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Review

Urban Horticulture for Food Secure Cities through and beyond COVID-19

Muhammad Mumtaz Khan [1,*], Muhammad Tahir Akram [2], Rhonda Janke [1], Rashad Waseem Khan Qadri [2], Abdullah Mohammed Al-Sadi [1] and Aitazaz A. Farooque [3]

1 Department Plant Sciences, College of Agriculture and Marine Science, Sultan Qaboos University, P.O. Box 34, Al-khod 123, Oman; rhonda@squ.edu.om (R.J.); alsadi@squ.edu.om (A.M.A.-S.)
2 Institute of Horticultural Sciences, University of Agriculture Faisalabad, Faisalabad 38000, Pakistan; tahiruaf786@gmail.com (M.T.A.); waseemrana_83pk@yahoo.com (R.W.K.Q.)
3 Department of Engineering School of Sustainable Design Engineering, University of Prince Edward Island, Charlottetown, PE C1A4P3, Canada; afarooque@upei.ca
* Correspondence: mumtaz@squ.edu.om

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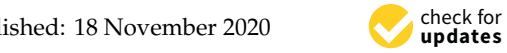

Abstract: Sufficient production, consistent food supply, and environmental protection in urban +settings are major global concerns for future sustainable cities. Currently, sustainable food supply is under intense pressure due to exponential population growth, expanding urban dwellings, climate change, and limited natural resources. The recent novel coronavirus 2019 (COVID-19) pandemic crisis has impacted sustainable fresh food supply, and has disrupted the food supply chain and prices significantly. Under these circumstances, urban horticulture and crop cultivation have emerged as potential ways to expand to new locations through urban green infrastructure. Therefore, the objective of this study is to review the salient features of contemporary urban horticulture, in addition to illustrating traditional and innovative developments occurring in urban environments. Current urban cropping systems, such as home gardening, community gardens, edible landscape, and indoor planting systems, can be enhanced with new techniques, such as vertical gardening, hydroponics, aeroponics, aquaponics, and rooftop gardening. These modern techniques are ecofriendly, energy- saving, and promise food security through steady supplies of fresh fruits and vegetables to urban neighborhoods. There is a need, in this modern era, to integrate information technology tools in urban horticulture, which could help in maintaining consistent food supply during (and after) a pandemic, as well as make agriculture more sustainable.

Keywords: cropping systems; ecological sustainability; hygienic food; sustainable food supply; urban horticulture

1. Introduction

Since the advent of the 21st century, phenomenal changes in human civilization have been witnessed throughout the globe. People are opting to live in big cities, where they enjoy diverse amenities. The land around cities is being used for commercial purposes and converted into malls, housing developments, roads, and small and large industrial establishments. This trend of population concentration in urban areas has created problems, such as a reduction of farmable land, increased malnutrition, and increased distances to traditional sites for food production [1]. In addition to these urban problems, the general increase in population, food scarcity, and climate change are emerging concerns of this century, globally [2].

The world population is increasing exponentially, and according to some estimates, it could grow to 9.6 billion by 2050 [3]. In the future, there will be pressure to increase agricultural productivity

to fulfill peoples' need for food, while, at the same time, water and land resources are being rapidly depleted. The earth's climate is always changing, and there have been persistent increases in temperature. Under these circumstances, 10% of agriculture land may become uncultivable for farming [4]. The variability in weather due to climate change is threatening food production and distribution systems, and a significant number of people throughout the world are suffering from hunger and malnutrition [2,5]. This scenario varies within (and between) developing and developed countries of the globe. In addition, several anthropogenic activities, such as applications of unbalanced fertilizers, pesticides, inappropriate farming practices, and usage of heavy machinery, have resulted in soil degradation and depletion of fertile land [6]. Besides poverty, the documented migration towards urban areas, lack of resources, natural disasters, and conflict are key constraints of food security. Moreover, the reduced availability of fertile land, crop production, and high market prices of agricultural products have also limited the food supply [7].

Recently, the outbreak of novel coronavirus 2019 (COVID-19) has reached pandemic proportions and has disrupted the food chain in different ways. It has constrained peoples' capability to access food by reducing income and increasing job insecurity. Further, worldwide lockdown strategies have increased transportation interruptions, labor shortages, and limited market access, which has resulted in food loss and waste [8]. Countries with the highest food insecurity levels were less prepared for the COVID-19 outbreak. Globally, governments have implemented lockdown policies to secure their citizens during the epidemic. However, there has been uncertainty in developing countries, regarding feeding their people under these conditions. Moreover, with this pandemic, the major threat for developing countries is hunger, as more people will die due to hunger, instead of the disease, if lockdowns continue to persist. In effective lockdowns, approximately 40% of a population would be unable to stock food for 14 days, and in just three days, most families would start to suffer from hunger [9]. The current COVID-19 pandemic has emphasized the importance of local food production [10].

Under the above circumstances, "Urban Horticulture" has emerged as a viable concept with the aim to provide sufficient fresh and safe food to cities, to achieve a sustainable food supply and food security. "Urban Horticulture" is the cultivation of fruits, vegetables, mushrooms, herbs, and aromatic and ornamental plants that can grow easily in a city and its surroundings [11]. The current COVID-19 pandemic, and lockdowns, have resulted in advantages to city dwellers who grow fruit and vegetables at homes, providing an opportunity to enhance urban horticulture. People, planners, and governments all are rethinking ways to utilize vacant lands in cities for food production under this dynamic condition [12]. Kitchen gardening is an older term, with a similar concept, in which edible plants are grown in home yards/gardens and rooftops to satisfy some of the home requirements for food. Many horticultural crops are considered ideal in urban agriculture production systems because they occupy a small space, produce more per unit area, have high nutritional value, and short production cycles. For example, diverse vegetable crop species may be grown and harvested within a short period of time (60–90 days) or even less for some herb/leafy crops [13].

