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Review

Where the wild things are: How urban foraging and food forests can contribute to sustainable cities in the Global North

Filippo Oncini [a,b,*], Steffen Hirth [a,c], Josephine Mylan [a], Clare H. Robinson [d], David Johnson [d]

[a] Sustainable Consumption Institute, Alliance Manchester Business School, University of Manchester, Booth Street West, Manchester M15 6PB, United Kingdom
[b] Maastricht Sustainability Institute, Maastricht University, Minderbroedersberg 4-66211 LK, Maastricht, the Netherlands
[c] Sustainability Research Institute, School of Earth and Environment, University of Leeds, Woodhouse, Leeds LS2 9JT, United Kingdom
[d] Manchester Environmental Research Institute, Department of Earth and Environmental Sciences, University of Manchester, Manchester M13 9PL, United Kingdom

A R T I C L E I N F O

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A B S T R A C T

Humanity is faced with interacting socio-environmental challenges such as securing food while the climate changes and biodiversity declines. These global crises are partly caused by major land-use change arising from deforestation and agriculture, and are exacerbated by the high demand for resource-intensive foods from populations in the Global North, which are increasingly concentrated in urban centres. The demand by urban populations on the food system has stimulated research on developing sustainable and healthy sources of food within cities. However, debates largely focus on typically treeless urban agriculture and tech-food approaches. This bias neglects the pivotal role of trees and shrubs for ecological and cultural ecosystem service provision, and thus the multifunctional potential of foraging "wild" foods or "semi-wild" cultivation such as in designed food forests in or near cities. In a wide, emerging, and multidisciplinary research field, the actual or potential contribution of urban woodlands to food security and other societal needs such as carbon sequestration and habitat provision often remains taken-for-granted, implicit, or ambiguous. To evaluate the extent to which urban food forestry in the Global North may generate socio-ecological win-win outcomes for climate, biodiversity and society, we review evidence from natural and social sciences along four analytic dimensions: (1) climate change, (2) biodiversity, (3) food production, and (4) relational aspects. Our findings demonstrate the multifactorial benefits of urban foraging and food forestry, but also flag potential risks and disservices ascertained in the literature. We use the synthesised evidence along these dimensions to identify existing gaps and future research directions for optimising socio-environmental benefits. We conclude that much is to be gained from upscaling spaces "where the wild things are" but that requires certain systemic changes to be taken seriously.

1. Introduction

Food production for, and consumption in, the Global North are particularly unsustainable and in need of transformation if global socio-environmental challenges such as securing food in a changing climate are to be overcome. The food demand of cities is a driver of productivism and over-exploitation of ecosystem services through conventional agriculture in rural areas, but vibrant urban communities are also considered part of the solution. Increasing the share of foods produced within urban and peri-urban spaces may reduce the burden on ecosystems elsewhere. Urban gardening and tech-approaches such as vertical farming or aquaponics have received ample attention in this context (e.g. Asciuto et al., 2019; Carolan, 2022; Grewal and Grewal, 2012; Lal, 2020), whereas foraging and "semi-wild" cultivation of foods in urban woodlands have been relatively neglected or discussed in a Global South context (for exceptions see Bunge et al., 2019; McLain et al., 2014; Poe et al., 2014).

It is widely recognised that the agri-food system, and society as a whole, face interacting socio-environmental challenges, where food provision is both the cause of crises and threatened by them (FAO, 2006; IAASTD, 2009; IPCC, 2019; Willett et al., 2019). In need to create foodscapes supporting a net-zero, healthy, resourceful, and resilient future, the roles of ecosystem services, nature-based solutions, and nature-positive production have recently taken a more central role in

* Corresponding author at: Sustainable Consumption Institute, Alliance Manchester Business School, University of Manchester, Booth Street West, Manchester M15 6PB, United Kindgdom.
E-mail address: filippo.oncini@maastrichtuniversity.nl (F. Oncini).

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academic debates (Goodwin et al., 2023; Hodson de Jaramillo et al., 2023; IUCN, 2016). Trees and shrubs in particular are pivotal regulators enabling ecological ecosystem services due to their relationships to other plants and soil biodiversity, including beneficial mycorrhizal fungi. They can also be convivial places providing cultural and social habitat for animals and humans. Woodland-based foods have thus advantages regarding the provision of ecological and cultural ecosystem services over those from typically treeless agriculture.

It has been recognised for some time that urban green spaces offer potential to provide several ecosystem services, notably those specific to urban systems, such as urban cooling, air pollution mitigation, sound attenuation and aesthetics (Anguelovski et al., 2022; Kabisch and van den Bosch, 2017; Keeler et al., 2019; Rova et al., 2015; Schittko et al., 2022; Theodorou et al., 2020). However, there has been limited consideration of using these spaces as sources of food. Therefore, this review explores socio-environmental benefits of foods from (peri)urban woodland areas. We focus on cities of the Global North, where dietary change would have the highest positive impact regarding emissions reductions, and where due to the high degree of commercialization significant sources of potential food are under-exploited. Most of the foods found in woodlands are types of food that would improve the overall health of diets in the Global North (Willett et al., 2019), notably mushrooms, fruit, nuts and seeds, leaves, shoots, and roots.

More specifically, our focus derives from a range of issues justifying our focus on urban forest food. Firstly, a critical challenge in food system sustainability transformations concerns the availability of land. There is currently a tension between land for agriculture and land for non-food products, such as timber from forestry. Approaches such as food forestry (Box 1) bridge the typical spatial and functional divide between agriculture (for food) and forestry (for either logging or conservation). Many of these multifunctional woodland-based food systems are in (or near) cities, yet remain societal niches. The urban and peri-urban environment thus offers potential to mitigate these tensions and provide a suite of other benefits by upscaling food forestry. To do so, a better understanding of an interdisciplinary field of research is required.

Secondly, there is also a perception that urban land is unsuitable for agriculture; for example, because soils are contaminated, or lacking the biological, chemical, and physical properties needed to sustain food production (McBride et al., 2014). These concerns also hold for urban foraging and food forestry, particularly in the context of the capacity of fungi or fruit trees near roadsides to absorb heavy metals and other pollutants. A critical review thus also needs to consider (the aversion of) possible disservices of urban food forestry.

Finally, there is a view that urban agriculture is “tokenistic”, with limited capacity to make meaningful contributions to food security and other societal needs (e.g. Kroll, 2021; Larder et al., 2014). At the same time, where urban food production capacity was determined, trees – the land they use and shade they cast – have been regarded as “competing” for urban food production with agricultural means (Richardson and Moskal, 2016). However, it is important to acknowledge that trees can generally be a *source* of food. It is unclear, though, whether urban foraging and food forestry are significant sources of food for urban populations, and if not, whether this is due to hard biophysical features or just their current status as societal niche practices. At least the latter case would hold opportunities for policy intervention, and given that the proportion of edible species among urban trees is typically lower than 5%, there is considerable potential in the expansion of fruit and nut trees (Grafius et al. 2020). Therefore, it is crucial to identify evidence in the body of literature on urban food production about the ways in which these initiatives can become not only vital urban communities, but also make significant contributions to food and climate security.

