Challenges in Sustainability
https://www.acadlore.com/journals/CIS

Assessing the Potential of Urban Orchards, Berry Bushes, and Apiaries for Local Food Production and Carbon Mitigation in a Small European City

Rok Kamnik*

Faculty of Civil Engineering, Transportation Engineering and Architecture, University of Maribor, 2000 Maribor, Slovenia

* Correspondence: Rok Kamnik (rok.kamnik@um.si)

Received: 02-11-2025 **Revised:** 03-28-2025 **Accepted:** 06-11-2025

Citation: Kamnik, R. (2025). Assessing the potential of urban orchards, berry bushes, and apiaries for local food production and carbon mitigation in a small European city. *Chall. Sustain.*, *13*(2), 266–280. https://doi.org/10.56578/cis130208.

Abstract: With the growing concentration of populations in urban centres, ensuring resilient and sustainable food systems has become a critical priority. Disruptions in food supply chains, particularly in small cities with limited logistical flexibility, can severely compromise food availability. In response, the utilisation of urban green spaces for food production has been increasingly recognised as a viable strategy to enhance local self-sufficiency while contributing to broader environmental goals. This study evaluated the potential for integrating urban orchards, berry bushes, and apiaries within the public green spaces of Maribor, a small Slovenian city with a total area of 40 km². Emphasis was placed on publicly owned or publicly accessible land—including municipal holdings, state-owned plots, and land managed by public companies—that remains underutilised yet suitable for edible landscaping. Using spatial analysis conducted through QGis, available green space was quantified and assessed for suitability in supporting fruit trees, edible shrubs, and beekeeping installations. Estimates were then derived for the number of fruit and berry seedlings that could be planted, the volume of potential fruit and honey yields, and the corresponding contribution to carbon dioxide reduction through enhanced urban vegetation and decreased food transport dependency. The results indicate that even fragmented and seemingly marginal green areas possess significant aggregate potential for improving local food resilience, fostering community engagement, and delivering measurable carbon mitigation benefits. Furthermore, urban food forests and community orchards were identified as multifunctional landscape interventions that not only enhance food security but also improve urban biodiversity, air quality, and residents' mental well-being. These findings align with the European Union's objectives for urban ecosystem efficiency and carbon neutrality by 2050 and underscore the importance of integrating edible green infrastructure into urban planning frameworks. The study contributes to the growing body of evidence supporting the role of decentralised, nature-based solutions in urban sustainability transitions.

Keywords: Urban green infrastructure; Urban orchards; Edible landscaping; Community food forests; Local food resilience; Urban apiaries; GIS-based spatial analysis

1. Introduction

Food security remains a fundamental pillar of human well-being, with consistent access to nutritious meals being indispensable to daily life. Yet, the fragility of the global food system is frequently underestimated, as is humanity's dependence on a stable and well-functioning biosphere. Growing pressures on ecological balance, driven by climate change, land degradation, and biodiversity loss, have exposed the vulnerabilities inherent in contemporary food supply chains.

A pronounced trend of urbanisation has been observed globally, with increasing numbers of people relocating to urban areas. Between 1985 and 2015, the global urban extent expanded at an average rate of 9,687 km² per year (Liu et al., 2020). According to the United Nations Department of Economic and Social Affairs (United Nations, 2018), the majority of the world's population already resides in urban centres—a proportion projected to rise further in the coming decades (Table 1). It must be noted that the classification of urban versus rural populations varies across countries and regions, shaped by distinct geographical, cultural, and socio-economic factors.

Rapid urbanization can bring with it challenges such as transport, infrastructure, access to water, housing needs, environmental impacts, social inequality, a healthy environment, and food demands. As we saw during the pandemic, countries, regions, and municipalities are very dependent on transport and supply routes. At that time, international and national traffic in most countries fell drastically (Elbert et al., 2023; Trček & Kamnik, 2022; Zhang & Hayashi, 2022), which also disrupted food deliveries and changed urban logistics (Dablanc, 2023). Only then did we really perceive our dependence on others and the importance of (local) self-care. Involuntary starvation in humans, often referred to as hunger, can have a profound effect on the behavior of individuals. Hunger can have many physical, emotional and behavioral consequences. Lack of food can lead to exhaustion, weakness and other health problems (Most et al., 2017), which can affect one's ability to perform daily tasks and participate in society. Hunger can trigger emotional reactions such as anxiety, depression, attention deficit hyperactivity disorder, dementia and irritability (Gibson et al., 2013). Individuals may experience decreased motivation, difficulty concentrating, and an increased risk of aggression or irritability. Individuals experiencing hunger may adapt through behavioral and lifestyle changes (Stubbs & Turicchi, 2021). This may include foraging, sharing resources with the community, seeking help, or other adaptive behaviors. Hunger can also affect social relationships. Individuals may withdraw from society or lose interest in social activities due to a lack of energy and emotional strain. Involuntary starvation can affect the economic and educational opportunities of individuals. It is important to understand that the effects of hunger are complex and vary from individual to individual. Acute hunger leads to self-protective behavior (Elbæk et al., 2022).

Table 1. World percentage of urban population and trends (United Nations, 2018)

Region	% Urban	Trend Until 2020 [%]	Trend Until 2050 [%]
World	55.3	+89.7	+130.9
More developed regions	78.7	+44.4	+58.1
Less developed regions	50.6	+192.3	+270.5
Least developed countries	33.6	+359.5	+596.0
Less developed regions, excluding least developed countries	53.9	+190.0	+265.3
Less developed regions, excluding China	48.0	+140.0	+208.2
High-income countries	81.5	+39.9	+51.1
Middle-income countries	52.6	+170.1	+243.5
Upper-middle-income countries	66,6	+208.9	+274.0
Lower-middle-income countries	40.6	+141.7	+243.0
Low-income countries	32.2	+256.1	+439.0
Sub-Saharan Africa	40.4	+273.3	+422.9

Table 2. World top 10 countries in self-sufficiency, the year 2022 (The Economist Group, 2022)

Country	Score
Finland	83.7
Ireland	81.7
Norway	80.5
France	80.2
Netherlands	80.1
Japan	79.5
Canada	79.1
Sweden	79.1
United Kingdom	78.8
Portugal	78.7

There are many solutions for greater food security and providing people with food, from food sharing (Rut & Davies, 2024) to greater personal, local, and national self-sufficiency. In the village of Beshbulak in northwestern Kyrgyzstan, household self-sufficiency is valued not primarily as an end in itself, but for the way it enables broader forms of social sufficiency. The village's moral economy fosters networks of mutual responsibility, binding individuals and households through enduring social ties and systems of reciprocal support. (Light, 2015). Self-care therefore has a much wider impact and meaning than it might appear at first glance. According to The Economist Group (2022) and the global food security index for the year 2022, there are in the top ten places in the world in terms of self-sufficiency countries like Finland, Ireland, Norway, France, the Netherlands, Japan, Canada, Sweden, the United Kingdom and Portugal (Table 2). A study by Hassan et al. (2024) in Multan, Pakistan, examined the conversion of mango orchards to urban housing developments and its perceived socio-ecological consequences. Orchards can serve not only as sources of fresh produce but also as urban forests contributing to biodiversity, carbon sequestration, and green space equity (Davivongs & Arifwidodo, 2023). As shown by Faber et al. (2013), in peri-urban areas of KwaZulu-Natal, South Africa, 52% of households had fruit trees and 25% had vegetable gardens. The study of Kazemi et al. (2018) illustrates how strategic urban planning using SWOT analysis can support the integration of fruit-bearing trees and shrubs into city landscapes, highlighting their ecological, social, and economic benefits.

Self-sufficiency for Slovenia for the past ten years is presented in Table 3. Ten-year data shows a positive trend in wheat, meat, eggs and honey production, a stable trend in vegetable production and a negative trend in potato and fruit production. As we can see, Slovenia has a very low percentage of self-sufficiency in potato, vegetable, and fruit production. There is no rice production. The average percentage of self-sufficiency for the year 2022 is 56%. What is most worrying is the low percentage of self-sufficiency in the field of vegetables and fruits.