In low income urban areas, the dietary deficiency of micronutrients, such as iron, zinc, iodine, and vitamin A is more common [14]. Horticultural commodities, such as fruits and vegetables, are rich in minerals, fibers, and bioactive compounds (e.g., phenolics and antioxidants), and have the potential to reduce malnutrition. Moreover, when these products are fresh and hygienic, this local food supply can have multiple positive impacts on humans, such as strengthening social cohesion and the local economy [15,16]. It also increases positive attitudes toward nature and natural habitats [17].

In recent years, interest in urban agriculture has increased because of climate change and the desire for a sustainable food supply in urban localities [18,19]. Urban horticulture has furthered its significance during pandemic diseases, such as COVID-19, which, globally, has triggered food insecurity. Moreover, higher poverty rates, malnutrition, stunted growth, and rising populations across the world have enhanced the importance of urban horticulture [13]. To fulfill the food needs of people, vacant spaces in urban areas will be a prime priority in order to compensate for lack of food and urban ecological

losses if land is left barren. Growing horticultural food crops in urban landscapes, and open spaces, will improve the sustainability of food and the environment. Urban horticulture is, essentially, a way to mitigate societal social challenges (Figure 1).

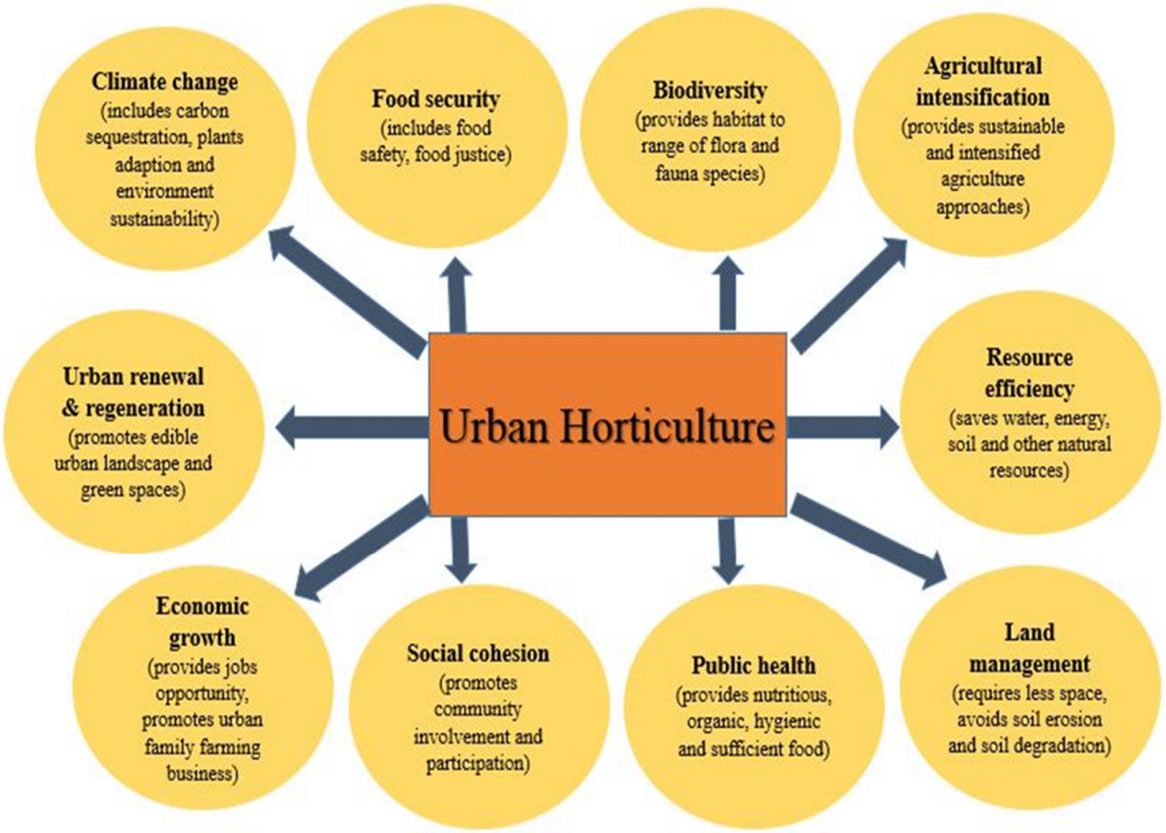

Figure 1. Societal social challenges that can be mitigated through urban horticulture.

Our main objective is to demonstrate the significance of urban horticulture, combined with new technologies to meet the needs of people in urban settings, for safeguarding community livelihoods, food security, and the environment. Moreover, the objective of this study is to discuss, in detail, the traditional, innovative, and modern cropping systems that can be easily adopted in growing agricultural commodities in urban dwellings, for sustainable food supply, during (and beyond) COVID 19. It is also hoped that the findings of this research will contribute to promoting urban horticulture in developed and underdeveloped countries. This comprehensive review on urban horticulture also provides an investigation into the following research questions (RQs):

RQ1: what are the socioeconomic features of urban horticulture?
RQ2: what are the traditional and innovative sustainable crop production approaches that can be used in urban horticulture?
RQ3: how can information technology (IT) play a role in providing fresh food supply during (and beyond) COVID-19?

2. Materials and Methods

In order to achieve our research objectives and to answer the above-mentioned research questions (RQs), information was collected from peer-reviewed articles that were published during the last twenty years; 2000 to 2020. The peer-reviewed articles were collected from well recognized journals that were present in the databases of Scopus, Web of Science, ResearchGate, and Google Scholar.

In order to meet and address the research objectives and questions, this review article was divided into the following four main sections:

(1) Significant features of urban horticulture;
(2) Traditional and innovative cropping systems used in urban horticulture;
(3) Modern cropping systems;
(4) Smart cities and urban horticulture.