The focus of this study is on both urban foraging and urban food forestry. To begin with, there are differences between the two land uses that need to be recognised. Foraging or gathering relies on “wild” or pre-existing sources of food, whereas food forestry involves cultivation, i.e. deliberate proliferation of edibles through the design of new, or interventions in existing, woodland (see the notion of “semi-wild” food in Hirth et al., 2022). While new urban green infrastructure may provide spaces for foraging, these spaces are neither necessarily nor typically designed to maximise the density of edible species. Foraging can take place on public and private land and may happen in conflict with environmental or private property law, whereas the design of food forests typically involves dedicated, authorised spaces for either public access or commercial exploitation. However, foraging and food forestry also have much in common. Urban spaces that are being foraged could also be changed to food forests; harvesting the latter, in turn, requires knowledge and practices similar to foraging. Even though our review mostly generalises evidence on foods from urban trees and shrubs, where applicable, we highlight differences between foraging and food forestry.

In this review, we bring together evidence from social and natural sciences regarding the potential for urban and peri-urban food systems in the Global North to contribute to overall food security and provide a suite of valuable ecological and cultural ecosystem services. The insights gained from this review show existing gaps and future research directions for optimising socio-environmental benefits of urban and peri-urban food production. This synthesis requires an inter- and trans-disciplinary approach to capture the diverse range of issues including the role of soil processes, food production systems, and the potential social, economic, and health benefits of urban food production. Our synthesis aims at harmonising the targets of carbon storage in soils and vegetation, producing sufficient local and healthy food, conserving biodiversity, and contributing to social cohesion in ecologically and socially challenging times. We thus aim to evaluate the extent to which

Box 1: Urban Food Forestry.

The term generally describes designed woodland-based food production spaces in (peri)urban areas. Food forestry is also referred to as forest gardening. The debate and method has been pioneered by practitioners who create young woodland while mimicking natural succession and maximising the density of edible species (Burnett, 2014; Crawford, 2010). Forest gardens have a vertical dimension, with multiple layers of edible species from treetops to ground cover and roots, and their dense design is considered beneficial for productivity (Bjorklund et al., 2019) and carbon sequestration (Schafer et al., 2019). Food forests are not confined to urban contexts, but it has been argued that their dense design and spatial frugality is a particular advantage in cities where land is scarce and expensive (Guerin-Laguette, 2021). Both in and outside urban contexts, food forestry is a multifunctional approach aiming at ecosystem service enhancement and the multifactorial benefits of woodland-based food systems such as biodiversity conservation, carbon sequestration, and food security (Clark & Nicholas, 2013; Thomas & Vazquez, 2022). Compared to other multifunctional, yet more commercially applied, land use approaches such as alley cropping systems in polycultural agroforestry (Wolz et al., 2018), food forests tend to be less apt for mechanization but more dense and diverse.

urban woodland-based food systems generate socio-ecological win-win outcomes for climate, biodiversity and society.

After describing our search strategy and analysis (Section 2), we synthesise the reviewed literature (Section 3) and present our main findings by help of four dimensions: climate change (3.1), biodiversity (3.2), food production (3.3), and relational aspects (3.4). We then discuss gaps and future developments in the study of urban foraging across the scientific spectrum (Section 4). We conclude that much is to be gained from upscaling urban green infrastructure that includes food production, as long as certain systemic changes are taken seriously.

2. Review protocol

2.1. Search strategy

To provide an in-depth account of the scientific literature that could provide insights across disciplines, during February 2022 we searched the Web of Science database for articles containing in their title, abstracts or keywords at least one term related to wild food and urban foraging across Global North countries between 2000 and 2022. Following a trial after each search, using common synonyms and keywords relating to the main themes, we searched the following list of keywords referring to "urban forag* " (on its own), and wild food (wild food*, wild edible, non-timber forest product*, food forest*, NTFP) combined with keywords referring to the urban context (urban, city, cities). This strategy permitted us to obtain a first list of 445 articles. We hence screened the abstracts and considered eligible 100 articles based in Western and Eastern European countries, North America, and Australia, and a minority taking into consideration Europe or the whole globe. All these articles explicitly focused on foraging and wild food use in urban and peri-urban contexts. Finally, we read all the manuscripts and removed additional 26 articles because they were not directly relevant to our research questions, thus obtaining a final pool with 74 articles. Fig. 1 illustrates the steps of the systematic literature review, following the PRISMA protocol (Moher et al., 2009).

2.2. Analysis

In each paper, we identified the location and country of the study, the methodology used, the main focus, and then summarized the main results of interest for each of the four themes: biodiversity conservation, climate change (i.e. carbon capture), food production and relational aspects. The first and second author analysed all the papers separately and produced two internal reports distinguishing the most important results for each section. The two reports where then compared and discussed to identify the main findings with the other authors.

Interest in the topic has increased considerably over the years, although it reached a peak in 2019 and then slowed down in the following two years (Fig. 2). Most studies focused on North America and Europe, and only one article was conducted in Australia (Melbourne). The US (26) is by far the country where most of the studies have been conducted, followed by Italy and Canada (8), Germany and the UK (7), Austria (4) and Switzerland, Spain and Netherlands (3). Other European countries have 2 or less studies, and we also included 4 studies with a wider reach (Europe or the world) and 7 reviews (Fig. 3). Most literature focuses on specific urban sites, and some cities (London, Berlin, Seattle, New York City) recur more than once (Fig. 4).

The articles considered in this review also exhibit great heterogeneity in terms of main discipline of reference. The treemap in the supplemental material (Figure A1) shows the journal categories of the selected articles according to Web of Science. Many articles were published in environmental studies and forestry journals, but the topic clearly attracted the attention of scholars across disciplines, ranging from sociology and geography, to mycologists, urbanists, and sustainability scientists. In general, however, both social and natural scientists investigated the potential of wild food for cities' food economies. In turn, methodological approaches are extremely multifaceted, comprising qualitative methods – especially interviews and participant observation – as well as quantitative population surveys, spatial data, nutrient analysis, and field measurements. As we will discuss later, this multidisciplinary approach has potential benefits, but also highlights the need for more organized efforts to bring together diverse pieces of knowledge in order to identify potential uses of wild food in urban food supply chains.

3. Findings

The following subsections outline the main findings ordered by the four main analytic categories of climate change (3.1), biodiversity (3.2), food production (3.3), and relational aspects (3.4). Table 1 provides an overview by linking references to specific subthemes recurring within these four categories, as well as a fifth category focused on knowledge and policy gaps.

3.1. Climate change

Foraging and food forestry are discussed for their potential to mitigate and adapt to climate change in cities. Research and debates in this context are largely centred on four topics: the capacity to store carbon in soils and biomass; policies and economic incentives for carbon sequestration; food practices to reduce footprints and mitigate climate change; as well as creating resilience and adapting to climate change.

