drought and pests; (6) sustaining aquatic food, as fish and shellfish are an important source of energy and protein; and, lastly, (7) harnessing digital technology such as robots and artificial intelligence to increase the yield of plants and the health of animals [23].

At the same time, we can see that consumers are more interested in complex food that, apart from nutritional value, provides prohealthy aspects. This kind of function is what makes a food "functional". "A food can be regarded as functional if it is satisfactorily demonstrated to affect beneficially one or more target functions in the body, beyond adequate nutritional effects, in a way that is relevant to either improved state of health and well-being and/or reduction of risk of disease. A functional food must remain food and it must demonstrate its effects in amounts that can normally be expected to be consumed in the diet: it is not a pill or a capsule, but part of the normal food pattern" [23]. Functional food can be whole food, fortified, enriched, enhanced or altered food products [24]. It can also include medical food and foods for special dietary use. However, products that are called functional foods in the European Union must first of all comply with the requirements of the Regulation 1924/2006 on nutrition and health claims made on foods [25]. Functional foods are associated with sustainable food production as they focus on the use of raw materials that are produced naturally or with minimal processing to preserve the high qualities naturally present in the product [26]. Additionally, the waste from fruits and vegetables such as peels, leaves, seeds and pulps can be rich in active substances for functional foods and can therefore be reintroduced into the production process [27]. Examples of functional foods include products or foods that contain omega-3 fatty acids, probiotics, plant sterols, plant stanols, tea that contains catechins or berries that are rich in anthocyanins [28]. Many active substances can be found in plants and their products that have a beneficial effect on human health that are eligible to be grown or are

already being grown in urban environments. Table 1 shows examples of plants, highlighting the active substances contained in some parts of the plant with health-promoting potential, which can be grown in urban spaces in different latitudes. Compared to the baseline diet, which was balanced according to healthy eating recommendations, the introduction of functional foods into the diet helped to reduce some micronutrient deficiencies and meet the recommended intake more effectively [29].

Table 1. Examples of plants containing substances with health-promoting properties that could be considered whole functional foods.

Part of the Plant	Name of the Plant	Active Substances
Leaves	green tea	Catechins [30]
	wheatgrass	Chlorophyll, beta carotene, ascorbic acid, polyphenols, magnesium, zinc, selenium [31]
	ginkgo leaves	Biflavones (ginkgetin) [32]
	lemon balm	L-ascorbic acid, carotenoids, quercitrin, ramnocitrin, luteolin, neral, geranyl acetate [33]
	basil	Phenolic acids, flavonol-glycosides [34]
	aloe vera	Vitamins A, C, choline, folic acid; glucomannans, xylose potassium, chlorine, glycosides (anthraquinones aloin A and aloin B) [35]
	olive leaves	Oleuropein, hydroxytyrosol [36]
	rosemary	Trans- and cis rosmarinic acid, luteolin-O-glucuronide [37]
	oregano	Phenols derived from caffeic and rosmarinic acid, apigenine, luteoline, aglicons, terpenic compounds, essential oils (limonene, cariofilene, cymene, camphor, linalool) [38]
	parsley	Apigenine, luteoline, quercetin, carotenoids, vitamin C [39]
Vegetable fat	rapeseed oil	Linolenic acid [40]
	avocado oil	MUFA (oleic, palmitic, linoleic) [41]
	olive oil	Tocopherols, sterols, hydrocarbons (squalene), beta carotene, MUFA, phenolic compounds, vitamin K [42]
Beans	black soybeans	Isoflavons (daidzein, genistein) [43]
	adzuki beans	Caffeic acid, resistant starch, linoleic acid, linolenic acid [44]
Seeds	flax	Lignan (secoisolaricresinol), fiber, alpha linolenic acid, phosphorous, calcium, magnesium, sulfur [45]
	chia	Fiber, omega-3 fatty acids [46]
	sunflower	Minerals, PUFA, MUFA [47]; lignan (sesamin) [45]
	fenugreek	Fiber (galactomannan); diosgenin, trigonelline [48]
Grains	oats	Beta glucans, tocopherols, tocotrienols, phytic acid, avenanthramides [49]
	barley	Lignan (7-hydroxymatairesinol) [45], beta glucan, tocopherols, phosphorous, potassium [50]
Fruit	date	Fiber, anthocyanin, carotenoids, tocopherols, tocotrienols, phytosterols [51]
	plum	Anthocyanin [52]
	mulberry	Moracin, mulberroside, morin, maclurin [53]
	fig	Vitamin C, carotenoids (zeaxanthin, lutein, carotene), phenolic compounds (chlorogenic acid, epicatechin), flavonoids (rutin, quercetin) [54]
	apple	Fiber, pectin, malic acid, potassium, calcium, magnesium, zinc [55]
Flowers	chokeberry	Fiber, vitamins C and K, anthocyanins (cyanidine 3 glucoside, 3 galactoside, 3 xyloside, 3 arabinoside, chlorogenic acid) [56]
	pollen	Vitamin A, E, C, carotenoids, flavonoids, selenium, PUFA [57]
	sambucus nigra, hedysarum coronarium	Quercetin, rutin [58]
	capparis spinosa, anchusa azurea, robinia pseudoacacia	Anthocyanin, carotenoids [59]
Stems	garlic, wild garlic	Alliin, allicin, ajoene, phosphorous, potassium, sulfur, zinc [60]
Root	ginseng	Polysaccharide rhamnogalactouronan [61], ginsenosides [62,63]
	carrot	Beta carotene, ascorbic acid, tocopherol, fiber [64]
	beetroot	Nitrates, betalain [65]
Fruiting bodies of mushrooms	reishi	Iron, calcium, magnesium, protein, vitamin D, alpha and beta tocopherol [66], polysaccharides, steroids, triterpenoids [67]
	cordyceps	Ergosterol [68], polysaccharides, nucleosides, terpenoid [69]
	champignon	Bioactive amines [70], alpha glucan and beta glucan [71]
	shiitake	Beta-glucan, amino acids, nucleotides, 1-octen-3-ol [72]

3. Opportunities and Constrains to Create Edible Cities and Have Access to Wholesome Functional Food in a Sustainable Way

Opportunities and constraints to create edible cities to have access to whole functional food are discussed in detail in individual paragraphs, and the most important are summarized in Figure 3.