The first section has been further divided into subsections that describe the importance of urban horticulture and ways that it contributes to food security, food safety, and food supply throughout (and beyond) COVID-19. It describes major cities of the world that are moving towards self-sufficiency by growing horticultural products and are fulfilling the needs of urban dwellers (Table 1). This section explains the significance of urban horticulture in reducing environmental pollution and the recycling/reutilization of organic and inorganic household items in the urban environment Figure 2). In addition, it also defines the significance and role of urban horticulture in reducing the effects of the changing climate and on human health.

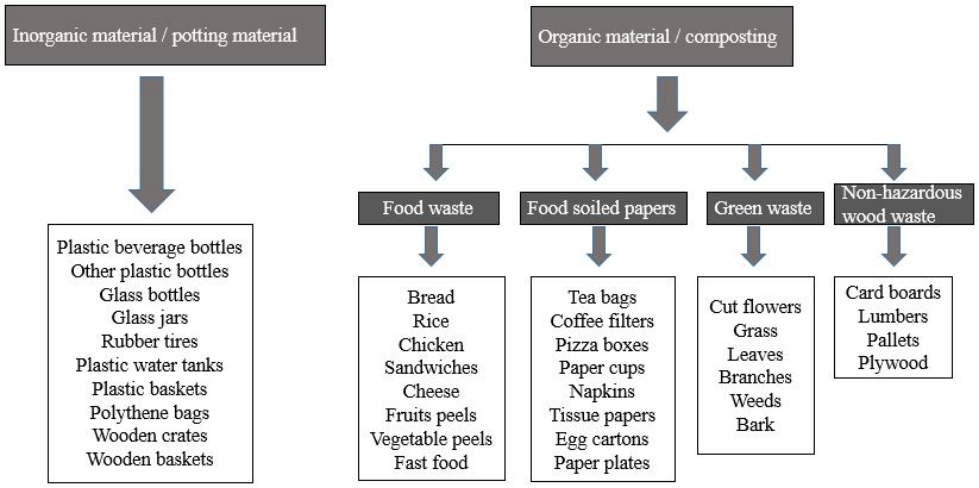

Figure 2. Inorganic and organic house waste items that can be recycled or reused in urban horticulture.

The second section describes both traditional and innovative cropping systems, such as home gardening, community gardens, and urban edible landscapes that have been used for a long time to meet the food demands of local urban people of a particular place.

The third section critically reviews several modern cropping systems, such as Z-farming, indoor farming, vertical green houses, rooftop greenhouses and gardens, edible green walls, aeroponics, hydroponics, organoponics, and aquaponics, which are being used in several countries for urban horticulture production. Moreover, it also explains how these approaches are environmentally-friendly and supply consistent food throughout the year to ensure food security.

The fourth and last section focuses on the use of digital IT tools in urban horticulture and the ways that they are helpful in the food supply chain during pandemic conditions, such as COVID-19, when movement is restricted and markets are closed.

3. Results and Discussion

3.1. Significant Features of Urban Horticulture

3.1.1. Source of Income Generation

In developing countries, poverty is more prevalent and job opportunities are extremely marginal, particularly outside the agriculture sector [20]. Cities are increasing in population, and the demand

for healthy and safe food is under intense pressure. Urban horticulture offers a source of local food production and employment generation opportunities for the future, particularly in developing countries [21]. Currently, many from the developing world are using urban horticulture as a direct source of income generation by running their own businesses [22]. In Africa, urban agriculture is becoming an important source of employment, where roughly 40% of urban citizens are involved in urban agricultural jobs [23]. This was also supported by other researchers, who stated that the agriculture sector has increased urban and rural employment by increasing labor empowerment [24].

In many countries, urban areas are filled with large buildings and the most fertile lands are converted into structures. Under these circumstances, urban agriculture may be limited to low fertile lands on which only selected crops can be grown. For example, growing short duration crops, such as leafy vegetables, is a good option, and gardening practices may help in restoring soil health [25]. There are still some marginal and vacant lands available in or near cities where local people can develop community food gardens. It has been documented that low-income families struggle to get hygienic and affordable food [26]. Such communities could be integrated into urban horticulture activities to improve their livelihoods and ensure food security [27]. Urban horticulture provides work opportunities to those who have the least employment opportunities, and is a way for the unemployed, as well as day-wage earners, to become self-reliant entrepreneurs [28].

3.1.2. Control of Environmental Pollution and Waste Management

Urban horticulture can help mitigate ever-increasing environmental pollution because of the ability of plants to absorb air and soil pollutants. Cities are becoming denser due to rapid urbanization, the increase in the numbers of structures, and the addition of industry. Heavy transportation pressure on roads results in vehicles that emit harmful gases, such as CO_2, CO, SO_2, etc., which are harmful to urban inhabitants and contribute to global warming. Edible urban horticulture plants can help alleviate environmental pollutants. Plants absorb CO_2 and in return exhale O_2 during photosynthesis. This phenomenon is important for all living organisms, both rural and urban. When vegetable and fruit crops are grown near city boundaries, the city will become the site of agricultural production. In cities, green vegetation reduces air pollution, dust particles, and nitrogen dioxide [29]. If enough food can be produced locally, urban horticulture can contribute to the reduction of the transport flow on roads, which ultimately reduces smoke and harmful gases from vehicles. The other advantage is reduced transportation costs and closer market access from which fresh food is easily available [17]. Moreover, high-tech urban horticulture produces more year-round production of food as compared to traditional methods, and reduces CO_2 emissions generated though transportation [30].

Currently, at international levels, several strategies are being adopted to reduce food loss and waste [31]. In the last few years, awareness has been created among the public to reduce food waste, and, it has been observed that this gradual change depends on cultural, political, geographical, economic, and social drivers [32]. Waste management is another serious hazard that can be minimized, to some extent, by integrating horticultural plants into the urban landscape. Inorganic waste, such as plastic bottles, rubber tires, plastic water tanks, baskets, and polythene bags can be used as pots and hanging baskets by filling them with potting substrate and plants. In some places, these materials were used successfully as roofing material for plants and soilless cultivation [33,34]. However, household inorganic materials, such as bottles and cans of motor oil, paint, and pesticides should be avoided, as they are hazardous. In addition, during reuse and recycling of inorganic products, batteries and mercury thermometers should be avoided, as they are enriched with heavy metals [35].