Carbon sequestration is one of multiple ecosystem services that woodland provides (Table 2). Urban woodlands are not able to match the capacity of primary forests to store carbon, but they have potential to make a significant contribution to carbon capture while providing multifactorial benefits such as food production and other ecosystem services (Lehmann et al., 2019; Schafer et al., 2019). Increasing plant diversity (including species richness, evenness and genotypic diversity) is another factor that can enhance carbon in both belowground and aboveground components.[1] The few available quantifications of belowground, overstorey, and understorey carbon stocks of a peri-urban food forest highlighted the often-overlooked importance of small trees and the understorey vegetation as stores of carbon, as well as the neglected sequestration potential of expanding agroforestry in temperate regions (Lehmann et al., 2019; Schafer et al., 2019). Agroforestry can also improve other soil properties and thus carbon storage capacity. Soil carbon monitored over 10 years showed increases of up to 21% in agroforestry relative to treeless agriculture (Schafer et al., 2019; see also Schroeder, 1994). Another quantitative study showed that urban green infrastructure implementation had a positive balance comparing the biocapacity for carbon storage to the ecological footprint from machinery use and (e.g. fertiliser) inputs for urban agriculture.[2] However, in their study, urban forestry (non-food) and urban agriculture (food) was spatially separated within a patch of green infrastructure. Such spatial separation may limit possible benefits of implementing a fully multifunctional food system. In summary, there is some evidence for carbon sequestration and climate mitigation potential of urban food forestry, though more research is needed, whereas the potential of urban foraging for mitigation lacks data and remains an implicit, taken-for-granted assumption in the literature.

A second theme are policies and economic incentives aiming at carbon sequestration. New instruments that set land management standards are demanded such as the soil cadastre for Italy (Raimondi et al., 2020). The literature documents a few cases of municipalities implementing urban food forest policies (e.g. in Nanaimo, Canada).

[1] See also Schittko et al. 2022 for an urban context and Liu et al., 2018 for a non-temperate climate example (these references were not part of the review sample).

[2] Gomez-Villarino et al., 2021 (reference is not part of the review sample)

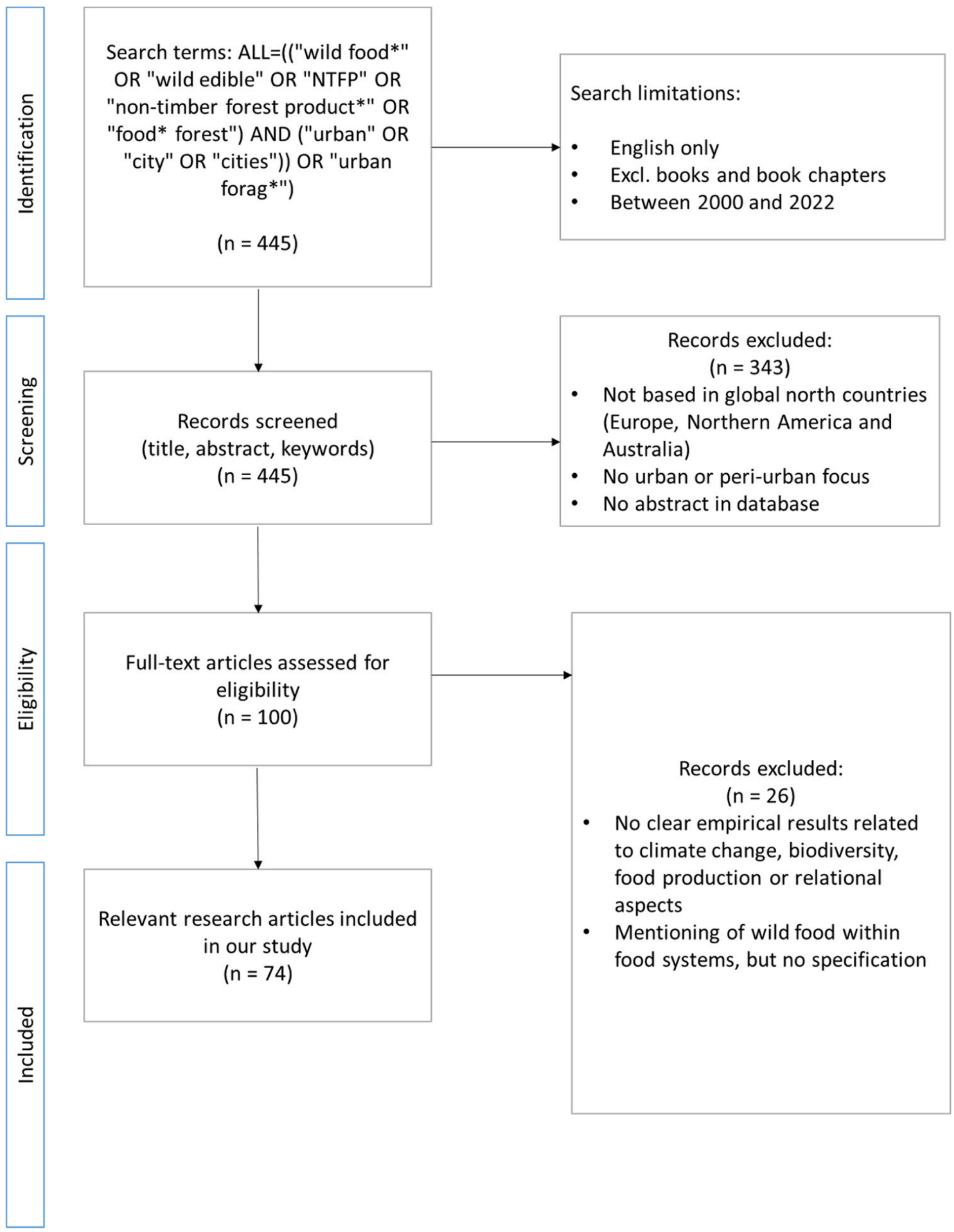

Fig. 1. PRISMA protocol used for articles selection.

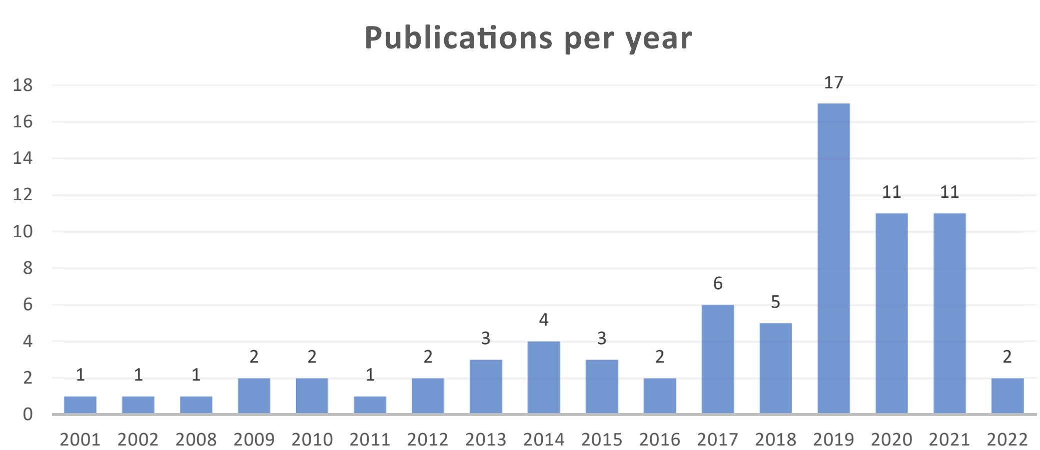

Fig. 2. Number of publications per year.