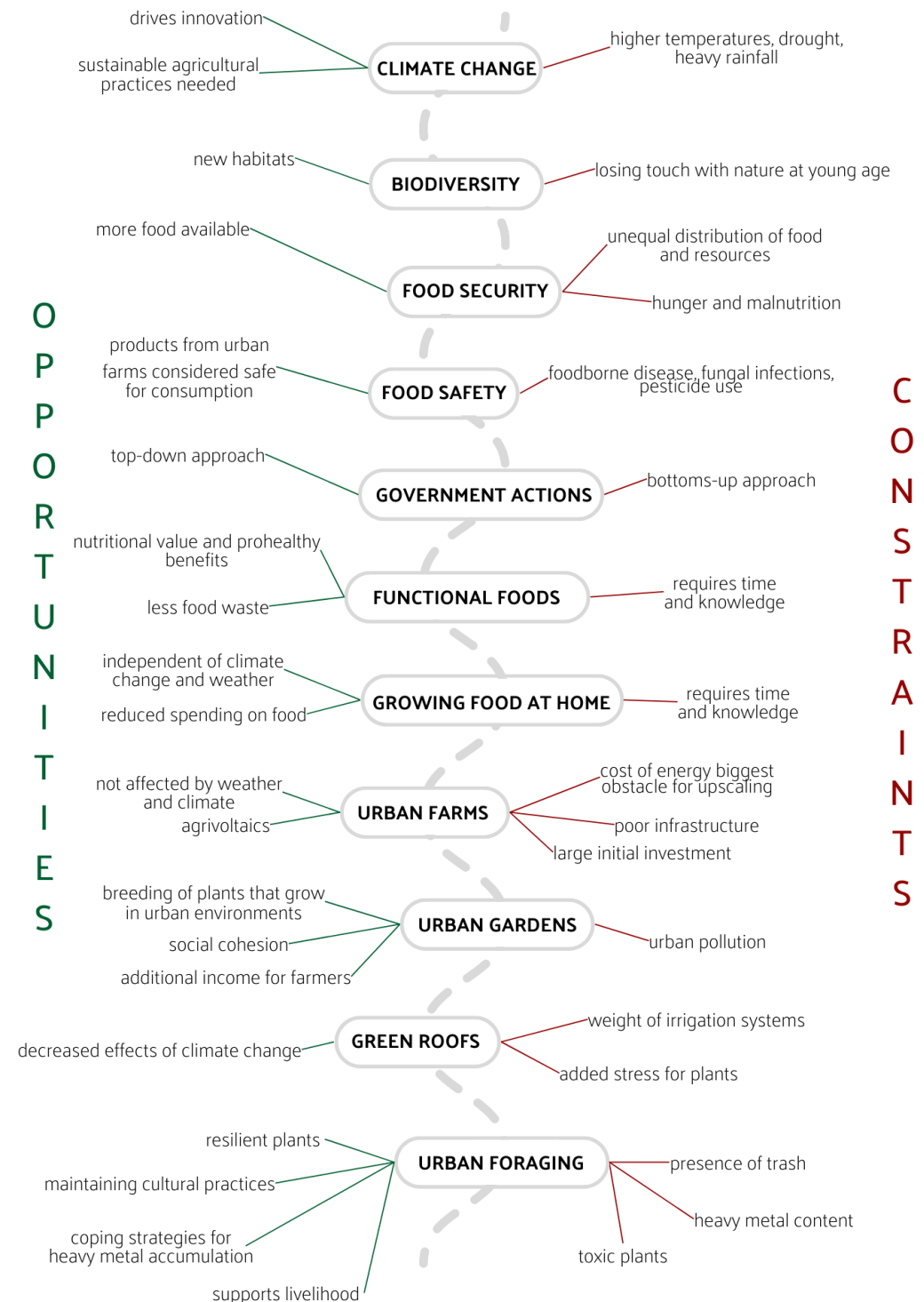


Figure 3. Opportunities and constraints to create edible cities and to have access to whole functional food [11,23,24,27,29,73–95].

3.1. Sustainable Agriculture

The implementation of the concept of edible cities can contribute to the United Nations Sustainable Development goals by increasing the income of small-scale food producers but also increasing agricultural productivity, ensuring sustainable food production, providing education and entrepreneurship opportunities, adapting to climate change and building resilience toward disasters, efficiently using natural resources, providing green public spaces to citizens, integrating biodiversity values into planning and development process and many other aspects [96]. It is what sustainable agriculture is and what it should ensure. It should meet the needs of present and future generations while ensuring social and environmental equity, nurturing healthy ecosystems and promoting food security [97].

3.1.1. Urban Farming Spaces and Techniques

At first glance, there are not many possibilities for an edible garden in urban areas in a traditional sense because space is quite limited, but thinking outside the box opens many different opportunities. We can divide them into four categories based on the typology of the city area: soil-bound spaces, mobile and soil-independent systems, building-bound spaces and water-bound spaces. Soil-bound spaces refer to traditional growing spaces such as arable lands, allotment gardens, family gardens, squatter gardens, community gardens, parks and other public green spaces, urban derelict lands and guerilla gardening. Mobile and soil-independent systems refer to growing boxes and bags and mobile containers, such as the PAFF box. A Plant and Fish Farming Box is a mobile container that combines the aspects of soilless planting and the growing of fish in an enclosed environment while using a recirculatory aquaculture system that enables the reuse of water after biological and mechanical filtration [98,99]. Water-bound spaces include urban streams, urban stagnant waters, such as ponds and lakes, and amphibia systems such as floating islands. The last, but most exciting, option is growing bound to buildings which can become a significant contributor to the greening of the city but is currently still poorly utilized. Building-bound spaces refer to rooftops that can be open, covered, flat or inclined, facades that can be open or covered, building extensions, mostly balconies and window sills, and indoor spaces with/without artificial lighting [3,22,100].

In urban farming environments, plants can be grown with the use of soil or with a modern approach without soil—soilless growing. When we talk about urban soils, they put up with many influences that cause contamination and structural changes, so before planting in them, they should be tested for exceeding contaminant limits. If the concentrations are too high, the soil can be remediated using physical or biological techniques, such as soil excavation, washing, vapor or microbial, fungal and phytoremediation [101–103]. Soils can be made of substrates of organic and inorganic origin, and both of these contribute to soil quality based on their specifications.

Soilless farms still do not have a single definition because they include different technologies such as hydroponics, aeroponics and aquaponics (Figure 4), and they are used in greenhouses or vertically stacked systems, but they are collectively considered “controlled-environment agriculture farms (CEAs)”. Vertically stacked systems are farming systems in which animals, plants and fungi are cultivated so that they are artificially stacked above each other vertically. This concept reduces the dependency on land, and building multi-store vertical farms can increase the effectiveness of arable land [104,105]. Hydroponics is a system where plants are grown in an inert medium such as rocks and coco coir fiber, and the solution fed to plants contains all the micronutrients needed for growth [73]. This way, large plant populations can be grown in a very small area, and nutrients, water and aeration are controlled to the finest degree [106]. Aeroponics is a subset of hydroponics that uses mist to water and support the plants. The plants are suspended in a sealed container in a way that roots are openly exposed to the air to get the nutrient-rich water spray [107]. Aquaponics is a combination of aquaculture and hydroponics that raises marine life in symbiotic systems with plants [74]. “The effluent from the fish (or other aquatic organisms) production unit supplies the horticultural unit with water

and nutrients for plant growth. Since the nutrient profile can be individually adjusted by measuring the nutrient profile and adding missing nutrients, multiple plants can be grown as monocultures or in polycultures (e.g., intercropping, companion planting)” [108].