Daily household organic waste, such as papers, tissues, fruits peels, vegetable peels, and plant remains can be recycled into compost (Figure 2). Other organic household waste that can be recycled include wood, cardboard, other biodegradable packaging, natural fiber clothing, newspapers, furniture, food scraps, and grass clippings. Organic waste is normally defined as plant and animal-based organic material that is degradable into carbon. This type of material is normally kept separate from other material and is used for composting. Composting is a positive initiative to keep the urban environment

clean and can be used as a natural soil amendment for fresh food production [36]. Compost from organic materials is ecofriendly and reduces consumption of chemical fertilizers. The extracts prepared from organic compost are also used to control plant diseases in Togo and Senegal [37]. Organic composts and other biosolids have been shown to improve the quality of urban soils [38], and the use of compost also reduces lead uptake in vegetable crops on contaminated sites, resulting in crops that are safe to eat [39].

3.1.3. Ensures Food Supply and Sustainability in the Era of COVID-19 and beyond

Consistent food supply is at high-risk due to natural disasters, climate change, conflicts between countries, the refugee crisis, and worsening inequality. According to the Food and Agriculture Organization (FAO), 820 million people are suffering from hunger, out of which, 113 million are at risk (concerning their lives and livelihood). In addition, the outbreak of the COVID-19 virus has further threatened the lives of 820 million people. Due to the COVID-19 virus, urban food systems are highly disrupted. Worldwide, lockdown polices are being adopted to cope with this problem, which has impacted food commodity production, processing, supply, marketing, and transportation, significantly. Due to lockdowns and food supply restrictions, the cost of food items are being inflated, and there is food scarcity, especially in urban areas. Poor urban residents are not able to purchase food due to increased prices. Moreover, borders are closed worldwide, and there are overall restrictions in food exports and imports. The World Food Program has claimed that, at the end of 2020, there will be severe food insecurity due to COVID-19, and the number of people affected by food insecurity will be doubled, particularly people having limited resources and who work for daily wages.

Under these circumstances, urban horticulture provides an opportunity to supply healthy and safe food to cities and its surroundings. It will be helpful in stabilizing food prices by reducing the price volatility in markets under COVID-19 pandemic conditions. Growing vegetables in urban horticulture will enable the continuous flow of food with high food safety standards. This strategy was adopted by the Wuhan municipality and they started the project "Vegetable basket". They have cultivated vegetables (on 20,000 hectares) since February 2020, in order to provide a continuous supply of fresh vegetables [40]. Growing vegetables at homes in (nearby) vacant spaces will fulfil the food needs of poor people, and keep them engaged in positive, healthy activities during lockdown.

Urban horticulture can be helpful in adding resilience to our food systems during the COVID-19 pandemic as it will strengthen markets by supplying food, and prevent supply-chain disruptions. The practice of urban horticulture will be helpful in keeping food systems running smoothly during a crisis, and the innovative techniques used in urban horticulture will protect individual workers from spreading COVID-19. We must show unity in our societies, so that local farmers, and people in general, can continuously produce and sell their crops safely.

3.1.4. Food Security

Global food security is under intense pressure due to urbanization and industrialization of productive agricultural lands throughout the globe [41]. Due to population increase, it is estimated that, by 2030, world food demand will increase to 43% [42]. Food security requires that every person will have safe, nutritious, affordable, and sufficient food for their health, according to the personal preference of each individual. It is suggested that urban horticulture can meet the challenge of providing safe and abundant fruits and vegetables [43]. Urban horticulture fulfills much of the vegetable demands in Singapore, as 35.5% of vegetables are grown by people on rooftop farms and gardens [44].

However, the sustainability of urban horticulture depends on access to and appropriate management of available spaces, such as vacant lands, rooftops, lawns, and commercial places provided for urban agriculture, as well as individual initiatives and behavior to grow fruits and vegetables [45,46]. Food security can be augmented if urban dwellers opt for self-production of food at home. Using these various methods, urban horticulture has already contributed significantly to food security and livelihoods in developing cities [25].

Because of constant migration towards cities in developing or developed countries, food needs are increased, and there is need to provide local sustainable food [47]. Besides food quantity, quality is becoming one of the major concerns of cities. Urban horticulture has the potential to reduce food pressure and, thus, urban food security can be safeguarded [48]. Throughout the world, urban agriculture has played a significant role in food security, for example, in Japan, after a natural disaster, it helped with food resiliency [49]. Similarly, Cuba lost a major trading partner after the Soviet Union breakdown, and, at that time, urban agriculture helped Cuba to become food independent, and played a prominent role in food security. Currently, more than 35,000 ha in Havana is used for urban and peri-urban horticulture, and Cuba is one of the leading countries in urban horticulture [50]. Other cities of the world that produce urban horticulture products through efficient land utilization are presented in Table 1. Urban horticulture is not only a source of nutritious food production, but is also a way to secure food supply. In the USA, urban agriculture declined from 2002 to 2007, but there was an increase in small farms, and the most common products were vegetables, eggs, and goats [51].

Table 1. Cities/countries producing urban horticulture products by efficient land utilization.