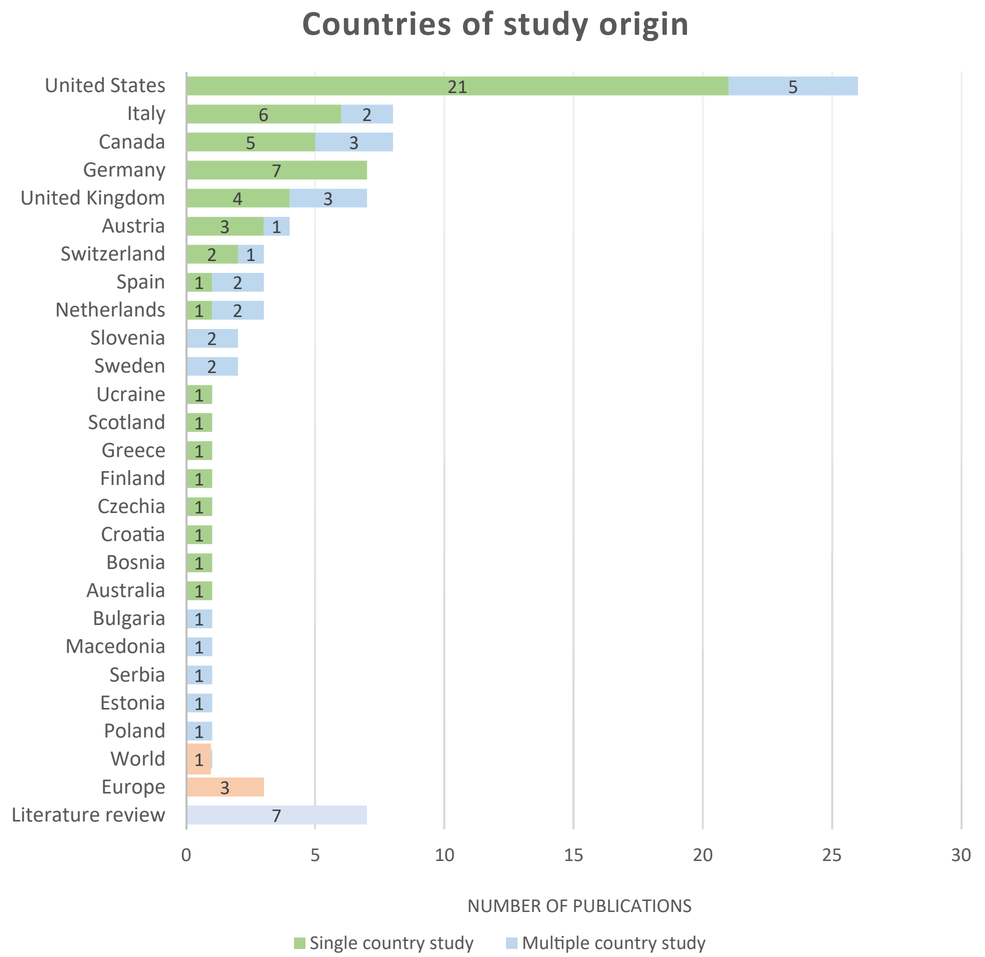

Fig. 3. Countries of study of origin of the articles selected for the review.

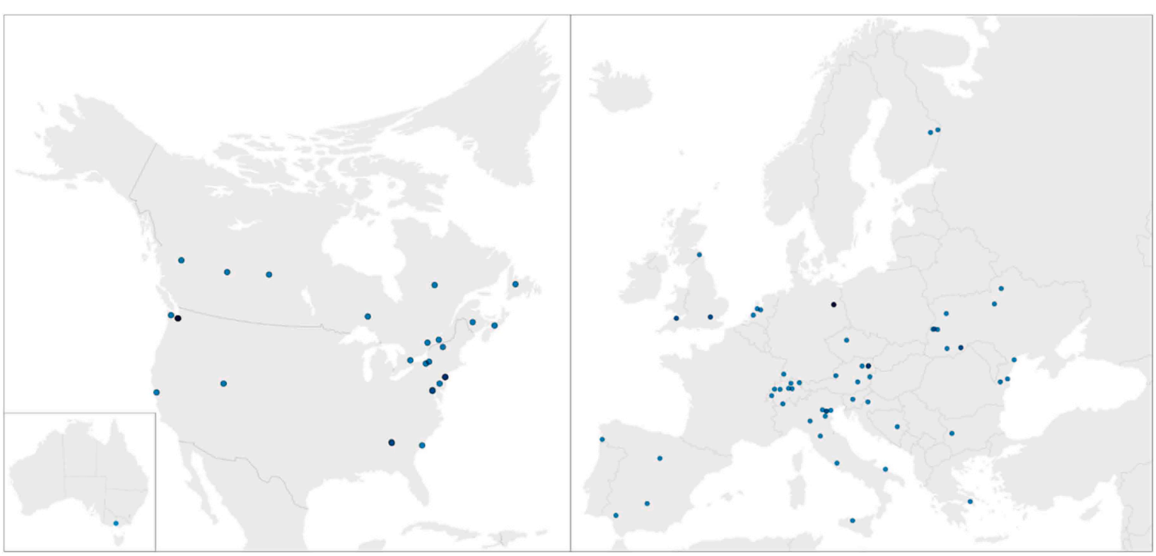

Fig. 4. Location of case studies reviewed. Note: Three studies (Kowalski and Conway, 2019; Schunko and Vogl, 2020; Sõukand et al., 2020) report more than 10 locations at the same time. In these cases, we report only the state (in Canada) or region (in Austria and Ukraine) of reference. Darker dots identify cities where more than one study has been reviewed.

These policies explicitly connect tree preservation and additional tree planting to carbon sequestration and food production goals (Kowalski and Conway, 2019). Another finding suggests that, in principle, both small-scale family forest owners and large-scale industrial landowners can pursue carbon sequestration, though current policies grant better incentives to large operations (Mayer, 2019). Carbon sequestration and pollution removal through trees has an economic value which amounts to USD 41.20 per acre in the case of New York (Hurley and Emery, 2018;

Table 1
References ordered by main analytic categories and their various subthemes.