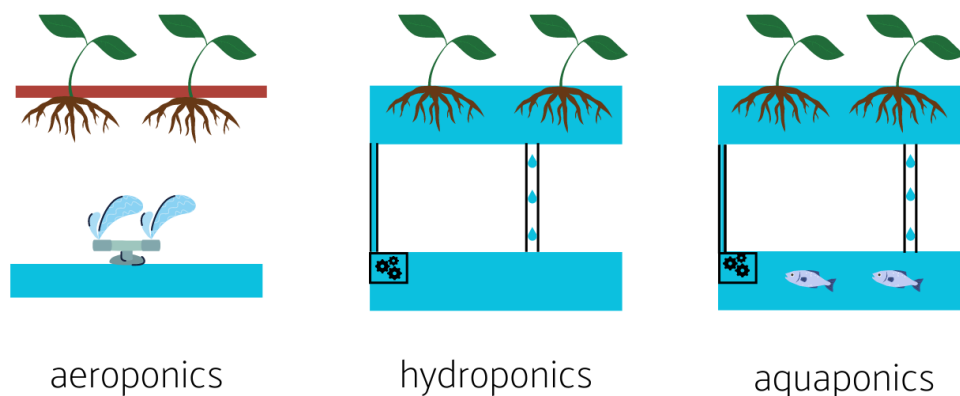


Figure 4. Soilless types of farms.

Urban farming does not have to only include creating new spaces in the cities and their structures. A vastly unexplored option is to create urban farms underground—whether it is reclaiming abandoned infrastructure or creating a new one. Current underground farms are used to produce greens, mushrooms and specific vegetables using aquaponics or hydroponics. These spaces cannot be affected by extreme weather, flooding, earthquakes and climate change, and it is easier to control the climate according to the ideal growing specifications of the plants. Growing Underground and SCAUT (Swiss Center of Applied Underground Technologies) Underground Green farming are underground farms located in Europe [109]. Growing Underground is located in the WW2 shelter tunnels below London, and it operates as an unheated hydroponic farm that grows pea shoots, mustard plants, coriander, pink radish parsley and salad rocket [110]. The SCAUT Underground green farming is a concept study of the production of food underground by using aquaponics while implementing the zero-carbon, zero-waste and zero-land-use principles [111].

About half of all indoor farms rely on hydroponics, while aquaponics takes a 15% share and aeroponics around 6%, and the rest of them are hybrids. A quarter of all indoor farms still use soil but control other aspects of the environment in a closed system. An important aspect of the control is the type of facility, and we can separate them into indoor vertical farms, glass or poly greenhouses, container farms, indoor DWC (deep-water culture) and low-tech plastic hoop houses. Before 2000, glass greenhouses and poly greenhouses were the most popular types of farms, while in recent years, many other types are becoming desirable. These modern farms also develop their own technology based on their needs, such as LED lighting, structures for growing and water cooling, in order to maximize the yield, minimize the cost and broadly scale up their production. LED lights made it possible to assemble vertical indoor farms as they can provide light from a very close distance without burning the plant, and there is a constant increase in their efficiency. As they emit one light color, they can be adjusted to emit the exact wavelength a plant required for photosynthesis—blue, red and infrared light. This means less energy and resources will be wasted [74].

Vertical and urban farms produce mostly herbs, microgreens and leafy greens, with some producing flowers and tomatoes, but almost none are working toward producing fruit. It is not because they cannot be grown this way but because the cost is too high and production is not sustainable. The cost of energy is generally the biggest obstacle in upscaling and diversifying production on urban farms, taking up almost a quarter of the operating costs of vertical farms. They have become popular as LED lighting gained popularity which made it possible to operate using far less energy and producing far less heat, but as the cost of energy will not decline any time soon, this is where the vertical farms hit a plateau [74]. Vertical farms are applied in countries such as Japan, Singapore, England,

the USA and the Netherlands, and it is expected that the market will increase even further in the upcoming years. While growing crops is still economically not profitable, the increase in the need for crops for animal feed might lead to more research and a decrease in prices in the future. Barley fodder has great potential to be farmed vertically. Until then, most crops that are grown in vertical farms that are used for human consumption are carrots, radishes, tomatoes, potatoes, peppers, peas, cabbage, spinach, lettuce and strawberries [112].

Products grown on urban farms, or controlled-environment farms (CEAs), are currently more expensive for consumers than products grown conventionally. However, what is not visible to the everyday person is that CEAs take up much less land, often remodeling unused spaces in the city, and use up much less water than conventional farms. CEAs currently use up high amounts of electricity due to LED lighting used to grow plants. This could be overcome if the farms could directly source solar or wind energy; it would decrease the production cost and lower the impact on human health and the environment [74]. Vertical farming is feasible in areas that have a lot of sunlight which would provide enough energy to light the rooms and pump the water. However, because a lot of vertical farms still generate energy from conventional sources, this adds up to a carbon footprint that is larger than that of conventionally grown products. Currently, the carbon footprint of lettuce grown vertically is five times higher in the summer and two times higher in the winter compared to lettuce grown conventionally. This, of course, is apparent in the price of the product as well [113]. Agrivoltaics is an emerging concept of the joint use of land for food and energy production by integrating photovoltaic modules into buildings. The energy produced on site can be sold to the grid to increase income or utilized by the farm itself, leading to decreased production costs and more affordable product market prices [75].

While traditional gardens are subjected to the climate conditions of their geographical location, CEAs can operate in harsh climates, producing food all year round which is why it is possible to find them in Canada, Sweden, Egypt and Dubai [76].

For many developing countries that are fighting hunger and malnourishment, urban farms could help reduce the number of people suffering every day. However, there is a myriad of obstacles affecting the development of CEAs, and the most important among them are poor existing infrastructure, a large initial cost of investing to these systems and the knowledge to operate them. Poor infrastructure means a lack of a stable power supply which is essential for running an urban farm. The costs of starting up an agricultural business are high due to the lack of subsidies from the government and the lack of investors willing to support these systems in an environment with unstable infrastructure. Lastly, if the farm was to open, there would be a shortage of educated and trained experts to keep the farm running successfully [73].

3.1.2. Growing Food at Home

Community gardens in cities provide a sustainable way of growing food while encouraging people to become more involved in food production. People of different backgrounds can participate, no matter their skillset. The beginners feel free to experiment with planting and educate themselves during the process but also ask for advice from seniors with more experience [114]. Some of the common vegetables that can be found on balconies and in terrace gardens in Mumbai are eggplants, spinach, red and green amaranths, fenugreek, cauliflowers, chilies, tomatoes and cucumbers [115]. There are multiple attempts to optimize home gardening and community gardening. Sensory sticks are being created with the possibility to track the conditions the plants are in, monitoring the amount of moisture, light and temperature the plants are receiving. The collected information can be sent to the central unit and connected to the app where the current conditions are compared to the optimal ones and users can receive feedback on what the plants lack [114]. Another example is CityVeg, a small-scale robot that acquires the data from the garden, processes them and provides precise irrigation based on plants' specific needs. These gadgets could encourage home gardening practices in developed countries where the time availability of citizens is the main reason for not adopting home gardening [77].

Green roofs have many benefits for the environment, such as the retention of stormwater, lowering of the temperature, mitigation of urban heat island effects, filtration of air pollutants, creation of habitats for urban plants and animals and insulation for buildings [116]. While providing all of this, they also place a significant amount of stress on the plants growing on them because of their unique characteristics—limited amounts of soil, the limited moisture of soil, higher changes in temperatures and wind and more sun rays [78]. To ensure the plants have optimal growing conditions, irrigation systems could be installed, but they add up to the weight put on the roof and often have technical restraints [117]. From the perspective of biodiversity conservation and sustainability, there is another practical solution. Instead of installing costly systems to create the desired environment, edible plants can be planted next to other species and form a plant symbiosis. In order to achieve this, plants with shallow roots that can lower soil temperatures and maintain moisture are the ideal candidates [118,119].