Table 3. Slovenian self-sufficiency for ten years by food segment (in %) (Republike Slovenije Statistični Urad, 2023)

Year	Wheat	Meat	Eggs	Potato	Vegetables	Honey	Rice	Fruits	Milk
2010	57	84	93	63	30	74	0	47	116
2011	71	85	96	63	37	85	0	46	120
2012	70	83	92	55	34	51	0	37	117
2013	55	82	91	46	34	82	0	43	118
2014	77	80	90	67	38	20	0	42	120
2015	72	74	93	59	40	71	0	47	125
2016	74	76	95	55	42	59	0	32	132
2017	63	81	90	50	38	45	0	15	134
2018	69	81	96	48	41	79	0	47	129
2019	75	81	95	47	43	44	0	30	127
2020	88	84	95	60	48	67	0	36	133
2021	84	85	97	44	43	15	0	14	136
2022	72	86	94	36	39	90	0	29	na

There are several solutions for improving food safety like food sharing (Rut & Davies, 2024) and, of course, increasing food production in urban green areas and informal surfaces. The cities of today face the challenge of converting urban land into green space to ensure enough square meters per inhabitant. Here the standards are quite different from country to country. Many authors refer to the non-existent standard of the World Health Organization (WHO) and to 9–11 m^2 of green areas per inhabitant. This number comes from 1968, when this standard for new development surfaces was published by Italy and was somehow unofficially adopted by the WHO. Information System for the Evaluation of Urban Development (SIEDU) establishes a provision standard of 10 m^2 per inhabitant (Information System for the Evaluation of Urban Development, n.d.). This standard has been widely used and was also included in the United Nations “Methodology for the Preparation of GEO Cities Reports” (UN Environment Programme, 2009). Of course, some countries/cities don’t meet these standards (de la Barrera et al., 2023), while others exceed them significantly. According to the European Commission, Ljubljana, Slovenia had the highest amount of urban green space per capita in Europe in 2021, with 542 m^2 per inhabitant—significantly more than other European cities such as Helsinki, Lahti, Bern, Grenoble, Stockholm, Copenhagen, Nijmegen, and Tallinn, based on 2016 data. This level of green space provision aligns with the goals outlined in various sustainability frameworks, although the World Health Organization has not formally established a universal standard in its Brief for Action. The award criteria are grouped around seven environmental and climate focus areas: air quality, water, biodiversity, green areas and sustainable land use, waste and circular economy, noise, and climate change (mitigation and adaptation) (European Commission, n.d.).

There is a pragmatic recommendation for European cities: every inhabitant must have, at a distance of 300 meters, or a 5-minute walk from their home, a hectare of green space for play, regeneration and recreation (WHO, 2017). Regarding accessibility, van den Bosch proposes a pragmatic guideline for spatial planners and decision-makers, namely that the generally recognized need of residents for a sufficiently large volume of green areas near the dwelling should be satisfied by the 3-30-300 rule: at least 3 trees visible from each apartment, 30% of the area in each neighborhood should be covered by tree canopies, and 300 meters (usually a 5-10 minute walk) to the nearest park or for regeneration, play and recreation landscaped green areas (van den Bosch, 2021). This approach is significantly associated with better mental health, less medication use, and fewer psychologist or psychiatrist visits (Nieuwenhuijsen et al., 2022).

Informal surfaces serve as connecting elements and thus also strengthen the overall effect of the arrangement; at the same time, even with small interventions, it is possible to increase their attractiveness (Włodarczyk-Marciniak et al., 2020). Small areas (e.g., pocket gardens, parks, or green corridors) are also important. Altogether, all these green areas, elements and also green areas (roofs and walls) contribute to the overall effect of green areas in urban settlements, and we must consider them as public investments in health, well-being and quality of life (Bassetti, 2021). This is also confirmed by the International Association of Parks, The Parks Alliance, which emphasizes that the investment in parks is small compared to the benefits they bring (The Parks Alliance, 2020).

New greening solutions such as green roofs, walls and urban roof gardens are increasingly relevant in practice to ensure the benefits of green areas for settlements, and there are a lot of worldwide examples of that (Al-Kodmany, 2023; Comunicati Stampa Città di Torino, 2017; Kabisch, 2015; Leonardi, 2023; Norton et al., 2015;

Sturiale et al., 2020; Sturiale & Scuderi, 2019; Stutz, 2018; Wei et al., 2018).

The Presidency of the Council of Europe and the representatives of the European Parliament reached a temporary political agreement regarding the regulation of the restoration of nature in November 2023 (News European Parliament, 2023). The initiative seeks to implement measures aimed at restoring at least 20% of the EU's terrestrial and marine environments by 2030, with the objective of achieving full restoration of all degraded ecosystems by 2050. It outlines specific, legally binding targets and responsibilities for the rehabilitation of various ecosystems covered by the regulation—including agricultural areas, forests, freshwater bodies, marine habitats, and urban green spaces. This Regulation forms a key component of the EU's 2030 Biodiversity Strategy and contributes to fulfilling the EU's global environmental obligations, notably those outlined in the Kunming-Montreal Global Biodiversity Framework adopted at the 2022 UN Biodiversity Conference (News European Parliament, 2023).

As seen, there is a general agreement to make urban areas greener. The other thing is what to plant in those areas. To mitigate the effects of extreme heat, Metro Vancouver recommends planting climate-resilient tree species such as Garry oak (*Quercus garryana*), shore pine (*Pinus contorta*), and deodar cedar (*Cedrus deodara*), all known for their tolerance to heat and drought. Residents are also encouraged to incorporate native and drought-resistant vegetation, including Oregon grape (*Mahonia aquifolium*), Douglas maple (*Acer glabrum*), and snowberry (*Symphoricarpos albus*), into their landscapes. Scientific studies confirm that green spaces—ranging from expansive urban parks to private gardens and street tree corridors—can contribute significantly to urban cooling. (Bosshart, 2023). So, in this context, every tree counts. And why not plant trees with edible fruits and berry bushes?

Pollinator decline is a global threat with serious consequences to biodiversity. Mosaic (Jachuła et al., 2019). A very thorough study of pollinators was conducted by Klein et al. (2007). The group found that 87 crops worldwide employ animal pollinators, compared to only 28 that can survive without such assistance. Honeybees are by consensus the most important animal pollinators, so it is obvious that we also need apiaries in the cities. No more than one (1) beehive shall be kept for each 223 m^2 of lot area, and no beehive shall be kept on a lot less than 223 m^2 in area (Mogk et al., 2010). The versatility and importance of bees on pollen plants in city microhabitats is described in the study of Vossler (2023). The trees and shrubs are major sources of food for the dominant bee species in early spring and spring (Twerd et al., 2021). Connected and creatively arranged green areas have a positive effect on taxonomic and functional diversity in bee communities (Buchholz et al., 2020). Of course authors have also considered other pollinators like butterflies (Dylewski et al., 2020), hoverflies and birds (Silva et al., 2023), insects (Lequerica Tamara et al., 2021), bumble bees (Bellamy et al., 2017), wild bees (Dietzel et al., 2023), etc.

Growing recognition exists of the diverse benefits that urban greenery offers to city dwellers (Andersson-Sköld et al., 2018). Among these, green roofs are emerging as valuable habitats for pollinator conservation in cities, especially when planted with a variety of native forbs that supply forage and designed to support bees with varying nesting needs (Tonietto et al., 2011). Similar to other forms of urban green infrastructure, green roofs can play an important ecological role by attracting and sustaining urban fauna, thereby enhancing ecological functionality in areas that were previously biologically impoverished (Wooster et al., 2022). Furthermore, urban forests hold considerable promise for promoting native biodiversity in city environments (Andreas et al., 2023).

2. Historical Background

The practice of tree planting has deep historical roots. Both the ancient Greeks and Romans were skilled in arboriculture, with the Romans documenting detailed planting techniques in comprehensive horticultural manuals (Henderson, 2004). During the Middle Ages, monastic gardens represented some of the most advanced systems, featuring extensive orchards of fruit and nut trees alongside large-scale vegetable cultivation (TCV, n.d.). Traditional food forests also have a long-standing presence, as evidenced by those still thriving in the Maya and Amazonian rainforests (Fogarty, 2012). One notable example is a 2,000-year-old food forest oasis in southern Morocco, sustained by over 800 community members and continuing to flourish today (Wallace, 2019). Similarly, in Hà Tĩnh province, a two-acre food forest has been cared for by 28 generations of a single family over the past 300 years.

Today there are some examples of orchards and berry bushes in the urban areas. Sheffield, United Kingdom (UK), is known for its project Edible Streets, where orchards and other edible plants are planted in public areas (Sheffield Environmental, n.d.). Bristol (UK) is also running similar initiatives, which include planting fruit and berry trees in accessible places in the city. As part of the "Beacon Food Forest" program, the city of Seattle (United States of America) has established a public orchard on public land where people can pick fruit (Fogarty, 2012). Similar it is in San Francisco and Portland (USA), Vancouver (Canada) with the City Fruit project (Vancouver Fruit Tree Project, n.d.) and Toronto, also in Melbourne (Australia) and many others: Madrid (Spain), Göteborg (Sweden), Baltimore (USA), Edinburgh (UK), Milan (Italy), Budapest (Hungary)…

There are well-known examples in Slovenia, when during the Second World War, specifically in 1942, the Congress Square in Ljubljana became a kind of "city field", as the lawns were ploughed and potatoes were planted, and two years later, the latter was replaced by soybeans. (Kamra, n.d.)