City/Country	Horticulture Products Grown	Land Utilized	References
Havana/Cuba	Vegetables (beans, tomatoes, lettuce, okra, eggplant) Fruits (Papaya, pineapple, avocado, guava, coconut)	Community gardens, vacant spaces, green spaces, parking, highways, rooftops	[50]
Jakarta/Indonesia	Cabbages, ginger, chilies, pineapples, and mangoes	Vacant land, uneven spaces, riverside, roadside, and coastal lands	[52]
Rubi/Spain	Tomatoes and green houses	Rooftops	[53]
Munich/Germany	White cabbages, grapes, and apples	Green spaces, building facades, rooftops, and car parking	[46]
Boston/USA	Dark green vegetables and fruit trees (according to climate and cultural practices)	Vacant residential areas, vacant commercial areas, and rooftops	[43]
Montreal/Canada	Vegetables (according to climate and consumer preferences)	Vacant spaces, residential gardens and rooftops	[16]
Toronto/Canada	Summer vegetables	Residential gardens and rooftops	[54]
London/UK	Strawberries, lettuce	Farmlands, private gardens, and small plots	[52]
Maputo/Mozambique	Lettuce, kale, cabbages, tomatoes, and carrots	Green belts and small plots	[55]
New Town/Singapore	Vegetables and hydroponic products	Rooftops and public buildings	[44]

3.1.5. Improvement of Climate and Microclimate

In recent years, many people have developed an interest in urban agriculture due to concerns about climate change and sustainable food supply in urban areas [18,19]. Worldwide, urbanization has negatively impacted the climate. Moreover, deforestation, greenhouse gases, heat and smoke emissions from vehicles, industries, and homes have raised pollution levels, and the temperature of the earth. Modern facilities and home appliances, such as air conditioning and refrigerators, are also prime reasons for the temperature increase. The effects of climate change, particularly rising temperatures and erratic rainfall patterns, are notable in reducing crop yields and environmental growing conditions [17,56]. Extreme climatic conditions have a negative impact on all living creatures. Cities are being polluted

with transportation, industries, and domestic activities [50]. Planned, well organized vegetation can change the urban microclimate, as well as reduce temperature and greenhouses gases significantly [57].

In cities, vacant and neglected places can be used for green vegetation. Trees and shrubs can be planted along roadsides, highways, and even the center of wide streets. Vegetation assists in decreasing solar radiation and dust particles, and increasing atmospheric humidity, which will modify the microclimate of a place. Moreover, the strategy of planting aromatic plants can help in mitigating bad odors from polluted cities. Urban horticultural plants have played an important role in making cities more natural, greener, and beautiful. For example, in the town of Sofia, Bulgaria, increased vegetation in vacant spaces has resulted in milder temperatures [58]. The use of tall trees, green shrubs, grasses, and mulches in urban settings has been shown to have a cooling effect [59].

3.1.6. Conservation of Biodiversity

Another benefit of urban horticulture is that it makes a major contribution to balancing the ecosystem by maintaining biodiversity. In urban areas, human activities have disturbed the biological ecosystem, including the habitat of several flora and fauna species. It has changed ecological patterns, increased environmental pollution, and changed natural cycles and processes [60]. The diversity of flora and fauna are greatly reduced in urban areas compared to rural areas [61]. The reduction in biodiversity results in decreased natural resources and disturbed nutrients and water cycling [62,63]. However, research on urban agriculture shows that cities still have the potential to support biodiversity, and the conservation of endangered and threatened species [64]. Green spaces in urban areas offer important refuge sites and natural habitats [65].

Urban landscape practices in cities contribute to the conservation of biodiversity, and can be even better in some ways, as compared to natural or non-urban landscape. It has been observed that urban landscapes are richer in flora and fauna species compared to rural landscapes [58]. In urban horticulture, there is usually less use of fertilizers, pesticides, and fungicides, which helps with the coexistence of other components of the ecosystem. In urban horticulture, mostly organic and natural materials are used to produce crops, which saves the growers and consumers from the hazardous effects of pesticides. Organic farming in urban horticulture is considered an essential tool in enhancing the biodiversity of urban areas because the flora and fauna survive better in these natural habitats [21].

3.1.7. Source of Recreation and Reduction of Gender Inequality

A trend for more urban horticulture in developed countries is increasing significantly. People frequently practice horticulture on small areas of private land, home gardens, school gardens, and even on leased lands [22]. Along with food production, people are doing urban horticulture as a hobby or recreational activity. Gardening promotes social association and cultural activity among people. In urban horticulture, older people are also able to participate and keep themselves engaged in gardening. It has been shown helpful in reducing mental stress. Urban horticulture is also helpful in the reduction of gender inequalities. Both males and females work together at the same place and in a good environment. In developed countries, more than 65% of participants in urban horticulture are women [25]. The involvement of women in urban horticulture empowers them to become independent [27]. It is also observed that home gardening has positive effects on mothers and children [13].

3.1.8. Self-Reliance and Land Management of Cities

Urban horticulture is a way to increase the self-reliance of cities. It can lead to cities that are self-sufficient and independent. They can strive to produce enough fruits and vegetables for their residents. It is argued that, if cities are sustainable, then the world would be sustainable [58]. Several cities are independent and self-sufficient in horticulture, while some are self-sufficient up to a certain limit [26]. In Berlin, urban horticulture was of utmost importance as it provided fruits and vegetables during a crisis of limited food [66].

To meet the food demands of an urban population, land in and round the cities, such as green belts, land adjacent to sidewalks, vacant plots, community gardens, botanical gardens, and rooftops should be used efficiently. A recent case study from Sheffield, UK, showed that there are large potential spaces available to produce more than enough fruits and vegetables to fulfill the needs of urban inhabitants [67]. Cleveland, Ohio, a city of 400,000 inhabitants, has the potential to fulfill resident demands by growing fresh vegetables on rooftops and conducting vertical gardening in vacant spaces [68]. If less productive, conventional production methods are used, then 14 times more land will be required to fulfil the needs of the residents. That all urban cities could be self-reliant and self-dependent is a future challenge; it is only possible through adopting urban horticulture initiatives. This is challenging, but targets can be achieved with the financial and technological support to communities.

Water use can be a concern in urban horticulture in arid regions of the world. A study of household water recycling, showed that "greywater" from sinks and showers in the household could be used for home gardening, but should be filtered. Public acceptance was high; 76% of respondents would reuse greywater for gardening, but infrastructure/plumbing changes would be necessary to promote widespread implementation of these systems [69].