The cities of Southeast Asia are areas of high urban density with economic disparity becoming bigger over the years. To ensure food security for the growing population, the introduction of urban farming on balconies and rooftops is vital. This way of producing vegetables and fruit overcomes certain problems that appear in this region, such as droughts throughout the year and floods during the rainy season, decreasing amounts of agricultural land, which is turned into residential and industrial areas as the cities expand, importing food from overseas to feed the citizens and therefore the use of chemicals in these products and the lack of fresh produce, and it also decreases the frequency of flooding as green rooftops and balconies provide a rainwater storage effect [120].

Gardening on balconies and rooftops has led to an increased interest in plant genetics and adaptability to different environments. In the context of edible cities, it might be useful to breed plants that can withstand soil compaction, pollution, high temperatures, drought, a lack of light or too much light, nutrient deficiency or heavy metals [79]. The selection of compact or dwarf phenotypes in plants is an important trait in plants selected for balconies and rooftops. Focusing on varieties that are small in size in terms of shoots, roots and lateral growth allows growing more plants in planters and pots and harvesting more produce [121]. Micro-Tom and Micro-Tina are examples of miniature tomatoes that have been created for planting in small pots, baskets and windowsills [122]. The trend of balcony fruits has led to the optimization of fruits to bear the abiotic stress factors of the urban environment, such as strawberries [123].

As having land or rooftops and balconies can be considered a luxury, new techniques of urban gardening come to light. For example, growing vegetables in sacks is an effective sustainable method of producing food. If a family needs more growth, the number of sacks can increase. Another plus is this does not depend on having a lot of land or even a permanent residence as they can easily be moved around in case of relocation. The weather conditions also have a smaller effect on these vegetables as they can be saved from floods, droughts, etc., just by moving around or inside the house [80].

3.1.3. Urban Foraging

Urban foraging can be defined as “collecting edible plants outside of maintained gardens” [124]. It is a way for people to connect with nature and better their understanding of processes related to food production [125]. The biggest advantage of urban foraging is that it is independent of sociocultural and economic backgrounds and it does not rely on specific cultivated areas, so anyone can do it [81]. Foraging has been an important way of collecting food and spending time in nature since prehistoric times [124]. It can be found in rural societies around the world, and its meaning and impact on everyday life are well-explored in the scientific literature. Contrary to that, urban foraging is critically underestimated but highly present in many cities, and reasons for practicing urban foraging range from maintaining cultural practices, supporting livelihoods and leading a healthy lifestyle to personal enjoyment. Wild, edible plants contain high levels of protein, fiber, minerals, antioxidants and vitamins and are known to be resilient—they can survive

drought and poor soil, which can be common for urban environments [126]. The percentage of people who practice urban foraging ranges from around 5% of people visiting parks in Europe to more than 50% of dwellers in South African cities [81]. It takes place in a wide range of green infrastructure types such as urban greenspaces, parks, wild vacant lands and urban forests [127]. Knowledge about the foraged plants can impact which species are collected more frequently and which are not [82] which may lead to the over-foraging of well-known but endangered plant species and become a threat to biodiversity. Even so, foragers tend to focus on “non-native or “weedy” species (widely abundant, spontaneous species)” [128] and are aware of risks connected to urban foraging such as pollution from traffic [83]. Fisher and Kowarik [81] reported that some of the barriers to practicing urban foraging can be as follows: concerns regarding contaminants, mistaking potentially toxic species with edible species, dogs not being allowed to the site of foraging and the existence of trash. With that in mind, urban foraging can be encouraged as a way to “enhance positive attitudes towards biodiversity conservation” by implementing the following concepts: (i) planting edible species in public greenspaces, (ii) enhancing vegetation diversity in greenspaces in general and (iii) accepting higher shares of spontaneous, wild vegetation in urban settings in particular [81].

We do not have to limit ourselves and focus on the search for wild food in the city (urban foraging), but it is worth thinking about food that is nutritious, has health-promoting qualities and can be grown in cities, such as functional foods, which in addition to being nutritious also have valuable health-promoting qualities.

3.2. Challenges Edible Cities Could Help Overcome

3.2.1. Malnutrition

Around 663 million people around the world were suffering from hunger in 2017. The Global Hunger Index, a scale to assess the nature of hunger using a 100-point scale, from 2021 indicates that there are extremely alarming data coming from ten African and Middle Eastern countries which are scoring between 40 and 65.1 points [129]. There are about 2 billion people worldwide suffering from some form of micronutrient deficiencies that come from undernourishment. While hunger is generally considered a cause of malnutrition, overweight and obese people can also be malnourished while having a too-high energy intake [130].

Focusing on malnutrition in 2018, the most affected countries were Haiti, Madagascar and North Korea, with 40–50% of individuals whose energy intake is on average below their nutritional and energy needs. The least affected, with less than 2.5% of individuals, are countries in Europe and North America [129]. The countries that are currently experiencing slow increases in undernutrition are the countries of Sub-Saharan Africa, the Middle East and North Africa, and the causes are mostly related to climate change and conflicts. Another way to measure how energy-deficient the population is is by using the “depth of the food deficit” score which estimates the number of calories an individual is missing per day, and the highest disproportion between intake and requirement, or the depth of the food deficit, affects Haiti with 546 kilocalories per person per day in 2016, followed by Zambia with 405 kilocalories per person per day [129]. Undernourishment is a serious condition that affects adults and especially children while they are young, growing and grown up. Lower energy and nutrient intakes can cause stunting, wasting, being underweight and improper bone and brain development. There is a steady decline in the number of underweight children, generally by reducing the percentage from the 1990s in half, but this is not a reason to stop focusing on continuously decreasing the incidence [129].

Poverty and malnutrition have been shifting from rural to urban areas as urbanization is increasing pressure on the global food systems [131]. As more and more people flee to cities for better life conditions, the institutions and infrastructure of low- and middle-income countries struggle to meet their requirements, causing people to live in poor conditions and face food insecurity on a daily basis. Poorer neighborhoods are saturated with advertisements for unhealthy foods which are now more affordable than healthy

alternatives and are high in much-needed energy while lacking vital nutrients for optimal health. Currently, one in three stunted children live in urban areas with adults who are overweight and nutrient-deficient, which is also known as the triple burden of the urban poor [131]. Poorer households allocate more money to food than the wealthier households and buying food on credit is a common strategy. Four out of five urban households in African cities will continuously not have enough food to eat [132].

3.2.2. Public Health

Edible cities can work toward the public health of the citizens, ensuring spaces for recreational activities and spending time in nature—bettering physical and mental health [133]. A survey conducted in Canada has reported that the majority of gardeners see this activity as a good physical exercise and a relaxing activity [84]. Aside from that, urban gardens can fill up the gap in vegetable supply that might occur in cities, providing additional support to food suppliers and bettering the health of citizens by offering nutrient-rich foods at their doorstep [134]. Urban gardens are an important aspect of addressing public health and malnourishment in urban areas as they provide food security for the poor [80]. Clinton et al. [135] created estimates for food production on rooftops, facades, vertical farming inside of buildings and vacant land in urban areas worldwide. If utilized, these spaces can provide up to 100–180 million tonnes of food annually, which would make up 10% of global vegetable output [136]. The WHO recommendation for vegetable intake is between 200 and 250 g per day, which adds up to 92 kg per person per year [137]. Following the numbers, by producing food in these urban settings, enough vegetables can be secured for 1 billion people to reach their daily vegetable intake for an entire year.