The first apiaries in cities began to appear in the 19th century. It is generally known that the emerging urbanization and the development of modern cities in the 19th century stimulated the development of beekeeping even in the urban environment. There are plenty of cities around the world that have apiaries already installed on roofs and parks (Berlin, London, Stockholm, New York, Melbourne, Montreal, Amsterdam, Tokyo, San Francisco, Barcelona, Shanghai, Copenhagen, Brussels…).

3. Materials and Methods

With the help of QGis, the narrower part (central part) of the city of Maribor, Slovenia, which has 95,000 inhabitants (the entire municipality is 111,000), was taken as our research area to find suitable green areas for urban orchards, berry bushes and beehives. The city was divided into quadrants of 1 × 1 km. There was a total of 44 quadrants with an area of 44 km^2 (Figure 1). Of this, just under 20.6 km^2 belong to public areas, which are defined as social property, public good, state property, property of the municipality or its public services, state companies, the University of Maribor or in general use (Figure 2). Within them, all potential surfaces were physically inspected. One specific potential green area had to be at least 25 m^2. All privately owned surfaces were excluded. Areas considered were those that are at least 10 m from roads and easily accessible to residents on foot. Those where trees or shrubs have already been planted were also selected.

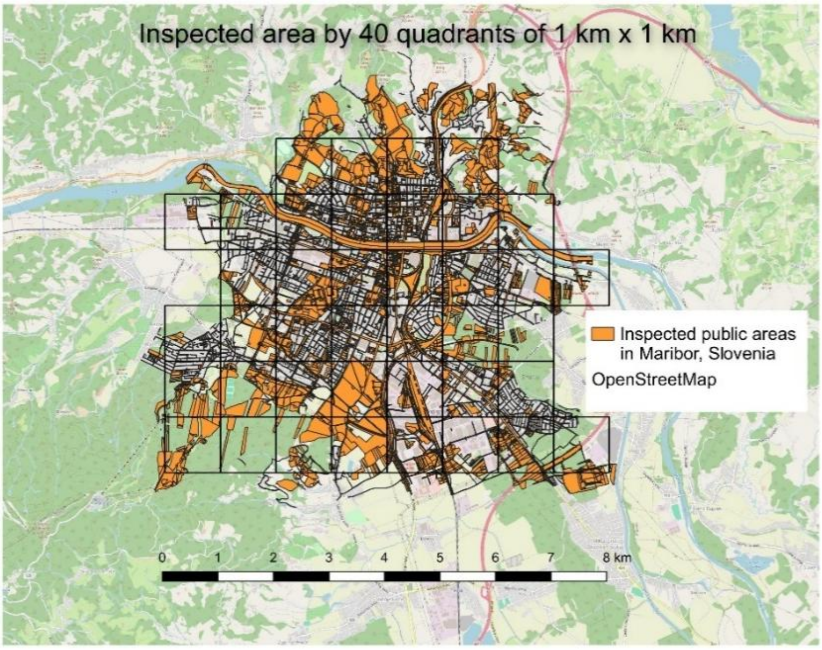

Figure 1. Layout of the inspected area in Maribor, Slovenia

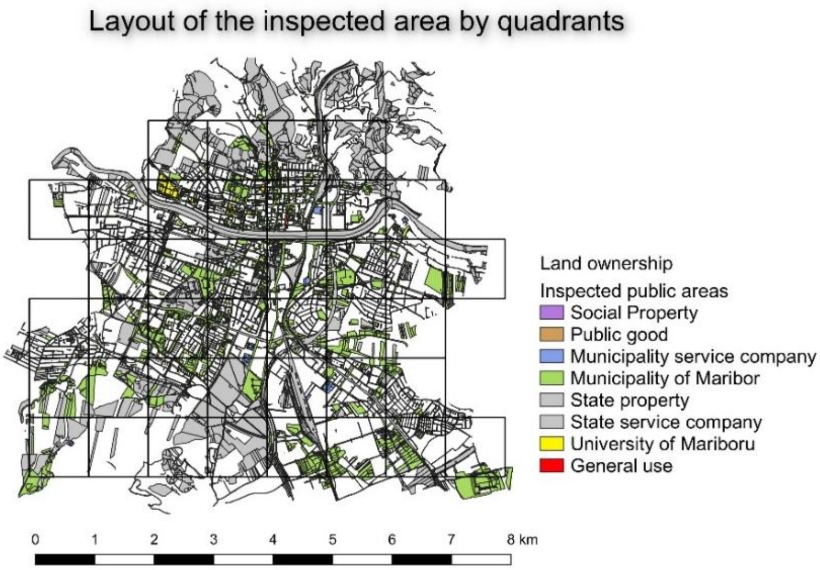

Figure 2. Layout of the inspected areas by ownership

Using QField, potential areas and their attributes for suitability for planting fruit trees and/or berry bushes were captured. A new polygon layer was created, and an additional attribute was included to indicate what the area would be suitable for (shrubs, trees or both). Each area was also photographed. The data was transferred to the cloud, and from there to the QGis project on the computer for further analysis. GIS data collection is well aligned with key international standards. The positional accuracy of 0.5 m was achieved, which is in line with ASPRS Class 1 and CE90 requirements for detailed urban planning. The polygon layer was created with thematic attributes (suitability for shrubs, trees or both) according to ISO 19157 for data quality. The use of the Slovenian National Coordinate System (EPSG:3794) ensures geodetic consistency and interoperability. This approach meets OGC/ISO standards and is suitable for spatial analysis in urban green infrastructure planning.

The captured data was checked, the topology was checked and cleaned (gaps between polygons, overlapping polygons, narrow unnecessary polygons, etc.). The Topology Checker plugin and the Geometry Checker plugin were used, as well as a manual check.

The CO_2 absorption of a tree is usually estimated based on a variety of factors, including tree species, tree age, leaf or needle area, growth rate, climatic conditions, light intensity, temperature, humidity and other factors. The most common way of estimating CO_2 uptake is based on the growth of the tree through the process of photosynthesis. During photosynthesis, the tree uses light, water and CO_2 to produce carbohydrates and oxygen. The amount of CO_2 absorbed by a tree is related to the rate of photosynthesis, which depends on the surface area of the leaves or needles on which the process takes place and other factors that affect the efficiency of photosynthesis. Therefore, CO_2 uptake is usually estimated by measuring the surface area of the tree's leaves or needles and related factors such as leaf density, light intensity, temperature and humidity. From this information, an estimate of the amount of CO_2 absorbed by the tree over a given period, usually on an annual basis, can be calculated.

In Table 4 there are some examples of trees for which there is data on their ability to absorb CO_2. Among the trees listed, full-grown apple and pear trees would probably best match lime (Tilia spp.) in terms of their leaf mass and growth rate. Both types of trees usually have widely branched crowns with a dense leaf mass. The linden tree is known for its large, heart-shaped leaves that form a dense canopy, like what we see in apples and pears. In addition, linden, pear, and apple trees usually grow in the same climatic conditions and have similar soil and light requirements.

Table 4. CO_2 absorption per different tree

Tree	Average CO_2 Absorption per Year [kg]
Apple (Malus)	18–25[1]
Aronia (Aronia)	10–15[1]
Beech (Fagus)	10–40[2]
Birch (Betula)	25–30[2]
Blueberry (Vaccinium)	10–15[1]
Cherry (Prunus)	10–20[1]
Cranberry (Vaccinium)	10–15[1]
Linden (Tilia)	20–30[2]
Maple (Acer)	20–25[2]
Oak (Quercus)	10–48[3]
Pine (Pinus)	20–30[2]
Pear (Pyrus)	20–30[1]
Poplar (Populus)	50–70[4]
Quince (Cydonia)	10–15[1]
Raspberry (Rubus)	10–15[1]

Note: [1] – (Bernet, 2023), [2] – (Ecotree, n.d.), [3] – (Daley, 2024), [4] – (Jin et al., 2023)

Table 5. Number of different seedlings per hectare (Barney, 2013; Mir et al., 2022)

Type of Fruit Tree	Number of Plants per Hectare	Plant Average per Hectare	Approx. Average Yield (kg per plant)	Average Yield (*t* per Hectare)
Apple	400–800	600	100–200	40–160
Pear	300–600	450	50–150	15–90
Cherry	200–400	300	10–30	2–12
Plum	200–400	300	10–30	2–12
Peach	300–600	450	20–50	6–30
Apricot	300–600	450	20–50	6–30
Walnut	40–80	60	20–50	0.8–4

The number of fruit tree seedlings you can plant per hectare depends on several factors, including the type of fruit tree, spacing between individual seedlings, planting method and management. In Table 5 there is a rough estimation of the number of seedlings per hectare for some common fruit tree species. These numbers are approximate estimates and may vary depending on fruit tree cultivars, climate conditions, growing method (for example, annual seedlings or multi-rooted trees), spacing between seedlings, use of intensive or extensive cultivation systems, and other factors. If we generalize, then we could plant about 370 seedlings of mixed fruit in empty areas per hectare, and one could yield approximately 10-48 t of fruit per hectare.