Main analytic category	Subthemes	References
Climate change	Adaptation & resilience	Arrington, 2021;Lehmann et al. 2019; Maye et al. 2022; Redzić 2010;Stark et al. 2019.
	Carbon storage	Nytofte and Henriksen, 2019; Schafer et al. 2019
	Policies combining carbon sequestration with food production	Kowalski and Conway, 2019; Mayer, 2019
	Vegetation carbon in agroforestry	Lehmann et al. 2019
	Soil carbon in agroforestry	Schroeder, 1994 (cited in Schafer et al. 2019)
Biodiversity	Crop diversity & culinary diversity	Fischer et al. 2019;Gaither et al. 2020; Maye et al. 2022; Redzić 2010; Sõukand et al. 2020;Zuin et al. 2010
	Food Forestry & biodiversity/habitat provision	Nytofte and Henriksen, 2019; Sacchelli et al. 2018; Sardeshpande and Shackleton, 2019;Stark et al. 2019;Tiwary et al. 2020
	Human-nature interaction	Carrus et al. 2015;Fischer and Kowarik, 2020;Egerer et al., 2019Palliwoda et al. 2017; Poe et al. 2014;
	Land use change, deforestation/reforestation	Maye et al. 2022;Mayer, 2019;Rova et al., 2015.
	Livelihoods and diversity of uses of NTFPs	Alexander et al. 2002; Gianotti and Hurley, 2016; Shackleton et al. 2017;
	Risks associated with foraging	Fischer and Kowarik, 2020; McLain et al. 2017; Shackleton et al. 2017; Schunko et al. 2021
	Soil biodiversity & nutrient circulation	Fischer et al. 2019;Raimondi et al. 2020;West, 2006 cited in Park et al. 2018
Food production	Ethnobotanical surveys and culinary uses	Abbet et al., 2014; Acosta-Naranjo et al., 2021; Arrington, 2021;Bunge et al., 2019;Gaither et al., 2020; Gianotti & Hurley, 2016; Hurley & Emery, 2018; Kilchling et al., 2009; Landor-Yamagata et al., 2018; Łuczaj et al., 2012; McLain et al., 2012, 2014, 2017;Poe et al., 2013;Redzić, 2010;Robbins et al., 2008; Schulp et al., 2014;Schunko et al., 2021;Schunko & Brandner, 2022;Schunko & Vogl, 2020;Synk et al., 2017.
	Elemental uptake	Gori et al., 2019;Ivanić et al., 2021;Kokkoris et al., 2019; Schlecht & Säumel, 2015; Stark et al., 2019.
	Quantitative mapping of foragers and wild foods	Alexander et al., 2002;Lovrić et al., 2020, 2021; Sardeshpande & Shackleton, 2019;Schulp et al., 2014; Shackleton & de Vos, 2022; Ulian et al., 2020;Weiss et al., 2020.
	Assessing urban foragers activity	Fischer & Kowarik, 2020; Gaither et al., 2020;Gianotti & Hurley, 2016; Grabbatin et al., 2011;Itchuaqiyaq & Matheson, 2021;Jay & Schraml, 2009;Kangas & Markkanen, 2001; Landor-Yamagata et al., 2018;Palliwoda et al., 2017; Poe et al., 2013;Šiftová, 2020; Synk et al., 2017.
	Food security	Hurley & Emery, 2018; Larondelle & Strohbach, 2016;Lovrić et al., 2021; Nyman, 2019;Phillipps et al., 2022;Sardeshpande & Shackleton, 2019;Sachdeva et al., 2018;Shackleton, 2021; Shackleton et al., 2017; Shackleton & de Vos, 2022.
	Urban food production	Ballamingie et al., 2019; Bunge et al., 2019;Clark & Nicholas, 2013;DiSalvo & Jenkins, 2017;Nytofte & Henriksen, 2019.
	Policies and initiatives	Kowalski & Conway, 2019; Riolo, 2019;Shackleton et al., 2017;Shortly & Kepe, 2021;Živojinović et al., 2017.
Relational Aspects	Transmission of knowledge	Abbet et al., 2014;Fischer & Kowarik, 2020;McLain et al., 2014;Poe et al., 2013; Sardeshpande & Shackleton, 2019.
	Foraging and social bonds	Fischer & Kowarik, 2020; McLain et al., 2014; Sardeshpande & Shackleton, 2019;Poe et al., 2013; Colinas et al., 2019
	Regulatory frameworks for foraging	Colinas et al., 2019;Fischer & Kowarik, 2020;McLain et al., 2014;Poe et al., 2013; Sardeshpande & Shackleton, 2019.
	Foraging and alternative economies	Larondelle & Strohbach, 2016;Sõukand et al., 2020; Veen et al., 2021.
Knowledge gaps & desiderata for research or policy	Clear legal frameworks for foraging	Schunko et al. 2021
	Better understanding of dietary contribution of wild foods	Borelli et al. 2020
	Better understanding of local toxicity situations	Gori et al. 2019; Ivanić et al. 2021
	More comprehensive analyses of the value of ecological and cultural ecosystem services	Alexander et al. 2002; *specifically in cities*:Shackleton et al. 2017
	Better understanding of the social and economic value of *non*-market food relations and the challenges of doing that within a capitalist political economy	Larondelle & Strohbach, 2016;Shackleton et al., 2017; Sõukand et al., 2020;Veen et al., 2021;Weiss et al., 2020.

see also Nowak et al., 2007). The latter highlights the need to foster policies and put urban food production based on trees in practice. Another advantage of food forests is that they can be small (>=0.05 ha) and thus easy to implement in (peri)urban settings where space is scarce and expensive, thus increasing municipalities' carbon stocks and helping to meet sustainable development goals (Nytofte and Henriksen, 2019; Schafer et al., 2019; see also Borelli et al., 2020; Sacchelli et al., 2018). This, too, should be facilitated through policies giving economic incentives.

Thirdly, climate mitigation is not only a result of carbon sequestration but also achieved through indirect emissions savings. Wild food foraging potentially reduces emissions by making obsolete a certain amount of food consumption produced with conventional means. Providing seasonal and local produce, urban foraging can be more sustainable by shortening transportation distances and can be combined with food waste reduction and composting for nutrient circulation in cities (Fischer et al., 2019; Kowalski and Conway, 2019). However, despite these advantages foraging can be hampered by social stigma when it is associated with poverty (Gaither et al., 2020). Dedicated food forestry sites, run by local communities, might free urban foraging from stigma that comes with informality.

Finally, already, and more so in the future, climate change threatens the ability of wild food plants to produce consistent yields, or even to survive (Borelli et al., 2020). At the same time, it is emphasised that food forestry provides resilience against climate change (Lehmann et al., 2019). Multi-functional land use reduces risks of forest fires (Maye et al., 2022) and helps with stormwater interception (Arrington, 2021). Another advantage is the resilience and reliability of wild edible perennials (i.e. relative to annual crops), found in abundance despite severe droughts (Stark et al., 2018). Perennials and fungal species also provide resilience in times of crisis, be it at war (Redzić, 2010) or in face of increasing future hardship due to climate change. Wild foods thus not only play a role in the context of the Global South, where they are often fundamental sources of food and income (Borelli et al., 2020), but they have been vital in the past and, in face of a more extreme climate and its social repercussions, will likely be increasingly so in the Global North as well.

3.2. Biodiversity

Together with climate change, rapid decline in biodiversity is a major crisis that threatens ecosystems, the services they provide, and potentially all life depending on them. The sustained sprawl of residential and industrial zones and mobility, resulting in permanent sealing of soils, reinforces ambitions to protect remaining biodiversity in cities or even "rewild" them. Focal topics discussed in the literature comprise the benefits of diverse crops, uses, and livelihoods; bioculturally diverse practices; foraging as a potential risk for biodiversity; and how to protect or increase biodiversity.