3.2.3. Climate Change

The need to address the impacts of climate change on agriculture has never been greater. With the rise in the Earth's temperature of over 0.85 °C since the industrial revolution and the atmospheric concentrations of carbon dioxide rising higher than they have been for the last four hundred thousand years, humans are experiencing a significant threat to every-day life and food production [85]. A certain share of events caused by climate change can be observed directly through the frequency and severity of extreme weather—rainfall, drought, heat and snowstorms [85]. Heavy rainfalls pose a threat to the drainage and sewage systems causing floods and disruptions of the city infrastructure. On the other side, excessive heat and drought lead to massive fires, such as the Amazon wildfires in 2019 and the Australian wildfires in 2020, reducing biodiversity and emitting vast amounts of carbon dioxide, smoke and ash into the atmosphere [138]. High temperatures can already be connected to increased mortality rates, such as after the 2003 heatwave in Europe when heat-related mortality in Paris increased by 70% [139]. The effect of urban heat islands in cities is enhanced during these periods of heat waves causing reduced optimal living conditions for their residents [140]. These occurrences will be even more frequent in the future, which will increase the demand for energy production to power air-conditioning systems [141,142]. Another way climate change can affect humans and their environment is through natural systems “by altering the burden and pattern of distribution of vector-, water- and food-borne diseases”. The most subtle way climate change can affect human health is through social institutions, causing undernutrition by interacting with global food markets [85]. Climate change can impact growing food at home and in open urban spaces through high temperatures, extreme heat, urban heat island effects, temperature variability from day to night, frost, flooding and water runoff, drought, water shortages, diseases, pests, high winds and storms and soil quality [143].

Some of the ways the edible city concept and designing greenspaces contribute to mitigating climate change is through regulating air quality and local climate, sequestration, the storage of carbon, run-off mitigation, rainwater management and land regeneration. Biodiversity can also be supported by providing new habitats and food sources for wildlife [11].

3.2.4. Food Security and Food Safety

With increasing climate change challenges and conflicts around the world, food security will stay a considerable issue to solve. With roughly 9% of the world experiencing food insecurity in 2018, using the FAO's Food Insecurity Experience Scale, the number can be expected to rise [129]. The Chicago Council on Global Affairs has estimated that food production needs to increase by 50 to 60% by 2050 to meet the upcoming demands [131]. Food security is an important aspect of food production in the future and should be emphasized more often while discussing the benefits of urban farming. Consumers demand fresh and local products all year round, and companies need to provide that, taking into account the safety of the product. Producing on urban farms could be the middle-ground solution for climate change, food security and increased yields. The biggest threats to food security, especially in the most vulnerable populations, are the loss of rural, marine, coastal, terrestrial and inland water ecosystems that support the livelihoods of millions of people. Climate change will allow for some species to be grown in new geographic ranges or altitudes, such as tropical species in the Mediterranean Basin, but it will also decrease production in others as temperatures rise too high and droughts or floods become frequent. Pollination is a vital step in growing many plant species, and yet this symbiotic relationship between plants and insect pollinators is endangered in tropical regions where temperatures are already on the higher end of the optimal range. Changes in wind, rainfall and temperature patterns will impact the relationships between plants, weeds and pests, making food production more difficult. A sufficient amount of food needs to be produced globally, but it is equally important to distribute the products so that each person has sufficient amounts of safe and nutritious food every day [86].

A key to more sustainable and healthy city development is the relocation of the food system and the shaping of localized, circular economy food systems [144]. The virus SARS-nCoV-2 and worldwide lockdowns showed a major problem in today's food supply chains—they are too long. The food chain contains five stages: "agricultural production, post-harvesting handling, processing, distribution/retail/service and consumption" [145]. The pandemic did not affect the production, post-harvesting and processing of the food beyond fewer workers or no workers showing up to their shift, but it massively affected the transportation segment by restricting movement and activities with other countries. The food safety and sanitary regulations of production came into question, shifting some of the regulations toward a stricter regimen. The shortages of workers caused problems in continuous food supply to markets, and postponing harvest and distribution affected the value and prices of short-shelf-life products [146,147]. Farmers were also forced to destroy their products by burning or abandoning them to respect the newly imposed restrictions [148]. The biggest problem of the food chain in general is to ensure the raw material that would guarantee continuous food flow into the industries for production [87]. Restrictions between cities, counties and regions have caused a shortage in staple foods—wheat, corn, maize, soybeans and oilseeds [149].

Simultaneously, a greater consumer demand for them, to create personal supplies at home, led to emptying shelves, and companies tried to prevent this behavior of panic-buying by offering free deliveries that would stop customers from going to the store themselves and limiting them to the number of packages [150]. When the export restrictive policies were applied, local sellers could not find buyers which resulted in excess supply and waste along with economic losses. Foods that are not grown locally but are needed for processing were not available due to the restrictions, and the capacity utilization of food-manufacturing plants to respond to the demand was also negatively affected [151–153].

Food safety is another concern that should be addressed when talking about food production. Food can be contaminated at any stage, from primary production to packaging. Climate change can have a big impact on food production, making it harder to produce food that is safe for consumption. Some of the proposed challenges for the future are increases in food-borne diseases, such as salmonellosis; fungal infections that lead to toxin

contaminations, such as mycotoxins in crops; pest migration which can lead to higher pesticide use; water and soil contamination; and a decrease in soil quality [88].

The US Centers for Disease Control and Prevention (CDC) issues warnings about food-related diseases, such as the occurrence of the contamination of romaine lettuce with *Escherichia coli*, which can be fatal after ingestion, but they have made a distinction between lettuce grown traditionally and on urban farms in one of their announcements saying that the warning about the contamination does not extend to lettuce grown in urban systems “(. . .) or labeled indoor, or hydroponically- or greenhouse-grown” [74]. What this means is that urban farming techniques could be used for the production of food that is safe for consumption.

3.2.5. Urban Environments

“There are three primary risks of gardening in cities and urban environments: soil, water and air pollution. For air pollution, there are three categories: (1) not accumulated in plants, (2) transport—vectors of pollutants and (3) pollutants that are taken up in plants” [89]. Pollutants from the air can be settleable by gravity which causes them to be deposited on the ground through wet and dry deposition which in turn causes salination, acidification and high levels of heavy metals in the soil [154].

An alternative water source used worldwide is reclaimed water, or treated domestic and municipal wastewater. It is mostly utilized in America and Asia, more specifically in places such as Texas and Singapore. It is even used as drinking water. In Europe, freshwater sources are still the primary source of drinking and urban water, but as the water treatment technology advances, reclaimed water could become the most important source of urban water in Europe and worldwide [155,156].