The number of berry bushes you can plant per hectare also depends on several factors, including the type of berry bush, spacing between individual seedlings, planting method and management. In Table 6 there is a rough estimation of the number of seedlings per hectare for some berry bush species. If we generalize, then we could plant about 7,000 berry bushes in empty areas per hectare, and one could yield 10-24 t of berries per hectare.

Table 6. Number of different seedlings of berry bushes per hectare (Barney, 2013; Mir et al., 2022)

Type of Berry Bush	Number of Plants per Hectare	Plant Average per Hectare	Approx. Average Yield (kg per plant)	Average Yield (kg per hectare)
Aronia	4,000–6,000	5,000	3–5	12,000–30,000
Currant	5,000–8,000	6,500	3–4	15,000–32,000
Gooseberry	5,000–8,000	6,500	3–4	15,000–32,000
Blackberry	3,000–5,000	4,000		
Blueberry- Vaccinium corymbosum	3,000–5,000	4,000	2.5–5	7,500–25,000
Raspberry	10,000–15,000	12,500	1.5–2.5	15,000–37,500
Japanese quince	4,000–6,000	5,000	3–4	12,000–24,000
Cranberries- Vaccinium macrocarpon	10,000–15,000	12,500	0.5–1	5,000–15,000

Fruits grown in cities are edible. According to Khalilnezhad et al. (2024), the cadmium and lead content in fruits harvested from the fruit trees in Tarasht Neighborhood falls below the maximum tolerance specified in Iran's national standard, rendering them safe and suitable for consumption. Of course, the level of cadmium and lead in the fruit depends on the location of the tree and is not recommended near the strongest and busiest roads.

Honey produced in urban apiaries is generally completely edible and safe for consumption, like honey produced in the countryside. However, it is important that apiaries are properly maintained and monitored to ensure honey quality. This includes careful selection of apiary sites, control of environmental quality (for example, checking air and plant pollution), control of bee diseases and ensuring hygienic standards in honey production and packaging. As for hiring additional people to manage urban apiaries, it depends on the size and scope of the apiary and the goals of the local community or organization that maintains it. Larger apiaries or those operated under city programs for environmental conservation or tourism development may require the employment of additional people to manage, maintain, promote, and sell honey and conduct educational programs. In some cases, local beekeepers can also hire or partner with them to establish and maintain apiaries in cities, which can contribute to job creation in the beekeeping sector. In addition, cities can support employment in related sectors, such as local produce shops, tourism and environmental education, which may be linked to the presence of urban apiaries.

The amount of honey produced by a single apiary varies widely and depends on several factors, including the type of bee, the type of flowers in the area, weather conditions, the beekeeper's management of the apiary, and the general health of the bee colony. On average, one hive can produce between 10 and 30 kilograms of honey per season. It is also important to note that honey is produced seasonally, so the amount may vary from year to year and season to season. In addition, beekeepers generally do not harvest all the honey produced by bees to ensure the survival of the bee colony, especially in winter when access to flower nectar is limited.

When choosing a location for setting up an urban apiary, it is important to consider several factors that can affect the success of beekeeping and the well-being of bees. Some key factors include:

Sunlight: Bees need sunlight to warm their hives and be active. Therefore, it is recommended that apiaries be placed in locations that are exposed to the sun for most of the day.

Protection from wind: Bee colonies are sensitive to strong winds, so it is important that apiaries are placed in locations where there is protection from strong winds. Building some sort of natural barriers, such as tall bushes or buildings, can help reduce the impact of wind on beehives.

Access to water: Bees need water to cool the hives and to dilute the honey, so it is important to have a source of drinking water near the apiaries, such as a river, lake or well.

Distance from busy roads: Bee colonies are sensitive to air pollution, so it is recommended that apiaries are placed as far away from busy roads as possible, where exposure to polluted air is less.

Height and stability: Beehives should be placed on stable bases and at an appropriate height to allow easy access for beekeepers while minimizing the risk of vandalism or unwanted interactions with people.

In addition, local regulations and legislation regarding urban beekeeping should be observed, and local authorities or communities should be consulted before deciding to set up an urban apiary.

4. Results

As mentioned before, just under 20.6 km^2 of public areas were inspected. In Figure 3, we see these areas classified according to ownership, of course excluding private areas. During the inspection, 667 areas were found as potential areas.

Figure 3. Green areas for urban orchards, berry bushes and beehives

Table 7 represents the area potential for the narrow part of the city of Maribor divided by fruit trees, berry bushes and both. Together, 667 different areas could be intended for those plants. All areas of more than 20 m^2 were considered as appropriate. 179 areas could be intended for fruit trees (32.39 ha), 359 for berry bushes (83.33 ha) and 271 for mixed plantations (154.72). Also, the number of plants, potential fruit and berry production and CO_2 reduction are estimated (Table 6). Almost 14 thousand fruit trees and more than 129 thousand berry bushes could be planted as monocultures, and a lot more in the areas where mixed planting could be done. The potential of more than 1,100 tons of fruit can be grown. The average CO_2 absorption of trees listed in Table 4 (without poplar) is between 17 and 31 kg CO_2 per tree per year (an average of 24 kg CO_2 per tree per year and 12.5 per berry bush). Potential CO_2 absorption is also estimated in Table 6 to be more than 1944 tons per year. This estimate is in line with the author (Fini et al., 2023), who studied stored CO_2 values in Rimini and Krakow on 15 different trees (11 deciduous and 4 coniferous) and concluded that the range is between 22.8 and 68.3 kg CO_2/year. This estimate was based on measurements of CO_2 assimilation, leaf area index (LAI), height and trunk diameter.

Also, 4 locations for bee houses (Figure 4) are proposed. A proposal for a beehouse is set, considering that a bee flies approximately 5 km away from his beehive. So, at the edge of the area, four bee stations can be placed. In Slovenia, 1293 tons of honey were produced in 2020, only 195 tons in 2021, and 2405 tons of honey in 2022. According to the data of the Statistical Office of the Republic of Slovenia, in recent years, the average Slovenian beekeeper has managed between 10 and 30 beehives. On average, bees produce between 20 and 40 kg of honey per hive per year. A total of approximately 80 beehives (4 × 20) could be set up at the 4 planned locations in Maribor and an average production of around 2,400 kilograms of honey could be expected in a year.

Table 7. Potential areas, number of seedlings and bee hives and potential production

Tree Species	No. of Areas	Area Potential	Planted Seedlings	Potential Production [t]	CO_2 Reduction [t/year]
Fruit trees	179	32.39 ha	13,765	770.84	330
Berry bushes	359	83.33 ha	129,161	366.65	1614
Both	271	154.72 ha	-	-	-
Sum	667	270.44 ha		1137.49+	1944+
Location potential			number	potential beehives	potential honey production [kg]
For bee house			4	80	2,400

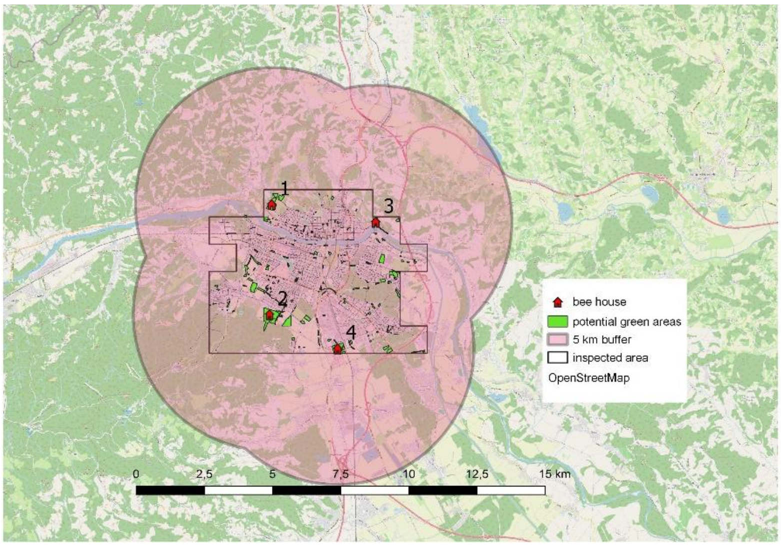

Figure 4. Four potential beehouse locations and 5 km buffers

According to the MOM report (Mestna Občina Maribor, 2018) on the state of the environment in Maribor, the soil in non-agricultural areas in Maribor, especially near traffic routes and former industrial areas, is contaminated in some places with heavy metals such as copper (Cu), lead (Pb) and zinc (Zn). Although widespread diffuse contamination has not been detected, elevated concentrations of these metals are mainly found in the industrial zones (Melje, Studenci, Tezno) and in the old town centre so those areas should be avoided. There are seven air quality monitoring stations in the municipality (two national and five stations of the city's monitoring network). Overall, the air quality in Maribor is suitable for growing fruit trees. However, during the winter months, mainly due to individual combustion and temperature control, elevated concentrations of PM_{10} and $PM_{2,5}$ can occur (Okolje Maribor, n.d.).