3.1.9. Public Health

To fulfil food demands, the intense use of fertilizers has significantly increased the nitrate concentration of crop fields, vegetable fields, orchards, and groundwater [70]. Moreover, the excessive use of pesticides and its surface runoff has degraded water quality and increased its toxicity to non-target organisms [71]. In this regard, urban horticulture has lessened the load of synthetic fertilizers and pesticides that are carcinogenic and hazardous to human health, and it has promoted the use of organic foods that are natural and healthier. The other advantage of urban horticulture is that the food produced locally is fresh and high in vitamins, minerals, and proteins when consumed [48].

Urban environment refers to areas that are dominated by made structures, such as large residential and commercial buildings made-up of concrete and glass. Urban environments are more polluted due to anthropogenic activities, such as smoke and toxic gases exhausted by vehicles and factories [72]. This urban environmental pollution causes several health related issues, such as respiratory and heart problems [73]. Moreover, congested spaces and less physical activity has led to increased sedentary behavior, depression, and techno-stress in adults, and an increased number of mental disorders in children [74–76]. Urban horticulture can complement parks with forest environments, and both will promote human health and quality of life [77]. Nowadays, in urban areas, green spaces are used by healthcare centers as a form of natural therapy in controlling diseases, as there is a positive relation between health and nature. Several studies revealed that time spent in natural green environments reduces nervous activity, improves immunity, cell activities, and stabilizes pulse rate [78,79], while it decreases cholesterol, salivary cortisol (stress hormone), and systolic and diastolic blood pressures [80,81].

In addition, there is an increased interest seen in indoor planting, as urban horticulture provides relief, reduces stress, and improves physical and mental health. Indoor planting improves the quality of air, visual stimulation, and has psychological benefits [82,83]. Green spaces and natural food in urban horticulture has increased the longevity (and socioeconomic statuses) of senior citizens [84]. Keeping in mind the positive physiological and psychological effects of urban horticulture on human health, it should be considered an essential part of urban civilization to promote health in the future.

4. Traditional and Innovative Cropping Systems Used in Urban Horticulture

Traditional urban horticulture has existed ever since humans began the transition from living in villages to urban environments. The existence of urban horticulture facilitates the consistent supply of fresh and inexpensive food to city dwellers. Traditional systems practiced are home gardening, community gardening, and edible urban horticulture landscapes. These systems facilitate growing

food crops on rooftops, balconies, garden plots, smaller areas around homes, along roadsides, and in any vacant space to fulfill the needs of urban residents.

4.1. Home Gardening

Home gardening is a global phenomenon of both rural and urban agriculture perceived by all levels of societies to abate malnutrition and meet home food requirements. It is a hobby of people worldwide, providing them with an opportunity to spend their leisure time in healthy outdoor activities [27,85]. Home gardening, also known as backyard or kitchen gardening, is one of the main types of urban crop farming. It includes various ways of growing crops in backyards, balconies, vacant spaces, or any kind of small garden. Rooftop gardening on urban houses has also increased vegetable production in homes. These gardens can be planted in the ground, or in various types and sizes of containers.

The advantages of home gardening is that it provides fresh vegetables, saves the home income spent on food commodities, and provides a surplus food production income that can be generated by selling vegetables in the neighborhood [86]. This is particularly valuable in developing countries, where 60 to 80% of a family's income is spent on food items [15]. Home gardening provides fresh, safe, and hygienic food to people in developed countries, which improves health and minimizes diseases incidence. It is argued that home gardening can enhance the quality and quantity of fruit and vegetables to communities as well [87]. Home gardening in Oman has been shown valuable as a source of food, exercise, shade, and aesthetic value. However, the quality of the results is jeopardized by poor gardening practices by unskilled gardeners, and points to the need for more educational efforts directed towards home gardeners [88].

There are some risks of home gardening in urban areas with a history of use of lead-based paints, prior industrial use, or buried trash [38]. Heavy metals, polycyclic aromatic hydrocarbons, and other anthropogenic wastes are often found when soils are tested. However, the use of compost and mulch to improve the soil for gardening also makes them safer for food crops, and reduces the likelihood that the soils will be tracked into the home as dust, which is also a health hazard, especially for young children [39].

4.2. Community Gardens

Community gardening is known as the collective cultivation of plants on a shared area by a group of community members. These gardens are located in urban environments and can be located in various areas of a city, and are usually owned or managed by the municipality. In some cases, home gardens may have limited land, insufficient infrastructure, or limited resources, or have other restrictions on their use for urban horticulture [85]. In community gardens, people collaborate with each other and share the facilities. Sometimes, these community gardens are supported by private organizations or governmental programs, which assist by providing access to water, mulch, fencing, seeds, or other required materials. In community gardens, vegetables, fruits, flowers, and herbs are planted in either individual or shared plots. If there is risk of soil pollution contamination, plants can also be grown in wooden boxes, raised beds, or containers; they may also use unusual vacant spaces [20].

In developing countries, community gardens are promoted for food security of the poor, as they provide the opportunity for residents to share subsidized land to grow their own food. While in developed countries, community gardens also help to provide food to struggling neighborhoods, and also strengthen communities, educate people, make the city greener, and can promote intercultural communication, along with providing a more continuous food supply [49]. According to an estimate from the American Community Gardening Association (ACCA), there are more than 18,000 community gardens present in the United States and Canada [89]. In cantonments in India, soldiers produce fruits and vegetables on vacant lands transformed into farms. It has expanded the supply chain of agricultural goods and has made the city more eco-friendly [1].