Heavy metals (HMs) are particularly concerning urban pollutants because of their presence, persistence and toxicity to humans. They cannot be degraded by microorganisms and can therefore persist in the environment even after the pollutant is removed [157]. Toxicity occurs even with quite low concentrations, and the outcome can be deadly [158]. “HMs are defined as those elements with a density higher than 5 mg mL^{-1} , but the collective term now includes arsenic (As), Cadmium (Cd), chromium (Cr), copper (Cr), lead (Pb), nickel (Ni), vanadium (V) and zinc (Zn)” [159]. “In urban environments, HMs are mainly anthropogenic. Road traffic, industrial plants and incinerators release heavy metals into the air, and HMs are subsequently deposited in the soils” [160]. Their concentration in the soil depends on the rainfall and is the highest in spring during the heaviest rainfalls [154].

It is very important to examine how safe the food grown inside the cities is and to which extent the pollution affects the edible plants in greenspaces. Plants that grow in urban settings can be exposed to high pollution loads because pollutants, primarily heavy metals, are found in the soil and also air as a component of particulate matter [161]. Stark et al. [162] reported that foraged wild edible plants in San Francisco’s East Bay were safe for human consumption because they did not exceed the safety levels of certain elements. On the contrary, Renna et al. [163] examined the wild edible plants in Bari and noticed elevated concentrations of lead and cadmium.

In the cities, air pollution primarily comes from the vehicular fleet—tailpipe and non-tailpipe emissions [164]. Heavy metals that are related to industrial emissions are chromium (Cr), nickel (Ni) and lead (Pb), while chromium (Cr), barium (Ba) and manganese (Mn) are present in vehicular brake dust [165]. Zinc (Zn) can be connected to tire wear and gasoline and diesel pipeline emissions. Aluminum (Al) and rubidium (Rb) appear as a result of road dust and soil resuspension [165,166].

Air pollution levels in Sao Paulo are often higher than levels in the guidelines presented by the WHO [167,168]. For this reason, it was interesting to explore the concentration levels of heavy metals in common edible plants from different parts of the city. The research showed that for most wild edible plants grown in parks, the concentrations were lower when compared to the same species grown close to roads, such as freeways and arterial roads. There is a decreasing spatial gradient of pollutants in relation to the distance of

traffic. Moreover, some species grown close to the roads contained the heavy metal lead in concentrations that exceeded values recommended by agencies. These results lead to the conclusion—and a suggestion to urban foragers—that foraging in large urban centers should be performed in low-traffic areas [90].

Several factors can affect the plant uptake of heavy metals: the characteristics of the plant itself, the type of metal, soil texture, organic matter content and soil pH. Fine-textured soils can decrease the bioaccessibility of heavy metals, but solubility increases as the soil pH decreases [169]. When it comes to the type of heavy metals, they can be less available to plants if easily absorbed into soil particles, such as lead (Pb) and copper (Cu), or fairly mobile and easily absorbed by the roots, such as cadmium (Cd) and zinc (Zn) [170]. Generally, plants absorb heavy metals in their ionic forms via active and passive transport [171].

Plants have developed different strategies to survive in urban environments with polluted soils, and the most common mechanisms are exclusion, passive accumulation and active accumulation [91,172]. Plants that have developed the exclusion mechanism can grow in heavily polluted soils because they restrict the uptake of elements through their roots or because they use active efflux pumps which require an energy supply. The next mechanism is passive accumulation, and plants that have developed this coping mechanism store metals in their roots, cell walls and vacuoles, to be exact, which prevents them from being transported to leaves and shoots. The final defense mechanism is active transport, and it entails the uptake of heavy metals and their conversion to inactive, inert forms [173].

Research and knowledge about the innovative design and management of tree-based urban landscapes are scarce, and there are no common guidelines present for producing fruit in urban settings [174]. Research showed that woody plants can accumulate high quantities of absorbed heavy metals in roots and leaves but not in the fruit [175]. Of course, this can greatly differ depending on the species and fruit type, and several studies describe that; high concentrations of lead were found in fruits from Copenhagen [176], and it was also reported that “nuts with compact protecting shell accumulate almost no Pb or Cd, while pome and stone fruits accumulate more Pb compared to nuts, and that berries accumulate more Cd compared to other fruit types” [177]. Although the root uptake is the main way plants uptake heavy metals, airborne particulate matter can also be a significant way to reach heavy metal pollution [178]. “Recent literature reveals that uptake of atmospheric metals occurs via foliar transfer, after deposition of PM on leaf surfaces” [179], as well as through cuticle pores and surface injuries [180], but the main pathways are still to be confirmed. Absorption through the leaf depends on the stomatal index, trichome density, length and leaf maturity [181].

An overview of the small amount of research on the topic of heavy metal load in fruits of woody plants can lead to the conclusion that uptake mechanisms need to be further explored and demystified, but woody species could be quite suitable for the production of fruits in urban greenspaces because of the lower deposition of pollutants in the fruits, compared to the deposition in vegetables.

Urban farming can also be affected by air pollution which decreases irradiance caused by solar dimming, which is a result of the increased reflection of radiation away from the ground. Air pollutants and aerosols stimulate this in urban areas which causes less solar radiation to the city compared to the rural area [182].

3.3. Social Impact

3.3.1. Social Connections

“The most often mentioned challenge to which edible cities may contribute is social cohesion” [11]. Urbanization has led to neighborhoods becoming more and more anonymous, and establishing edible urban gardens can rectify this problem before it gets worse. There appears a sense of social cohesion as people of different backgrounds and ages collaborate toward the same goal by collectively planting and harvesting. This is also a great opportu-

nity for different generations to learn from each other while learning about the environment through action. "... two visions edible cities and strive for: (a) strengthening human-food connection as part of a social-ecological transformation and (b) fostering social cohesion as part of a social-spatial transformation" [11]. In the past, urban gardening was primarily a way to fill in the empty spaces around newly built residential buildings, and it turned into places that offered social infrastructure, replacing markets, cafes and restaurants in impoverished areas [134].

3.3.2. Edible Schools

The concept of edible farming practices should be taught from a young age. Children spend more time indoors, avoiding physical activity by spending more time in front of computer screens and gaming consoles whilst consuming foods high in sugars and fats. Simultaneously, they are losing the experience of interacting with natural elements, such as climbing trees, playing in the grass, watching birds, etc. [183,184]. Losing touch with nature at a young age can be a tipping point toward decreasing awareness and ambition to conserve biodiversity later in life and in future generations [92]. Cook et al. [185] state that the lack of interest in biodiversity can stem from a lack of knowledge about where natural products such as fruits, vegetables and dairy products come from. Additionally, they are not familiar with the settings needed to produce food in nature, as Traversa et al. [186] found in 2017 that 75% of Italian pupils are not aware that locally grown fruit and vegetables are not naturally available during all the seasons. To bridge the gap that is becoming vaster, a transdisciplinary approach can be implemented to create biodiverse edible schools—safe environments where children will reconnect with nature, gardening and growing food, which will, in turn, lead to "(1) improved food and environmental education, (2) increased availability of locally grown, fresh, and seasonal produce for pupils, (3) enhanced awareness, use and management of local urban biodiversity" [187]. In order to implement this goal, the project needs to provide "(1) collaborative activities in planning, managing and using school garden and wild wasteland site; (2) a school kitchen supplied with food from regional producers; (3) a garden on the schoolground for producing local food; (4) a neighboring wild urban site as a habitat for wild edible plants" [187]. To put this project together, different policy fields and stakeholders need to be involved. Biodiversity policies need to support local strategies for biodiversity conservation, integrate urban landscapes into conservation strategies, enhance biodiversity where people work and learn and connect the new generation to the environment. When it comes to food policies, the most necessary ideas should be to keep short distances for food transport, establish networks and support local farmers, get to know where food comes from and grow vegetables and fruit oneself. While planning the implementation of biodiverse edible schools, it is important to involve the following stakeholders: school staff, pupils, municipality, local politicians, environmental organizations, researchers, landscape designers and gardeners and people moderating the process [187]. If they are given a chance to contribute to the design of the implementation, ideas and challenges will be considered from different points of view resulting in a higher-quality project.