5. Discussion

Urbanization trends are clear, as is the growing need for (locally produced) food. By 2050, according to forecasts, the number of inhabitants in cities will increase by just under 131%. Examples of good practices around the world indicate that food can (or should) be grown even in urban centers. Even smaller world cities should not be an exception, and Maribor, Slovenia is one such, as it has many existing green areas. As many as 8 European countries are among the top 10 self-sufficient countries in the world in terms of food, which can fill us with optimism that Europe is thinking about this and that climatic conditions are also suitable for this.

In most cases, trees planted in cities today are non-fruit-bearing, which presents a paradox given the rising demand for food driven by increasing urban populations. Edible shrubs and beehives remain exceptions, typically introduced as part of experimental projects rather than being established as widespread and consistently successful practices.

Europe (EU) has ambitious goals in the field of restoration of green areas in cities. Green European trends should also be followed by local (landscape) architecture by designing space and buildings in a more biodiversity-friendly direction. We use many more natural resources than we could, and nature's recovery processes are very slow.

Cities such as Sheffield, Bristol, Seattle, San Francisco, Portland, Vancouver, Toronto, Melbourne and others are a source of inspiration with their ambitious projects of planting urban green areas and setting up beehives, showing that urban centers can also be dedicated to food production. Other cities around the world should follow suit.

The city of Maribor has every chance of becoming one of such cities, both in terms of its geographical location and urban design. There are many green areas where additional or new plantings of trees and shrubs with edible fruits could be carried out. The Drava River runs through the city, which can be a source of water for watering seedlings and the needs of bees.

People who are not hungry are satisfied, more active and happier. Therefore, people should also be involved in urban plantation projects. Slogans like "Plant your tree and pray for it" could connect people and involve them in local self-care. People still know how to look after their own property more than other people's. If we involve people in such projects, they will be able to appreciate more every fruit that grows on these trees. In this way, more connected and strong local communities could be created, the need for imported food would decrease, and thus also the pressures on the environment. There are many examples of community participation in such projects around the world. In the Racehill Community Orchard (UK) project, the community was involved in all phases of the project, from planning to planting and managing the orchard. The orchard is located in one of the most deprived areas of the city and serves as a space for socialising, education and improving food security (Ardill, 2022). Oosterwold (The Netherlands) is an urban development project where residents are required to dedicate half of their plots to food production. The community is involved in the planning and management of the space, including planting fruit trees and establishing local food systems. The project promotes self-sufficiency, sustainability and community participation (The Guardian, n.d.).

The calculations of CO_2 absorption in this study are based on established empirical values from recent literature (e.g., Jin et al., 2023; Fogarty, 2012), which estimate average sequestration rates per tree or shrub species. However, we acknowledge that these rates are influenced by a range of contextual factors, including tree age (Fini et al., 2023), species-specific growth rates, maintenance practices, and urban stressors such as heat, drought, and soil compaction. While the model assumes uniform planting density and optimal growing conditions, these assumptions serve primarily to enable a standardized comparison across different planting scenarios rather than to predict precise carbon offset outcomes. In real urban environments, absorption rates may be lower due to constrained rooting volumes, pollution, or pruning practices that reduce biomass accumulation. Future refinement of this model should incorporate site-specific data such as actual soil conditions, microclimate variability, and species survival probabilities to better reflect local ecological dynamics and improve the accuracy of sequestration estimates.

The current model provides a simplified estimation based on tree counts and available surface areas. However, actual yield and ecological outcomes are influenced by dynamic variables including soil quality, air pollution, and microclimatic factors such as shading and wind exposure. Integrating such variables would enhance both the precision and practical relevance of future assessments. Additionally, while the selection of potential orchard sites was guided by spatial availability, a more rigorous approach would consider ecological sensitivity (e.g., soil contamination, urban biodiversity corridors) and social acceptability (e.g., proximity to underserved populations, community interest). Addressing these factors would support more effective, equitable, and resilient green infrastructure deployment.

Integrating fruit tree planting and beekeeping into actual urban planning requires balancing spatial, environmental, economic and social considerations. The municipal spatial plan or site plans should include fruit species as part of the envisaged green spaces. The concept of multifunctional green spaces should be used, where a nutritional function is provided in addition to recreation and shading. In Mexico City, urban foraging of edible plants in interstitial spaces such as sidewalks and vacant lots has emerged as a resilience strategy that supports local food security and cultural practices (Hare & Peña del Valle Isla, 2021). This example highlights the potential of multifunctional green spaces—even informal ones—to provide ecosystem services beyond aesthetics or carbon sequestration, especially in densely populated urban environments.

Beekeeping can be envisaged on public green roofs (schools, community centers, libraries), urban gardens and parks with designated beekeeping zones, and agricultural edge areas in peri-urban zones. Local fruit-growing guidelines should be adopted, specifying suitable species (low-growing, hardy, local varieties), planting distances, maintenance and hygiene standards, and minimum distances for bee hives from schools, hospitals, and busy roads. Public participation should be included at the design stage (e.g., participatory budget, questionnaires), and local associations (beekeeping, horticultural, ecological) should be contacted for maintenance and education. Such approaches have been shown to increase a sense of belonging, reduce vandalism and strengthen environmental literacy (Fogarty, 2012). Also, management models should be defined: e.g., public-private partnerships or community stewardship. Incentives for fruit trees should be included in tenders for subsidized planting of green spaces, and 'green elements with amenity value' should be included in tenders for urban regeneration.

While this study proposes strategic directions for urban greening and local self-sufficiency, it does not yet fully elaborate on the practical implementation pathways for integrating fruit tree planting and beekeeping into formal urban planning frameworks. Successful examples from both Slovenia and abroad illustrate viable approaches.

In Ljubljana, the municipality has promoted urban biodiversity through the Bee Path initiative, which connects schools, municipal departments, NGOs, and local beekeepers to promote urban apiculture and education (Metropolis, 2015). Furthermore, the city's rural development strategy, Trebuh Ljubljane ("Ljubljana's Belly"), supports fruit tree planting and local food production through coordinated stakeholder action and municipal planning (AIPH, 2020).

Internationally, the Beacon Food Forest in Seattle, USA, serves as a widely cited example of large-scale, community-driven edible landscaping on public land. Originally initiated by local volunteers and later supported by the municipality, the project integrates orchard-style planting with native vegetation, community workdays, and educational activities. It demonstrates how participatory models can be successfully embedded into broader urban sustainability agendas (Fogarty, 2012).

These cases emphasize the importance of stakeholder engagement, dedicated funding, and long-term management strategies in operationalizing urban greening. Future planning should include replicable policy instruments, cost-benefit assessments, and cross-sector coordination frameworks to ensure feasibility and lasting impact.

While this study demonstrates promising potential for enhancing ecosystem services through urban orchards, berry bushes, and apiaries in smaller cities like Maribor, a critical review of recent literature reveals several limitations and challenges that merit further discussion. For example, although urban fruit production can improve local food security and climate resilience, contamination of produce with heavy metals (such as lead, cadmium, and arsenic) is a recurring concern in urban soils (Cooper et al., 2020). Findings from urban gardens in San Diego and Bologna showed detectable levels of lead and arsenic in leafy vegetables and strawberries, particularly when planted directly in urban soil near traffic corridors or brownfield sites (Antisari et al., 2015). A study on pomegranate orchards along a roadside in Turkey further confirmed that even hardy fruit species such as *Punica granatum L.* can accumulate significant levels of cadmium, lead, and chromium in both leaves and fruits depending on their proximity to the road — with the highest concentrations observed within 50 m of vehicle traffic (Aydin & Pakyürek, 2020).