4.3. Urban Edible Horticulture Landscape

Edible landscaping is a holistic approach towards making urban infrastructure more sustainable. Edible urban landscapes started in Berlin, Germany, in the 19th century to enhance the self-sufficiency of residents with lower incomes, such as older citizens, workers, and for families with multiple children [90]. It is a sort of continuous productive urban landscape as it provides fruits and vegetables to cities [20]. In urban edible horticulture, outdoor areas are planted with fruit trees and vegetables. In cities, this practice varies from small scale to large scale [87]. In England, "Incredible edible Todmorden" was the first city where visitors and residents of the town could take free fruits and vegetables [87].

The intention of urban edible horticultural landscapes is to improve cities' food security and to connect to rural areas for food supply [85]. In developing and developed countries, edible landscapes can be started on vacant lands, green belts, and roadsides. Urban forests are an extension of the edible landscape idea—now being attempted in Seattle, Washington [91].

5. Modern Cropping Systems

In some urban horticulture environments, poor soil and water quality are the major constraints to urban crop production. In agriculture, new innovative techniques have been developed to maximize yield, while reducing environmental pollution. The techniques developed occupies less space and can be adopted efficiently in urban areas. These techniques are proven to be beneficial and efficient and have the possibility of making horticulture more sustainable [92].

5.1. Indoor Growing Systems—Overview

Currently, indoor crop farming systems are being used and the crops are grown in agricultural buildings to avoid external contamination by creating a protected environment [48]. Sometimes these indoor growing methods are called "Z-farming", which designates them as using zero acreage [93]. These are planting methods that do not use open spaces or farmland. It is believed that the roofs of schools, shopping malls, hotels, and supermarkets are the ideal places to build integrated agriculture [94]. Z-farming includes indoor farms, vertical green houses, rooftop greenhouses, rooftop gardens, and edible green walls [48]. Recently, projects on Z-farming have been initiated at the commercial level by several private and nonprofit associations in many cities of the world [95]. The main aspect of combining vegetable production with existing buildings is to save resources and improve resource efficiency [66]. Nowadays, Z-farming is the major concern of Europe, Canada, and the United States [96,97] and it is an innovative technique that contributes to sustainable urban agriculture [95]. It also provides a new pattern of food supply, farming technologies, specific networks, and improves opportunities for resource use efficiency in urban spaces.

5.2. Living Edible Wall or Vertical Gardening

Living wall landscapes or vertical gardens provide an alternative green system in which plants are supported along a wall vertically. In vertical farming, there is no support required from the ground for rooting, as nutrients and water are provided within the vertical structure. The installation of living wall systems creates healthy, vigorous, and long-lasting green systems, which are resource efficient and provide sufficient space to plants and their roots to anchor [98]. Vertical plantings along a wall have several other benefits, such as noise reduction and air purification. Moreover, it is helpful in maintaining the urban ecological environment [99]. Edible plants used in vertical gardening can provide abundant fruits and vegetables throughout the year. Besides edible plants, evergreen plants such as *Myrtus communis*, *Cistus purpurescens,* and *Teucrium xlucidrys* perform well in living wall systems [100].

5.3. Rooftop Gardens and Greenhouses

Rooftop gardens and greenhouses are situated on the top of houses or industrial buildings and represent an innovative alternative for promoting self-sufficiency and local living roofs and, eco-roofs by utilizing underused roof structures [101]. Generally, in a rooftop garden, the roof of the building is covered with substrate into which shrubs, trees and other plants are grown and these roofs are also known as roof gardens [102]. The first rooftop garden was developed in Germany to improve aesthetics [103]. By the year 1996, one out of ten roofs were made green in Germany while 70% of apartment roofs were made green in Switzerland [104]. At present, rooftops are being used worldwide for several purposes, such as in Singapore, where rooftops are used for cooling and to reduce energy consumption [105]. In Berlin, urban rooftop greenhouses are used as they are energy-efficient, depend on local resources, and have social and educational aspects [66]. Likewise, in Hong Kong, there are a lot of projects adding green rooftops to several governments, public, and school buildings [106].

There are several socioeconomic benefits of rooftops gardens, such as preventing heat loss in winter as compared to conventional roofs [107]. Moreover, these rooftops provide increased cooling by providing shade, evapotranspiration, as well as provide savings on energy consumption. It was observed in Ottawa, (Canada) that one green rooftop has reduced 95% of heat gains and 26% heat losses [108]. The studies also revealed that green rooftops have increased the lifespan of roofing membrane up to 40–50 years as compared to conventional roofs, which have life spans of 10–30 years, by protecting them from UV radiation and thermal stress [109]. In addition, these rooftops have aesthetic value and increase the value of the property [110]. The other social, economic, and environmental advantages of rooftop gardens are shown in Table 2.

Table 2. Social, economic and environmental advantages of rooftop gardens.

Social Sustainability	Economic Sustainability	Environmental Sustainability
➢ Source of education ➢ Source of recreational activity ➢ Source of food for poor people ➢ Provides employment opportunities ➢ Enhances community participation ➢ Creates community gardens and green belts ➢ Improves aesthetic value	➢ Increases production of organic fruits and vegetables ➢ Enhances local food supply ➢ Reduces production and transportation cost ➢ Safe biofuel and increase its availability ➢ Enhances property value ➢ Minimize building cooling load	➢ Enhances urban biodiversity ➢ Provides fresh food ➢ Improve air quality ➢ Recycling of organic wastes ➢ Reduces environmental pollution ➢ Reduces noise pollution ➢ Conserves fuel by reducing transportation

Vegetables, fruits, bees, and aromatic plants can be grown using soil-based or soilless systems, such as aeroponic and hydroponic [111]. In the future, rooftop gardens should be included in the building design. These rooftop gardens can provide ecosystem services, such as catching storm water, and also provide fresh and safe food, thus, playing a role in urban food security [112].