Many universities around the world are taking part in becoming more sustainable and greener by creating edible gardens tended by students and staff. The University of Oxford, the University of New England, Seattle University and East Carolina are just some of the examples [188–191]. UNGreen is an alliance project between European universities to share knowledge and encourage research in the fields of sustainable agriculture and the green economy [192].

3.4. Economic Condition

Rooftop gardens could supply up to 77% of vegetables in cities. Besides providing produce, citizens can get significant economic returns, creating another stream of income for the households [77]. Urban gardeners in Ljubljana can cover more than half of their household needs for mixed vegetables by tending a garden, while 17% of gardeners in

Milan or London can also do so. European cities tend to have a non-profitable outlook on home gardening with gardeners exchanging or donating their surfaces more than selling them [93]. In Japan, vacant spaces under elevated train tracks and units in shopping centers are designated for food production. Food grown in the city in 2017 was enough to feed around 700,000 people, which is about 5.4% of the city's population [94].

Further benefits of community gardens are visible to the farmers, local markets and the government. Farmers receive additional income when renting their land for community gardens, local markets have more products and sales, more jobs are created, and unemployment can be decreased [11].

Home food gardeners, both long-term and new gardeners, in Canada agree that the pandemic has led to an increase in food prices, and over a third of new gardeners have lost their income because of the pandemic. Half of the respondents stated that one of their motivations for growing food at home was to save money [84]. The same trend was observed in Taiwan as home food gardening increased with the outbreak [193]. There are more examples of links between economic hardships and increases in home food gardening, but a very important determinant of taking up home food gardening is the knowledge of it [194]. The increased interest in food gardens was visible during the Great recession of 2007 and the following 5 years thereafter [195,196]. Even so, food-insecure households are less likely to grow food at home [95]. Some of the reasons for this, depending on the country or region the households are located in, may be a lack of land, the quality of soil, time, knowledge and accessibility to water, seeds and equipment [197].

3.5. Government Actions

Urban greenspaces have been shown to positively affect problems such as urban heat islands, stormwater management and maintaining biodiversity within the city which is why green and edible landscapes are becoming more and more popular around the world [198–200]. Edible landscapes offer more advantages than simply green landscapes as they provide nutritious and cost-effective food for local dwellers and emphasize the importance of community and spending time in nature. A great example of people unifying for a better cause can be found in Baltimore, MD, USA, where locals collectively cleaned up an illegal dumping site and turned it into a shared garden with vegetables and flowers [133].

Countries and governments from around the world react differently to the idea of edible landscapes. We can generalize them into two different approaches, a bottom-up approach and a top-down approach, and they exist in parallel. Countries such as Australia, the UK and European countries utilize the top-down approach; the government and local councils legitimize agricultural zones that contain public green spaces, community gardens and allotments, and dwellers can use them freely or rent them for a fee [201]. There can also be a distinction between community gardens and allotments since allotments can be run by local government, and community gardens appear on vacant sites or wastelands. In countries such as the USA and China, a bottom-up approach is more present, meaning that people take over an abandoned public space and turn it into gardening sites, which are later legitimized by the local council [202]. A government's top-down approach initiated the implementation of an edible city concept in Andernach, followed by Haar, Germany. Munich is an example of an edible city that represents a bottom-up approach; the citizens planted informal small gardens around the city [11]. A positive example comes from the Democratic Republic of the Congo which received support from the FAO in developing urban and peri-urban-agriculture in five different cities. Aside from upgrading irrigation systems and improving vegetable varieties, citizens received training in good agricultural practices. In the city of Kinshasa, these gardens produce up to 85 thousand tons of vegetables a year which covers 65 % of the city's vegetable supply [203].

It is interesting to mention that the need for and interest in community gardens in developed countries such as Scotland, England, Wales and North America seem to appear in low-income areas with high perinatal mortality rates as initiatives for cheaper and safer food [133]. In developing countries, two trends can be noticed. In countries such as Brazil,

the Philippines and Mexico, urban farming is supported by the local government which provides the spaces for community gardens [15]. Simultaneously, as peasants in rural regions of China moved to the cities, they wanted to continue the practice of growing their own food. This resulted in turning many public open spaces for leisure into gardens with edible plants which is seen as illegal behavior or informal community gardening. Little is known about how the informal gardens are generated and operated which is a barrier to resolving conflict between people of different interests and outlooks on informal urban gardening [204].

He and Zhu [204] were interested in exploring the characteristics of informal community gardens in China. What they found is that dwellers decided to start gardening in green spaces that had been neglected, with damaged and bare surfaces or little recreational equipment or of unsatisfactory design and maintenance. In their view, the green landscapes were not fulfilling all the functions they should have been. The second characteristic was that people carefully planned how and where they would plant their plants, taking into account the surroundings and the needs of the plant. For example, many plants can be found alongside the river bank—close to the water supply or walls and fences—facilitating privacy from random pedestrians. Moreover, walls and fences were used by plants as supporting structures. Portable containers, such as flowerpots, washbasins and boxes were used for planting smaller plants, such as peppers, garlic and shallots. Flowers were planted on damaged and bare surfaces.

There were numerous reasons for dwellers to engage in urban gardening, some of them listed as follows: a personal hobby and an effective way to fill up their free time, eating healthier, feeling unsafe about the use of pesticides, fertilizers and pollutant residues in store-bought food, improving the attractiveness of surroundings and interest in social contact. Many agreed that gardening is a way to upgrade their quality of life and that planting in community gardens should not be done to earn money [204].

Thinking back on the gardens being of illegal origin, and with a number of people opposing this activity, many gardeners reported their worries about the government taking action against them, finding damaged or stolen plants and pots. While examining the opinions of non-gardeners about the informal gardening practices, the majority of them considered it an invasion of public green spaces, which should rather be conducted in rural regions outside the city. It is also interesting to report that among the non-growers, half of the subjects noticed illegal plantings, and the same amount of them did not notice this behavior suggesting that the planting strategies of growers do protect their plants but also that planted vegetables simply blended in with the urban green space and fit in with the rest of the vegetation [204].