Firstly, biodiversity is discussed as a strength and precondition for resilient food provision (Gaither et al., 2020; Maye et al., 2022). Generally, urban foraging and forestry allows for a diversity of uses (e.g. food, medicine, and aesthetics). The value of diversity is also emphasised in relation to the joint economic value of timber and non-timber forest products (NTFPs), e.g. edible fungi (Alexander et al., 2002; see also Guerin-Laguette, 2021). Many studies thus highlight the importance of biodiversity and NTFPs to the livelihoods of people worldwide (Gianotti and Hurley, 2016; see also Cavendish, 1999; Luckert and Campbell, 2012; Shanley et al., 2014). As outlined in the previous subsection, food forestry provides resilience in face of climate change, and the basis for this is biodiversity, the resulting "abundance" of potential foods, and the need for *culinary* diversity to tap the full potential of food provision. "Phyto-alimurgic" gardens are supposed to ensure resilient food supply. The notion of "alimurgic" suggests the vital role of foraging or cultivating a diverse range of resilient plants for alimentation in times of urgencies and emergencies (Zuin et al., 2010). Even in lack of planned perennial gardens, biodiversity offers foraging opportunities in times of disaster or war. During the siege of Sarajevo, for example, extending culinary practices with wild plants, fungi, and lichens not part of usual diets was coerced, yet essential for the survival of people trapped in the city (Redzić, 2010). In Ukraine, *babushkas* (grandmothers) sell home-grown and wild foods on informal markets, providing a wide range of "gastronomic biodiversity"(Sõukand et al., 2020). Biodiversity is thus vital when and where "normal" capitalist supply chains do not exist, fail, or are recognised as unsustainable.

Secondly, as a practice, urban foraging permits mutually beneficial interactions between the urban population and nature in support of health and wellbeing. Foraging allows humans and nature to (re)connect in the form of "bio-cultural habitats" and a "bioculturally diverse and rooted cosmopolitan nature practice" (Poe et al., 2014, p. 14), and it is important for the adoption of positive attitudes towards biodiversity conservation (Fischer and Kowarik, 2020). There are also positive correlations between the level of biodiversity and self-reported wellbeing and perceived benefits (Carrus et al., 2015; Egerer et al. 2019). A quantification of the use of foraged plants in relation to other activities in parks shows that biodiversity-related activities make up a large proportion of activities in parks and suggests biodiversity-friendly approaches to park design and management (Palliwoda et al., 2017). Initiatives to promote "biodiverse edible schools" are another multifunctional approach to support cultural and provisioning ecosystem services in cities (Fischer et al., 2019).

Thirdly, it is also discussed whether foraging practices have a harmful effect on biodiversity. If gathering involves picking rare species or over-picking native species, it could put biodiversity at risk, but research to date shows no evidence that rare or native species have declined in response to urban foragers (Fischer and Kowarik, 2020; Schunko et al., 2021). By contrast, rules can minimise negative impacts of foraging on individual organisms and habitats, and foragers can even enhance conditions for species and habitat, e.g. by scattering seeds and spores and removing waste and invasive species (McLain et al., 2017). Contrary to these findings, however, current legislation against biodiversity loss often impedes urban foraging (Shackleton et al., 2017).

Lastly, it is discussed how food forestry in or near cities alters or enhances biodiversity, including other plants (Stark et al., 2019). Food forests are designed to host diverse species and provide habitat in (peri) urban areas (Nytofte and Henriksen, 2019), but it is also recognised that they have potential to promote non-desirable biodiversity groups, such as hosts for zoonoses (e.g. Bellato et al., 2021). Maximising the biodiversity of species in three-dimensional space (i.e. horizontal extension and several vertical layers of edibles from canopies to roots and fungi), the food forest model mimicks.

young woodland for resilience and nutrient restoration (Riolo, 2019; Sardeshpande and Shackleton, 2019; see also Burnett, 2014; Crawford, 2010). Park et al. (2018) cite a Master's thesis that found the food forest in Dartington, Devon, to have greater invertebrate taxa richness than restored woodland (see West, 2006). Overall, it is convincing that food forests increase biodiversity, particularly when a low-biodiversity land, such as species-poor lawns, are turned into a mosaic of fruit trees, shrubs, and herbaceous plants as in the case of the Picasso Forest in Parma. However, there is a lack of peer-reviewed empirical studies quantifying biodiversity, and the benefits of urban food forestry and foraging tend to be taken-for-granted.

This does not diminish the need for concerted efforts to protect biodiversity. Generally, land use change and deforestation drive biodiversity extinction and impact ecosystem services provision (Mayer, 2019). Scholars point out the benefits of diversified agroforestry businesses over a monoculture afforestation model (e.g. eucalyptus plantations in Galicia; Maye et al., 2022). A contrary approach is to rely on technology such as aquaponics to create highly productive systems in cities and spare land for biodiversity conservation elsewhere (Asciuto et al., 2019). At the policy level, the European BiodivERsA project on Urban Biodiversity and Ecosystem Services (URBES) shows that cities such as Ljubljana, Amsterdam, and London now implement policies that combine local biodiversity enhancement with resilient and sustainable food systems (Tiwary et al., 2020), and the Italian soil cadastre includes measures for the conservation of soil biodiversity (Raimondi et al., 2020).

3.3. Food production

A recent discussion paper summarizing the main themes emerging from the analysis of urban foraging in India, South Africa, Sweden and the US, clearly shows that the collection of non-timber forest products for food consumption purposes is the most widespread form of use across the world (Shackleton et al., 2017). While these resources can often serve other purposes, such as medicine, crafts, and rituals (e.g. Grabbatin et al., 2011), the possibility to respond to the most basic human need by gathering, rather than cultivating, edibles often rich in proteins, vitamins, starch, and minerals has always been beneficial to local communities, both in the Global North and South (Fig. 5). This is barely surprising if we consider the vast amount of edible plant and fruit species all around the world, with many yet to be discovered and some with the potential to become successful crops (Sardeshpande and Shackleton, 2019; Ulian et al., 2020).

By their very definition, wild products are untamed, and therefore hard to quantify and profile with precision: ethnobotanical surveys conducted in specific sites, often collected using semi-directed interviews with gatherers and participant observation, have been extremely useful to identify a wide range of available taxa and classify their culinary uses in very diverse contexts and times (Łuczaj et al., 2012), mainly in Europe (e.g Berlin, Vienna, Sarajevo, Swiss villages, Spanish urban areas) (Abbet et al., 2014; Acosta-Naranjo et al., 2021; Kilchling et al., 2009; Landor-Yamagata et al., 2018; Redzić, 2010; Schulp et al., 2014; Schunko et al., 2021; Schunko and Brandner, 2022; Schunko and Vogl, 2020), and the USA (e.g. Atlanta, Syracuse, Baltimore, Philadelphia, New York City, Seattle) (Arrington, 2021; Bunge et al., 2019; Gaither et al., 2020; Hurley and Emery, 2018; McLain et al., 2012; McLain et al., 2014, 2017; Poe et al., 2013; Robbins et al., 2008; Gianotti and Hurley, 2016; Synk et al., 2017). Moreover, given the potential contamination of wild food gathered in urban areas, a handful of studies also examined the elemental uptake of mushrooms in Berlin (Schlecht and Säumel, 2015), Greater Athens (Kokkoris et al., 2019), Zagreb (Ivanić et al., 2021), and of wild greens in East San Francisco Bay (Stark et al., 2019). Evidence is still scarce, but it seems to suggest that while some overaccumulation may occur, an occasional intake is safe. Nevertheless, much more research is needed, particularly to provide guidance in urban food forest initiative (Gori et al., 2019), especially since this may be a major barrier for people to engage in urban foraging (Fischer and Kowarik, 2020).