While the presented scenarios highlight the spatial and ecological potential for increasing urban tree and shrub cover, several important contextual factors merit further consideration. Social acceptance and behavioral dynamics can significantly influence the success of urban greening initiatives. Residents may resist the introduction of fruit trees due to concerns about maintenance, pest attraction, or safety (e.g., fallen fruit creating slippery surfaces), especially if past experiences with urban vegetation were negative. Also, some people are allergic to bees.

Moreover, economic constraints—such as planting, irrigation, and long-term maintenance costs—can limit the feasibility of large-scale implementation. Municipal budgets often prioritize short-term infrastructural needs, and green infrastructure projects may compete for funding unless their multifunctional value (e.g., health, cooling, biodiversity) is clearly communicated and quantified.

Earth Overshoot Day marks the point in the calendar year when humanity's consumption of natural resources exceeds what the Earth can regenerate within that same year. To calculate this date, the Global Footprint Network (n.d.) compiles relevant data and applies the best available assumptions to evaluate the global balance between resource demand and the planet's regenerative capacity. Earth Overshoot Day in 1971 was December 29th; today, it falls on August 2nd, with some countries like Qatar reaching this date as early as February 10th (Geneva Environment Network, n.d.). For Slovenia, the Overshoot Day in 2023 was April 18th. These statistics highlight the pressing need for sustainable development practices.

6. Conclusions

Sustainable development alone is insufficient if it merely continues the current trajectory of resource consumption. We must recognize that nothing in nature grows beyond its limits or capabilities, and the concept of infinite growth is inherently flawed. Instead of focusing on continuous development, there should be a concerted effort to redistribute wealth and significantly reduce our consumption of natural resources.

Implementing urban orchards, berry bushes, and apiaries within small cities like Maribor, Slovenia, presents a viable strategy to enhance local food production, increase food security, and reduce carbon dioxide levels. These urban green spaces can transform fragmented and unused areas into productive landscapes that support local self-sufficiency, social well-being, and environmental sustainability.

Urban orchards and berry bushes can contribute to local food production, providing fresh fruits and berries while simultaneously sequestering carbon dioxide. For example, a hectare of mixed fruit trees can yield approximately 10-48 tons of fruit per year, depending on the type of fruit and cultivation methods. Moreover, urban apiaries can produce significant amounts of honey while supporting pollination and biodiversity. In Maribor, four proposed bee house locations could accommodate up to 80 beehives, potentially producing around 2,400 kilograms of honey annually.

Engaging local communities in these projects is crucial for their success. Initiatives like "Plant your tree and pray for it" can foster a sense of ownership and responsibility among residents, leading to more active participation and better care for urban green spaces. This involvement can also strengthen community bonds, reduce reliance on imported food, and alleviate environmental pressures.

Cities around the world, such as Sheffield, Bristol, Seattle, and Vancouver, have already demonstrated the benefits of integrating green spaces with urban food production. Maribor has the potential to join these cities by utilizing its existing green areas and the Drava River as a water source for irrigation and beekeeping. By doing so, Maribor can enhance its food security, promote environmental sustainability, and improve the overall well-being of its residents.

To build upon the findings of this study and address its limitations, several avenues for future research and methodological improvement are proposed:

- Future research should move beyond static estimations and incorporate spatially explicit environmental data—including soil quality, air pollution indices (e.g., $PM_{2.5}$, NO_2), microclimatic variation, and water availability—into models of plant growth, CO_2 sequestration, and food production. These variables significantly affect the real-world performance of urban orchards and apiaries and are crucial for precise yield and carbon offset estimation. It is recommended to design long-term monitoring studies that track tree survival rates, maintenance costs, pollinator diversity, and community usage patterns. This would enable a shift from theoretical potential to measured impact in urban settings.
- Qualitative and mixed-method studies should investigate public attitudes, user preferences, and resistance

factors to edible landscaping and urban beekeeping. In parallel, research into institutional readiness—such as interdepartmental coordination, legal frameworks, and governance models—can uncover barriers and enablers to implementation.

- Qualitative and mixed-method studies should investigate public attitudes, user preferences, and resistance factors to edible landscaping and urban beekeeping. In parallel, research into institutional readiness—such as interdepartmental coordination, legal frameworks, and governance models—can uncover barriers and enablers to implementation.
- Future work should include detailed economic evaluations of different implementation scenarios, including the cost of planting, maintenance, community engagement, and risk management (e.g., safety, vandalism, allergies). This could help municipalities and planners determine the return on investment and prioritize interventions.
- To increase practical relevance, further development of participatory scenario modelling is suggested. Engaging stakeholders such as residents, planners, maintenance staff, and environmental NGOs in co-design workshops can help refine assumptions, validate feasibility, and build ownership.
- Beyond carbon, future studies should incorporate broader ecosystem service metrics, such as pollination, noise buffering, heat mitigation, and biodiversity enhancement. Monitoring wild pollinator populations in relation to managed honeybee densities is especially important for avoiding ecological imbalances.

Data Availability

The data supporting our research results are included within the article.

Conflicts of Interest

The author declares no conflict of interest.

References

AIPH. (2020). *Initiative: The belly of Ljublana – urban agriculture and food systems in City of Ljubljana*. https://aiph.org/green-city-case-studies/ljubljana-slovenia/

Al-Kodmany, K. (2023). Integrating nature into high-rise buildings: Innovative design approaches. *Int. J. Archit. Plan.*, *3*(1), 14–51. https://doi.org/10.51483/ijarp.3.1.2023.14-51.

Andersson-Sköld, Y., Klingberg, J., Gunnarsson, B., Cullinane, K., Gustafsson, I., Hedblom, M., Knez, I., Lindberg, F., Ode Sang, Å., Pleijel, H., Thorsson, P., & Thorsson, S. (2018). A framework for assessing urban greenery's effects and valuing its ecosystem services. *J. Environ. Manage.*, *205*, 274–285. https://doi.org/10.1016/j.jenvman.2017.09.071.

Andreas, M., Prausová, R., Brestovanská, T., Hostinská, L., Kalábová, M., Bogusch, P., Halda, J. P., Rada, P., Štěrba, L., Čížek, M., & Horák, J. (2023). Tree species-rich open oak woodlands within scattered urban landscapes promote biodiversity. *Urban For. Urban Green.*, *83*, 127914. https://doi.org/10.1016/j.ufug.2023.127914.

Antisari, L. V., Orsini, F., Marchetti, L., Vianello, G., & Gianquinto, G. (2015). Heavy metal accumulation in vegetables grown in urban gardens. *Agron. Sustain. Dev.*, *35*, 1139–1147. https://doi.org/10.1007/s13593-015-0308-z.

Ardill, N. (2022). Case study of social innovation in urban food spaces: 'Racehill Community Orchard', Brighton & Hove Food Partnership, Brighton & Hove. In *Growing Food in Cities*, Springer, Cham, pp. 101–130. https://doi.org/10.1007/978-3-030-98475-5_7.

Aydin, S. D. & Pakyürek, M. (2020). Heavy metal accumulation potential in pomegranate fruits and leaves grown in roadside orchards. *PeerJ*, *8*: e8990. https://doi.org/10.7717/peerj.8990.

Barney, D. L. (2013). *Storeys Guide to Growing Organic Orchard Fruits*. Storey Publishing.

Bassetti, F. (2021). *The benefits of urban greening*. Foresight. https://www.climateforesight.eu/articles/the-benefits-of-urban-greening/

Bellamy, C. C., van der Jagt, A. P. N., Barbour, S., Smith, M., & Moseley, D. (2017). A spatial framework for targeting urban planning for pollinators and people with local stakeholders: A route to healthy, blossoming communities? *Environ. Res.*, *158*, 255–268. https://doi.org/10.1016/j.envres.2017.06.023.