5.4. Use of Soilless Culture

Recently, many innovative techniques have been developed to culture plants in soilless media. These techniques include such systems that do not require solid medium like soil. Instead of soil plants are grown on organic or inorganic substrates [113]. Modern cultivation systems include aeroponics, hydroponics, and aquaponics in which plants are grown on nutrient enriched water instead of soil [114]. These modern techniques require less water [115] and space as compared to traditional agricultural systems. Moreover, there is often reduced use of pesticides, and in controlled environment settings, there is constant production during the whole year [116]. In some cases, these techniques are expensive, and require a constant source of electricity for pumps for water flow and aeration, but they offer

value in providing a consistent food supply to ensure food security. Further, the vegetables and fruits produce under the modern techniques are of high quality and hygienic.

5.4.1. Hydroponics

Hydroponics is a cultivation method that does not require soil, but relies on nutrient enriched water. Roots are either suspended in water or supported by growth media such as rocks, clay, or pebbles [117]. Sunlight can be supplemented or replaced with lighting structures that supply light, usually light emitting diode (LED) lights. It is carried out in a controlled temperature environment, so that reduced chemical or chemical-free fresh produce will be available to urban areas year-round. It is the most adopted technology in countries that are not able to grow food during the winter. In hydroponics, all ecological factors like relative humidity and temperature are automatically controlled. This also reduces the risk of harmful insects, pests, and disease causing microorganisms [118,119]. Moreover, the product produced under hydroponic systems is dirt-free and free from animal excreta. This system has several advantages over traditional soil culture as it requires less maintenance, weeding, and tilling [120]. Further, it is a labor- and time-saving technology to manage larger areas of production, as nutrients and pH are easily manageable under this system [121]. Therefore, under ideal environmental conditions, and nutrients availability, the products produced under hydroponics are uniform and high yield (Figure 3). Hydroponics is an important alternative planting practice of growing fruit and vegetable in urban areas where fertile land is limited.

Figure 3. The successful cultivation of lettuce (**A**) and strawberry (**B**) in Muscat, Oman under hydroponic systems.

5.4.2. Aeroponics

Aeroponics is a vertical farm cultivation method in which 90% less water is used compared to hydroponics [122]. Under this system vegetables, flowers and fruits can be easily grown by using a system where mist is applied within a chamber to the living roots. Plants grown under aeroponic systems have higher nutritional quality, due to higher absorption of minerals [123]. This technology is also beneficial for growing a large amount of plants in limited area. Under this system, the plants are grown vertically and are arranged in a tubular frame or are suspended in a container, so it reduces the use of floor space [124].

5.4.3. Aquaponics

Aquaponics combine hydroponics and aquaculture practices [125]. In addition to producing healthy plants, the aquaponics system can also produce fish that can be sold through community supply networks [126]. Aquaponics only uses 2% of the water as compared to traditional soil-based agriculture, since most of the water is recycled. It is a closed loop system with reuse of waste from the fish used as fertilizer for the plants [127]. The hydroponic beds include exchange filters, which removes harmful acids, chemicals, and gases, and the gravel used in aquaponics provides habitats to nitrifying bacteria, which enhance water filtration and nutrient cycling. Aquaponics has the ability to become a model of sustainable food production by accomplishing the 3Rs (reduce, reuse and recycle) [128].

5.4.4. Organoponics

Organoponics is the cultivation of plants on organic substrates, without the use of any artificial chemicals but uses a seedbed formed by mixing soil and organic matter. This technology can be used with soils which have very low fertility. This technique is appropriate especially for developing countries and for those areas that have less infrastructure or access to fertilizers or other inputs. Because it is environmentally-friendly, it is very suitable for urban horticulture as well. Throughout the world, the demand for organic food is increasing [129] and the global sales of organic foods is now up to $97 billion annually [130]. In this aspect organoponics can play a major role in the organic production of horticultural products especially in cities.

6. Smart Cities and Urban Horticulture

Smart cities are urban places where the integration of technology intensifies working competence and information to improve the quality of life for inhabitants, the environment, and government services. Cities are getting smart because of IT solutions that enable efficient functions in real time [131]. However, it is not clear yet how to integrate urban green spaces usage into smart cities [132]. Possibilities include more use of cell phone "apps" to provide real-time information required for optimal crop management, and remote control and monitoring of climate controlled facilities.

Food supplies could be vulnerable due to a multitude of factors, e g., climate change, impacts on rural crop production, supply chain disruption, and commodity price upsurge [133]. The recent COVID-19 catastrophic lockdown phenomenon has limited the food supply chain, as some shopping malls and markets were closed, and there was some panic when purchasing through visiting markets. High COVID-19 cases among farm workers and employees at meat-processing facilities in the U.S. disrupted the supply of food from the source for a period of time. Online systems of purchasing fresh fruits and vegetables have somewhat resolved this issue in the COVID-19 era. In smart cities, people are getting their daily food stuff via the efficient use of this technology; however, there is a need to implement alternative food production systems as well.

The current scenario of COVID-19 forces us to use digital tools and technology to help target interventions by changing global communication systems [134]. The research and development sector of agriculture can pay a pivotal role in this transformation. The latest digital technological innovations can help farmers cope better with COVID-19, and with any future crises to the food system, by making agriculture more productive [134]. Urban horticulture in open spaces and skyscraper food production areas offer a potential way to mitigate the weakness of urban food supply in smart cities, or elsewhere too.

7. Conclusions

Urban horticulture has positive effects on social, economic, food, and ecological sustainability within cities. It increases community livelihood, saves energy, sustains the environment, and improves health through fresh food supplies in urban environments. It also offers recreational and aesthetic value to urban landscapes and individual homeowners. During the pandemic conditions of COVID-19,

it offers a more consistent food supply, prevents markets disruptions, increases food scarcity, and helps with stabilizing food prices. In addition, urban horticulture can help people become physically stronger and spiritually enriched; it can be considered a key component to promoting public health [135]. However, there remains unexploited potential for urban green infrastructures for vegetable and fruit gardening, which needs to be explored and integrated into urban food production systems to provide sustainable food supply to urban dwellers, as well as provide environmental protection, and enhanced food security.

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