While most literature focuses on single or a few sites, three studies attempted a more comprehensive mapping of wild food and foragers (Lovrić et al., 2020, 2021; Schulp et al., 2014; Shackleton and de Vos, 2022). While not specifically focusing on urban areas, they suggest that – wild game excluded – mushrooms, berries, and nuts are the most consumed non-timber forest products. Moreover, these works indicate that the economic value of wild food is not negligible, although it is extremely hard to assess and context-dependent (Šiftová, 2020; Weiss et al., 2020). In fact, according to the most recent study (Shackleton and de Vos, 2022), wild foods are widely gathered and consumed, potentially involving between 0.23 and 1.23 billion people in the Global North. In Europe, the total value of non-wood forest products has been estimated as representing €23.3 billion per year, an amount that is comparable to almost 70.7% of roundwood production (Lovrić et al., 2020). For some particular edibles (i.e. Matsutake mushrooms in the Pacific northwest) wild food value can even equal that of timber (Alexander et al., 2002) though this most likely depends on the rarity and gastronomic status of the specific produce.

Part of the reason why it is hard to estimate the number of wild food users and the exact economic value of the products, lies in the extremely protean nature of urban foraging. As many ethnographic and qualitative studies in very diverse contexts show, the practice can be carried out for

Fig. 5. Urban foraging and forest gardening in the UK. Note: a) to c) Jelly ear mushrooms (Auricularia auricula-judae), St. George's mushrooms (Calocybe gambosa), and wild garlic (Allium ursinum) abundant at Chorlton Ees Nature Reserve in Manchester (UK). d) the forest garden of Garden Cottage, Coldstream near Edinburgh, Scotland, with apple, hazelnut, and other trees, raspberry shrubs and other bushes, perennial and annual plants such as kale and broad beans and many more plant, animal, and fungi species. Courtesy of the authors.

Table 2
References with quantitative estimates on carbon storage and food production potential of urban food forests.

Source	Area	Type of estimate	Methods	Results
Lehmann et al., 2019	Devon, England	Carbon storage of the understorey of a peri-urban food forest	Calculation of above-ground biomass and estimation of below-gound biomass using allometric equations. Estimated carbon stock based on carbon content analysis of shrub samples of 31 species	Stored carbon per area: Average: 3.69 Mg C ha ˆ− 1 Lower limit: 3.32 Mg C ha ˆ− 1 Upper limit: 4.04 Mg C ha ˆ− 1
Schafer et al., 2019	Devon, England	Carbon storage of a peri-urban food forest	Calculation of above and below ground components of all tree layer woody biomass (528 trees across 28 species) using allometric equations, and stored carbon content calculated at 50% of the total biomass.	Stored carbon per area. Contribution by species available in the paper. 39.53 ± 4.05 Mg C haˆ− 1
Bunge et al., 2019	Syracuse, New York	Total seasonal nutritional productivity estimates	Weighing each day's harvest on a sample of trees producing serviceberry, mulberry, apple, and walnut and subsequent calorie conversion (multiplied by number of trees for each species)	Serviceberry: 164.958 g; 140.213 calories Mulberry: 9.433 g; 4.056 kcal Apple: 47.113 g; 24.499 kcal Black walnut: 70.422 g; 460.560 calories
Clark and Nicholas., 2013	Burlington, Vermont	Production capacity and calories conversion of urban open space planted with apple trees	Nine planting scenarios considering i) the amount of available open space planted with apple trees (5, 25, or 50%) and ii) low, medium, and high yields per hectare planted (based on achieving 25%, 50%, and 75% of optimal yields, respectively).	Worst scenario (5% open space planted, 25% mature yield achieved): 109 metric tons/year producing 59 calories Best scenario (50% open space planted, 75% mature yield achieved): 3.277 metric tons/year producing 1.729,3 calories
Nytofte and Henriksen, 2019	Coldstream, Scotland	Production and nutritional capacity of a peri-urban food forest	Calculation of total annual crop yield in chilograms, energy (kcal), protein(g), fat (g) and carbohydrates (g) based from an average output over the seven-year period of 2011 − 2017 for 16 species	Annual yield for Garden Cottage food forest (0.08 ha). Estimates by crop type in the paper. Produce: 713 kg Energy: 415.075 kcal Protein: 9868 g Fat: 8394 g Carbs: 85.627 g

recreational, professional, and self-sustaining purposes, and it is often hard to establish exact boundaries and to collect standardized data (Landor-Yamagata et al., 2018; Palliwoda et al., 2017; Park et al., 2019). Studies examining foragers' practices often underline the variable nature of their motivations: gathering wild food provides healthy and sustainable food while keeping active and spending time in nature, but it can also be recreational, didactic, an additional source of income, a way of generating social bonds, retrieving lost traditions, and reconnecting cultural identity and place-belonging (Fischer and Kowarik, 2020; Gaither et al., 2020; Jay and Schraml, 2009; Kangas and Markkanen, 2001; Poe et al., 2013; Gianotti and Hurley, 2016; Shortly and Kepe, 2021; Šiftová, 2020; Synk et al., 2017).

Perhaps most importantly however, wild food can become a safety net against food insecurity for low-income households and minorities (Shackleton, 2021). Foraging has always been an important source of nutrition in times of economic crises (Sachdeva et al., 2018) and war. During the siege of Sarajevo, for instance, reliance on wild food biodiversity permitted to overcome culinary monotony and to counter malnutrition (Redzić, 2010). But even in peaceful times, foraging has always an important source of nutrients for poorest households, thus pointing to the contradiction of how food can be abundant and scarce at the same time (Hurley and Emery, 2018; Nyman, 2019; Phillipps et al., 2022; Sardeshpande and Shackleton, 2019; Shackleton et al., 2017; Shackleton and de Vos, 2022). In Europe, this still contraposes wild food use on the two sides of the Iron Curtain: While in Western countries foraging is mostly a recreational pastime, in Eastern Europe it is more often a complementary source of income, especially for rural populations (Lovrić et al., 2021). For example, the higher density of fruit trees in East Berlin compared to West Berlin is linked to the focus on domestic food production in the former German Democratic Republic (Larondelle and Strohbach, 2016).