Bernet, R. (2023). *How much CO2 does a tree absorb?* One Tree Planted. https://onetreeplanted.org/blogs/stories/how-much-co2-does-tree-absorb

Bosshart, L. (2023). *Urban green spaces that beat the heat: Tips from a UBC expert*. UBC News. https://news.ubc.ca/2023/06/14/tips-to-plant-urban-green-spaces-that-beat-the-heat/

Buchholz, S., Gathof, A. K., Grossmann, A. J., Kowarik, I., & Fischer, L. K. (2020). Wild bees in urban grasslands: Urbanisation, functional diversity and species traits. *Landsc. Urban Plan.*, *196*, 103731.

https://doi.org/10.1016/j.landurbplan.2019.103731.
Comunicati Stampa Città di Torino. (2017). *La "Green Belt" di Torino*. https://torino.mobilita.org/2017/12/29/ecco-la-green-belt-di-torino/
Cooper, A. M., Felix, D., Alcantara, F., Zaslavsky, I., Work, A., Watson, P. L., Pezzoli, K., Yu, Q., Zhu, D., Scavo, A. J., Zarabi, Y., & Schroeder, J. I. (2020). Monitoring and mitigation of toxic heavy metals and arsenic accumulation in food crops: A case study of an urban community garden. *Plant Direct*, *4*(1), e00198. https://doi.org/10.1002/pld3.198.
Dablanc, L. (2023). Urban logistics and COVID-19. In *ransportation Amid Pandemics*, Elsevier, pp. 131–141. https://doi.org/10.1016/B978-0-323-99770-6.00002-8.
Daley, C. (2024). *How much CO2 does one tree absorb?* Treeapp. https://www.thetreeapp.org/blog/2024-12-20-how-much-co2-does-one-tree-absorb/
Davivongs, V. & Arifwidodo, S. D. (2023). Bangkok's existing mixed fruit orchards are tree diversity hotspots for city greening. *Urban Ecosyst.*, *26*, 991–1005. https://doi.org/10.1007/s11252-023-01352-w.
de la Barrera, F., Reyes-Paecke, S., Truffello, R., de la Fuente, H., Salinas, V., Villegas, R., & Steiniger, S. (2023). Comparing green spaces provision and accessibility indicators over a latitudinal gradient and multiple climate zones. *Urban For. Urban Green.*, *79*, 127791. https://doi.org/10.1016/j.ufug.2022.127791.
Dietzel, S., Rojas-Botero, S., Kollmann, J., & Fischer, C. (2023). Enhanced urban roadside vegetation increases pollinator abundance whereas landscape characteristics drive pollination. *Ecol. Indic.*, *147*, 109980. https://doi.org/10.1016/j.ecolind.2023.109980.
Dylewski, Ł., Maćkowiak, Ł., & Banaszak-Cibicka, W. (2020). Linking pollinators and city flora: How vegetation composition and environmental features shapes pollinators composition in urban environment. *Urban For. Urban Green.*, *56*, 126795. https://doi.org/10.1016/j.ufug.2020.126795.
Ecotree. (n.d.). *How much CO2 does a tree absorb?* https://ecotree.green/en/how-much-co2-does-a-tree-absorb
Elbæk, C. T., Mitkidis, P., Aarøe, L., & Otterbring, T. (2022). Honestly hungry: Acute hunger does not increase unethical economic behaviour. *J. Exp. Soc. Psychol.*, *101*, 103412. https://doi.org/10.1016/j.jesp.2022.104312.
Elbert, R., Roeper, F., Vanelslander, T., & Cavallaro, F. (2023). Freight operations in the European Union during the COVID-19 pandemic: A multicountry comparison. In *Transportation Amid Pandemics*, Elsevier, pp. 143–152. https://doi.org/10.1016/B978-0-323-99770-6.00021-1.
European Commission. (n.d.). *Applying for the NDIS*. https://environment.ec.europa.eu/topics/urban-environment/european-green-capital-award/applying-awards_en
Faber, M., Laubscher, R., & Laurie, S. (2013). Availability of, access to and consumption of fruits and vegetables in a peri-urban area in KwaZulu-Natal, South Africa. *Matern. Child Nutr.*, *9*, 409–424. https://doi.org/10.1111/j.1740-8709.2011.00372.x.
Fini, A., Vigevani, I., Corsini, D., Wężyk, P., Bajorek-Zydroń, K., Failla, O., Cagnolati, E., Mielczarek, L., Comin, S., Gibin, M., et al. (2023). CO2-assimilation, sequestration, and storage by urban woody species growing in parks and along streets in two climatic zones. *Sci. Total Environ.*, *903*. https://doi.org/10.1016/j.scitotenv.2023.166198.
Fogarty, J. (2012). *Food Forest Takes Root in Seattle*. The Epoch Times. https://www.theepochtimes.com/article/food-forest-takes-root-in-seattle-1485059?welcomeuser=1
Geneva Environment Network. (n.d.). *Earth Overshoot Day*. https://www.genevaenvironmentnetwork.org/resources/updates/earth-overshoot-day/
Gibson, E. L., Green, M. W., & Dyall, S. C. (2013). Behavior: Effects of diet on behavior. In *Encyclopedia of Human Nutrition*, Elsevier, pp. 129–141. https://doi.org/10.1016/B978-0-12-375083-9.00022-2.
Global Footprint Network. (n.d.). *Past Earth Overshoot Days*. https://overshoot.footprintnetwork.org/newsroom/past-earth-overshoot-days/
Hare, M. & Peña del Valle Isla, A. (2021). Urban foraging, resilience and food provisioning services provided by edible plants in interstitial urban spaces in Mexico City. *Local Environ.*, *26*, 825–846. https://doi.org/10.1080/13549839.2021.1922998.
Hassan, Z., Khan, F. Z. A., Aldosary, A. S., Al-Ramadan, B., Ahmad, A., Manzoor, S. A., & Rahman, M. T. (2024). Roots to roofs: Farmers' perceived socio-ecological impacts of converting mango orchards to urban areas in Multan, Pakistan. *Environ. Chall.*, *15*, 100935. https://doi.org/10.1016/j.envc.2024.100935.
Henderson, J. (2004). *The Roman Book of Gardening, 1st ed*. Routledge.
Information System for the Evaluation of Urban Development. (n.d.). *SIEDU*. https://www.seduvi.cdmx.gob.mx/servicios/servicio/siedu.
Jachuła, J., Denisow, B., & Strzałkowska-Abramek, M. (2019). Floral reward and insect visitors in six ornamental Lonicera species—Plants suitable for urban bee-friendly gardens. *Urban For. Urban Green.*, *44*. https://doi.org/10.1016/j.ufug.2019.126390.
Jin, S., Zhang, E., Guo, H., Hu, C., Zhang, Y., & Yan, D. (2023). Comprehensive evaluation of carbon sequestration potential of landscape tree species and its influencing factors analysis: Implications for urban