4. The Solutions That Already Exist

Incredible Edible Lamberth [205] and Slow Food Movement [206] are initiatives from the United Kingdom and Italy that focus on connecting communities through food, sparking interest in what people put on their tables every day. Wonderful Gardens [207], The Ecological and Educational Garden of Podmurvice [208] and the Green Classroom of the Faculty of Education and Rehabilitation [209] are great examples of projects that aimed to provide real-life skills in gardening and food growing by offering kids and adults workshops and a space to implement the gained knowledge. Numerous start-ups are providing solutions that could be used to create edible cities: Roofscapes [210] focuses on the creation of systems that could be placed on pitched roofs to create space for rooftop gardens; Agropolis Urban Farming [211] is specialized in installing vertical farms in Paris; Aralab [212] produce climatic research chambers; and Cycloponics [213,214] took empty underground parking garages of Paris and turned them into underground farms of mushrooms, microgreens and endives. A similar idea was implemented in London where Growing Underground [215,216] turned old World War II bunkers into underground hydroponics farms. Companies such as CityGreens farming d.o.o. [217] provide infrastructure for urban farms (e.g., high-pressure aquaponics systems), and Square Root [218] repurposes

shipping containers as climate-controlled vertical farms. Nordic Harvest [219] is a vertical farm in Europe that utilizes robotic technology and renewable energy to recycle water, nutrients and fertilizers needed to grow the plants. Citizens also have the option to hire services that can build vegetable gardens and provide classes on how to tend to them, such as Peas&Love [220] in Florida, or rent unused garden spaces through digital platforms such as AllotMe [221] in the United Kingdom.

While greenhouses require energy to heat, vertical farms are known to produce heat and energy. Even so, greenhouses can be built in colder climates without the increased cost of heating if they are collocated—built in a symbiosis with a system that produces heat. Examples of this are a Great Northern Hydroponics greenhouse in Quebec, Canada, which is adjacent to the power plant and is capturing its excess energy to heat the greenhouse. The same principle was applied while building Agriport 47 in the Netherlands; the indoor farm is built next to the Microsoft server hub and is capturing its excess energy for heating. In Stockholm, the Plantagon CityFarm built a farm underneath the office tower and provides its excess heat from LED lighting to heat the office spaces above [74].

Plenty is an urban farm that opened in 2019 in San Francisco which is fully operating on renewable energy sources from solar and wind power, and it is breaking ground for future innovation. Similarly, a company named Plantagon proposed a system that would integrate municipal systems of heating, water, waste and energy into food production in a way that waste from the municipality would be used to create an efficient growing system [74].

Farms in Japan are working on combining LEDs with AI to analyze production data and boost yields but not energy use. Companies are also beginning to produce seeds to grow and thrive in CEAs, and their focus is on the rapid biomass and early fruiting, multi-harvest capability and photo-induced quality traits that would allow us to gain different colors and flavors by changing the LEDs [74].

5. Conclusions and Future Perspective

The semi-systematic evidence presented in this review allows the research questions posed to be answered.

RQ1 allowed us to describe edible cities as a live concept currently spreading to cities with community gardens, sharing knowledge and resources for success and greener public spaces. It is changing the way citizens view the environment and the community [11,14,17,18]. While in some cities, this is the newest trend on the market that is sparking innovation and initiatives, in some areas, it has been an essential and quiet way of living for years. By introducing citizens to edible plants that provide them with functional foods such as garlic, champignons, rosemary, oregano, plums and many others, shown in Table 1, edible cities can help tackle the problem of malnutrition and specifically nutritional deficiencies [80,131].

RQ2 was aimed at identifying the opportunities and constraints for creating edible cities and accessing wholesome functional foods in a sustainable way. There are many positive outcomes of implementing the concept of edible cities, from decreasing the effects of climate change, reshaping our resource use and feeding more people to creating better human connections and government action, as seen in Figure 3. However, the change to a more sustainable system will not be easy. Urban farms are large investments that are not feasible for everyone, and citizens lack the motivation and knowledge to start planting their own gardens. These are just some of the constraints mentioned in Figure 3. Nevertheless, instead of emphasizing the importance of modern urban farms, a realistic approach to greening cities is through citizens' initiatives—by providing education and open spaces for community gardens and growing food at home. As the industry is working toward reducing the cost of upscaling and commercializing production on urban farms, we should focus on the education of citizens and the creation of initiatives led by governments and non-governmental organizations to engage people in gardening and becoming a part of the food production chain. With surveys showing that time and knowledge are the

biggest motivators to start gardening, citizens should have access to educational materials, guidelines and lessons to familiarize themselves with the basics of planting and selecting for cultivation plants with the highest health-promoting potential, which we classify as whole functional foods [222]. Children can be introduced to gardening from a young age through schooling systems, having urban farming and some forms of self-sufficient planting instilled as basic life skills for a more sustainable future [187]. By encouraging individuals to grow food in and around their apartments, we simultaneously foster the creation of social connections between neighbors, the sharing of knowledge and new ideas, care for the diversity in urban areas, the improvement of health through the bettering of diet, a reduction in deficiencies and an increase in physical activity, a reduction in the cost of food for the households and reconnection to nature [11,84,133]. In return, cities could thrive on reduced air and soil pollution, reduced temperatures, the management of stormwater, reduced pressure on supermarkets to provide fresh produce daily and sustainable landscaping [116].

RQ3 gives us the possibility to present the solutions that already exist. The concept of edible cities can be built through growing edible food on balconies, rooftops, in sacks, investing in the most advanced CEAs, such as farmscrapers, creating gadgets, utilizing abandoned buildings, yards, garages and shipping containers for urban farming, urban foraging and adding parks and pedestrian zones into food supply chains, all of which can already be found around the globe as motivation to keep investing our time and energy into bettering our cities. All of this already exists around us and contributes to making the global food system more sustainable [205–221].

All in all, there are many opportunities to create access to healthy food for city residents, but there are also many difficulties in implementing the ideas we have highlighted in this article. The future perspectives are optimistic. With the application of existing knowledge and an interdisciplinary approach to problem solving, and with the support of government and local authorities, there is a good chance for creating greener and more sustainable cities. What we can do now is start with ourselves and our own communities, spread knowledge and create small steps for big changes in the future, whether it is creating a garden in one's home to enjoy fresh produce or being vocal in local councils and pushing for the government to become more invested in this matter. Which kind of action would be most effective depends on the kind of problems cities face and the urgency to solve them. The FAO's report on 12 cities in Latin America and the Caribbean [223] is a great example of how governments' actions, in collaboration with NGOs, can make a big difference in turning the cities greener and more sustainable through utilizing community spaces for food production, encouraging citizens to create gardens in their own homes and providing workshops and classes on growing food. These actions have enabled citizens to increase their vegetable consumption, reduce hunger and malnutrition and increase income from selling the surplus of produce or by decreasing the monthly food expenses of households. Citizens are growing beans, beets, tomatoes, spinach, cassava, yam, thyme, chives, carrots, basil, cabbage and lettuce. Backyard gardens of Antigua and Barbuda alone have accounted for about 7% of the country's vegetable production, and this is just one of the ways food can be grown in edible cities. In order to find the best solutions for their cities, governments could use programs such as the Edible City Game [224] that take into account different environmental, financial and social indicators of sustainability in cities. These examples can be translated to cities around the world to start bringing the change in their food systems.

Author Contributions: Conceptualization, K.Ś. and D.Č.; writing—original draft preparation, K.Ś., D.Č. and D.G.; writing—review and editing, K.Ś., D.Č., K.N., A.P. and E.K.; visualization, K.Ś. and D.Č. All authors have read and agreed to the published version of the manuscript.

Funding: The research was financed by the Polish Ministry of Science and Higher Education with funds from the Institute of Human Nutrition Sciences, Warsaw University of Life Sciences (WULS), for scientific research.

Conflicts of Interest: The authors declare no conflict of interest.

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