green space management. *Carbon Balance Manag.*, *18*, 1–13. https://doi.org/10.1186/s13021-023-00238-w.
Kabisch, N. (2015). Ecosystem service implementation and governance challenges in urban green space planning-The case of Berlin, Germany. *Land Use Policy*, *42*, 557–567. https://doi.org/10.1016/j.landusepol.2014.09.005.
Kamra. (n.d.). *Kongresni trg in njegove podobe*. https://www.kamra.si/digitalne-zbirke/kongresni-trg-in-njegove-podobe/
Kazemi, F., Abolhassani, L., Rahmati, E. A., & Sayyad-Amin, P. (2018). Strategic planning for cultivation of fruit trees and shrubs in urban landscapes using the SWOT method: A case study for the city of Mashhad, Iran. *Land Use Policy*, *70*, 1–9. https://doi.org/10.1016/j.landusepol.2017.10.006.
Khalilnezhad, M. R., Taheri, M. R., Russo, A., Nasseh, N., & Taheri, A. (2024). Designing healthy edible cities: Investigating the environmental and spatial factors affecting urban fruit safety. *Cities Health*, 1–8. https://doi.org/10.1080/23748834.2024.2352233.
Klein, A. M., Vaissière, B. E., Cane, J. H., Steffan-Dewenter, I., Cunningham, S. A., Kremen, C., & Tscharntke, T. (2007). Importance of pollinators in changing landscapes for world crops. *Proc. R. Soc. B Biol. Sci.*, *274*, 303–313. https://doi.org/10.1098/rspb.2006.3721.
Leonardi, M. (2023). Nature-based solutions to regenerate mediterranean cities: A case study in Catania, Sicily. *Sustainability*, *15*(16): 12112. https://doi.org/10.3390/su151612112.
Lequerica Tamara, M. E., Latty, T., Threlfall, C. G., & Hochuli, D. F. (2021). Major insect groups show distinct responses to local and regional attributes of urban green spaces. *Landsc. Urban Plan.*, *216*, 104238. https://doi.org/10.1016/j.landurbplan.2021.104238.
Light, N. (2015). *Oikos and Market: Explorations in Self-Sufficiency after Socialism*. Berghahn Books, New York.
Liu, X., Huang, Y., Xu, X., Li, X., Li, X., Ciais, P., Lin, P., Gong, K., Ziegler, A. D., Chen, A., et al. (2020). High-spatiotemporal-resolution mapping of global urban change from 1985 to 2015. *Nat. Sustain.*, *3*, 564–570. https://doi.org/10.1038/s41893-020-0521-x.
Mestna Občina Maribor. (2018). *Poročilo o stanju okolja Mestne občine Maribor za obdobje 2007–2016*. https://okolje.maribor.si/data/user_upload/okolje/Porocilo_o_stanju_okolja_2007-16__koncno.pdf
Metropolis. (2015). *Ljubljana's Bee Path*. USE. https://use.metropolis.org/case-studies/ljubljanas-bee-path
Mir, J. I., Sharma, O. C., Raja, W. H., Sami-Ullah, S., & Raja, R. H. S. (2022). High density plantation in apple—A highly remunerative enterprise. *Indian Hortic.*, *66*(5), 24–26.
Mogk, J. E., Wiatkowski, S., & Weindorf, M. J. (2010). Promoting urban agriculture as an alternative land use for vacant properties in the city of Detroit: Benefits, problems and proposals for a regulatory framework for successfull land use integration. *Wayne Law Rev.*, *56*, 1521–1580.
Most, J., Tosti, V., Redman, L. M., & Fontana, L. (2017). Calorie restriction in humans: An update. *Ageing Res. Rev.*, *39*, 36–45. https://doi.org/10.1016/j.arr.2016.08.005.
News European Parliament. (2023). *EU Nature restoration law: MEPs strike deal to restore 20% of EU's land and sea*. https://www.europarl.europa.eu/news/en/press-room/20231031IPR08714/eu-nature-restoration-law-meps-strike-deal-to-restore-20-of-eu-s-land-and-sea
Nieuwenhuijsen, M. J., Dadvand, P., Márquez, S., Bartoll, X., Barboza, E. P., Cirach, M., Borrell, C., & Zijlema, W. L. (2022). The evaluation of the 3-30-300 green space rule and mental health. *Environ. Res.*, *215*, 114387. https://doi.org/10.1016/j.envres.2022.114387.
Norton, B. A., Coutts, A. M., Livesley, S. J., Harris, R. J., Hunter, A. M., & Williams, N. S. G. (2015). Planning for cooler cities: A framework to prioritise green infrastructure to mitigate high temperatures in urban landscapes. *Landsc. Urban Plan.*, *134*, 127–138. https://doi.org/10.1016/j.landurbplan.2014.10.018.
Okolje Maribor. (n.d.). *Kakovost zunanjega zraka*. https://okolje.maribor.si/delovna-podrocja/zrak/monitoring-zunanjega-zraka
Republike Slovenije Statistični Urad. (2023). *Stopnja samooskrbe (%) po vrstah kmetijskih proizvodov, koledarsko leto, Slovenija, letno*. https://pxweb.stat.si/SiStatData/pxweb/sl/Data/-/H205S.px/table/tableViewLayout2/
Rut, M. & Davies, A. R. (2024). Food sharing in a pandemic: Urban infrastructures, prefigurative practices and lessons for the future. *Cities*, *145*, 104609. https://doi.org/10.1016/j.cities.2023.104609.
Sheffield Environmental. (n.d.). *Edible Sheffield, Space to Grow*. https://sheffieldenvironmental.net/ediblesheffield
Silva, V. H. D., Gomes, I. N., Cardoso, J. C. F., Bosenbecker, C., Silva, J. L. S., Cruz-Neto, O., Oliveira, W., Stewart, A. B., Lopes, A. V., & Maruyama, P. K. (2023). Diverse urban pollinators and where to find them. *Biol. Conserv.*, *281*, 1100036. https://doi.org/10.1016/j.biocon.2023.110036.
Stubbs, R. J. & Turicchi, J. (2021). From famine to therapeutic weight loss: Hunger, psychological responses, and energy balance-related behaviors. *Obes. Rev.*, 22, 1–19. https://doi.org/10.1111/obr.13191.
Sturiale, L. & Scuderi, A. (2019). The role of green infrastructures in urban planning for climate change adaptation. *Climate*, *7*(10), 119. https://doi.org/10.3390/cli7100119.
Sturiale, L., Scuderi, A., Timpanaro, G., Foti, V. T., & Stella, G. (2020). Social and inclusive "value" generation in metropolitan area with the "urban gardens" planning. In *Green Energy and Technology*, Springer, Cham,

pp. 285–302. https://doi.org/10.1007/978-3-030-23786-8_16.
Stutz, B. (2018). *With a Green Makeover, Philadelphia Is Tackling Its Stormwater Problem*. Yale Environment 360. https://e360.yale.edu/features/with-a-green-makeover-philadelphia-tackles-its-stormwater-problem
TCV. (n.d.). *Tree Planting & Aftercare*. https://conservationhandbooks.com/handbook/tree-planting-aftercare/
The Economist Group. (2022). *Global Food Security Index (GFSI) 2022*. https://impact.economist.com/sustainability/project/food-security-index/resources/Economist_Impact_GFSI_2022_Global_Report_Sep_2022.pdf
The Guardian. (n.d.). *'You have to find your own recipe': Dutch suburb where residents must grow food on at least half of their property*. https://www.theguardian.com/environment/2024/nov/28/oosterwold-dutch-suburb-where-residents-must-grow-food-on-at-least-half-of-their-property
The Parks Alliance. (2020). *The Parks Alliance publishes 'Making Parks Count – The case for parks'*. https://www.theparksalliance.org/the-parks-alliance-publishes-making-parks-count-the-case-for-parks/
Tonietto, R., Fant, J., Ascher, J., Ellis, K., & Larkin, D. (2011). A comparison of bee communities of Chicago green roofs, parks and prairies. *Landsc. Urban Plan.*, *103*, 102–108. https://doi.org/10.1016/j.landurbplan.2011.07.004.
Trček, B. & Kamnik, R. (2022). How the volume of traffic affected air quality during the extreme event of covid-19 lockdown in a small city. *Promet Traffic Transp.*, *34*(5), 789–800. https://doi.org/10.7307/ptt.v34i5.4143.
Twerd, L., Banaszak-Cibicka, W., Sobieraj-Betlińska, A., Waldon-Rudzionek, B., & Hoffmann, R. (2021). Contributions of phenological groups of wild bees as an indicator of food availability in urban wastelands. *Ecol. Indic.*, *126*, 107616. https://doi.org/10.1016/j.ecolind.2021.107616.
UN Environment Programme. (2009). *Methodology for preparing GEO Cities Reports: Training Manual*. https://www.unep.org/resources/report/methodology-preparation-geo-cities-reports-training-manual-version-3
United Nations. (2018). *World Urbanization Prospects: The 2018 Revision*. https://population.un.org/wup/assets/WUP2018-Report.pdf
van den Bosch, C. K. (2021). *Promoting health and wellbeing through urban forests – Introducing the 3-30-300 rule*. https://iucnurbanalliance.org/promoting-health-and-wellbeing-through-urban-forests-introducing-the-3-30-300-rule/
Vancouver Fruit Tree Project. (n.d.). *No Fruit Left Unpicked*. https://www.vancouverfruittree.com/
Vossler, F. G. (2023). Pollen from urban flora in the ephemeral nests of solitary Megachile bees in three temperate and subtropical cities of Argentina. *Flora*, *305*, 152335. https://doi.org/10.1016/j.flora.2023.152335.
Wallace, E. J. (2019). *The Moroccan Food Forest That Inspired an Agricultural Revolution*. Atlas Obscura. https://www.atlasobscura.com/articles/what-is-permaculture-food-forests
Wei, J., Qian, J., Tao, Y., Hu, F., & Ou, W. (2018). Evaluating spatial priority of urban green infrastructure for urban sustainability in areas of rapid urbanization: A case study of Pukou in China. *Sustainability*, *10*(2): 327. https://doi.org/10.3390/su10020327.
WHO. (2017). *Urban green spaces: A brief for action*. https://www.who.int/europe/publications/i/item/9789289052498
Włodarczyk-Marciniak, R., Sikorska, D., & Krauze, K. (2020). Residents' awareness of the role of informal green spaces in a post-industrial city, with a focus on regulating services and urban adaptation potential. *Sustain. Cities Soc.*, *59*, 102236. https://doi.org/10.1016/j.scs.2020.102236
Wooster, E. I. F., Fleck, R., Torpy, F., Ramp, D., & Irga, P. J. (2022). Urban green roofs promote metropolitan biodiversity: A comparative case study. *Build. Environ.*, *207,* 108458. https://doi.org/10.1016/j.buildenv.2021.108458.
Zhang, J. & Hayashi, Y. (2022). Research frontier of COVID-19 and passenger transport: A focus on policymaking. *Transp. Policy*, *119*, 78–88. https://doi.org/10.1016/j.tranpol.2022.02.014.