The dynamic realm of wild foods and urban foraging suggests that it can become a valuable tool for urban environmental policy and education. It can help to reduce the environmental impact of food production while increasing access to fresh, healthy food in urban areas. In this light, several initiatives attempt to utilize effectively such potential, from social enterprises rescuing urban fruit and nuts that are subsequently redistributed to stakeholders and sold to manufacturers or restaurants (Ballamingie et al., 2019), to creative projects attempting to use sensor systems to detect when fruits in urban trees are ready to be collected (DiSalvo amd Jenkins, 2017). Perhaps the most systematic approach to exploit the possibilities of wild food is through the creation and management of urban food forests, namely 'the intentional and strategic use of woody perennial food producing species in urban edible landscapes to improve the sustainability and resilience of urban communities' (Clark and Nicholas, 2013, 1652). According to the studies available, food forests can provide healthy, nutrient-dense foods and potentially contribute to the urban food system. Clark and Nicholas (2013) estimated the potential nutritional yield of apple trees planted in the available open space of Burlington (Vermont) under different scenarios, showing that in high yield conditions the total annual minimal recommended fruit intake would be guaranteed for the whole population. Bunge et al. (2019) focused instead on the yield of serviceberry, mulberry, apple and walnut in an urban forest sited in Syracuse – one not explicitly envisioned as a food forest. They found that, despite many zero-yielding individual trees, the mean-yield was never zero. However, the total yield was still low to be considered as a meaningful contribution to the city's food security. Finally, Nytofte and Henriksen (2019) focused on a peri-urban food forest of 0.08 ha in Scotland and found that, scaled up to 1 ha, it would have the potential to produce the yearly energy requirements of up to six adults, the carbohydrate requirements of up to nine adults, the fat requirements of up five adults, and the protein requirements of up to four adults. Using this data, it is possible to create a rough estimate of the potential contribution of food forestry to sustainable cities. For instance, a city of 1,000,000 inhabitants (about the size of e.g. Birmingham) would require a food forest of 2500 km^2 to meet the protein requirements of its whole population, that is, an area about 9 times of the city itself (Birmingham has 268 km^2), or a food forest of 1111 km^2 and 4 times the surface of the city to meet its carbohydrate requirements. This is a thought experiment and a calculation assuming total self-sufficiency based on food forestry. By contrast, urban foraging – from spaces with a "random" rather than deliberately optimised occurrence of edible species – would consequently require a much larger area to provide the nutritional requirements of a whole city. However, this does not mean that its contribution would be insignificant. While a city's self-sufficiency through foraging is a scenario that is neither realistic nor necessarily desirable, a combination of urban foraging, food forestry, and regional-scale agriculture could considerably shorten supply chains, decrease import-dependency, and help making cities sustainable. In any case, many more studies are needed to assess how much, and in which conditions, wild food can contribute to the dietary intake of urban populations (Table 2).

Despite their potential, available literature suggests that food forests are still not widely considered in public policies: in Canada for instance, less than 1/3 of urban forest management plans include any discussion of food (Kowalski and Conway, 2019). Similarly, a study on innovations in the commerce of non-timber forest products (NTFP) in Slovenia, Serbia and Macedonia did not find any specific institutional support for NTFP businesses (Živojinović et al., 2017). Nevertheless, as pressure to improve the sustainability and self-sufficiency of our urban food systems increases so does the proliferation of bottom-up approaches, local and grass-roots initiatives towards higher abundance of forageable foods, e.g. the Picasso food forest in Parma (Riolo, 2019) and biodiverse spaces with edible species in schools (Fischer et al., 2019).

3.4. Relational aspects

Even when practiced as a solitary endeavor, foraging remains an inherently social activity. While relatively cost-free, the capacity to identify fruitful spots in the right season, to distinguish edible and toxic taxa, and to transform the harvest into a meal, a drug, or a craft, clearly requires knowledge sharing. The emergence of several online tools providing digital mapping of foraging spots are another potent example of the relationality of foraging.[3] While research also points to the use of reference books, the ever-changing nature of wilderness (e.g. landscape transformations, non-native species appearing, new uses being discovered) requires information to be continuously shared and updated. This can take place as an intergenerational transmission of expertise from older to younger generations (Abbet et al., 2014), but also across the foraging community (Fischer and Kowarik, 2020; McLain et al., 2014; Sardeshpande and Shackleton, 2019). In addition, while most often foraging occurs for personal use, swaps and gift giving are common practice (McLain et al., 2014; Poe et al., 2013). This social bond has clear benefits, as it permits to preserve cultural heritage and traditions, to promote a sense of belonging, inclusivity, and community; most importantly it encourages environmental conservation, sustainable food practices and stewardship for natural resources, which in turn can positively affect the wellbeing of the people involved (Colinas et al., 2019; Itchuaqiyaq and Matheson, 2021). As Poe et al. (2013, 418-419) write:

> "Gatherers share knowledge, products, and time in procuring and processing wild goods. These exchanges are instrumental in opening dialogue between strangers as well as strengthening existing friendships and ties across generations within a family. The social connections and shared activities are part of what constitutes gatherers as a community of practice. Moreover, shared experiences help keep gathering traditions alive".

A second social aspect that is often considered in the literature concerns the relationship between foragers and the regulatory framework. Regulations across cities and countries vary widely, ranging from explicit prohibitions, to management plans encouraging urban foraging, to total lack of regulations (McLain et al., 2014; Shackleton et al., 2017). However, while over-foraging may have a potential impact on native biodiversity and threaten the local ecosystem sustainability, most studies highlight that foragers engage in practices and moral calculations that fit common definitions of stewardship, such as picking small amounts of fruits and nuts, avoiding the collection of rare species and leaving edibles for wildlife (Charnley et al., 2018; Fischer and Kowarik, 2020; Schunko et al., 2021). Since most municipalities appear to lack explicit management plans, multiple levels of government often overlap. And since foraging itself is a practice characterized by unclear boundaries, informality, and common-sense norms, this situation can create confusion, vulnerability, but also loss of potentially edible harvest, as urban foragers rely mostly on public spaces such as parks and gardens. For instance, standard trespass laws may require foragers to obtain permission from landowners to access private sites, which in turn can create conflict with foragers, especially in the case of abandoned fields (Gianotti and Hurley, 2016). Conservation easements could be a compromise solution to keep land in the control of landowners while ensuring availability to sustainable agriculture and forestry (and potentially foraging). However, it requires landowners to relinquish certain property rights, which many may not be willing to do (Brenner et al., 2013).

Finally, a third recurring element concerns the embedding of foraging within capitalist structures – i.e. its relation with the mainstream food economy. In line with Gibson-Graham's (2006) idea that alternative economies can help promote more sustainable and equitable forms of economic organizations, many scholars see foraging as a way to challenge the dominant food system on different levels. Food obtained through foraging creates a space within the urban environment that is distinct from – and for some opposed to – mainstream production and supply chains, one that can increase access to fresh, diverse and sustainable produce and promote a more equitable distribution by reclaiming power and ownership over livelihoods (Sõukand et al., 2020). Being often rooted in local communities and based on sharing and mutual aid practices, it can also promote a sense of connection with other people and with the land that many see as opposed to the individualism often associated with market-based economies. Nevertheless, other authors emphasize how foraging – or more generally food prosumption – is not necessarily a statement against capitalism, and underline how mainly recreational activities can be over-interpreted as political acts (Veen et al., 2021).

4. What is missing? Gaps and future developments in the study of urban foraging across the scientific spectrum

As the review suggests, there is consensus that wild food and urban foraging can meaningfully contribute to both environmental and social sustainability of food systems. However, despite the growing interests in foraging and its potential benefits, more effort is needed to implement it on a larger scale and to generate tangible benefits for urban populations. The fact that many people forage in cities and appreciate wild foods is an encouraging signal, but it does not necessarily lead to their routinised and widespread provision as part of everyday consumption practices. While the scientific community is confident that wild foods can become a valuable part of urban foodscapes, there are critical elements to be addressed to realize their full potential. We see five points that require critical discussion.

First, and most importantly, more interdisciplinary studies and transdisciplinary projects are needed, with special attention to the interaction between social and natural sciences, and the involvement of practitioners (foragers, agronomists, grassroot movements etc.) and local administrations. Literature so far is at best multidisciplinary – i.e. it looks at urban foraging and wild foods from different perspectives in an additive manner. Yet, to fully comprehend and evaluate the capabilities of foraging and food forestry in proximity to cities, we need to design dedicated urban and peri-urban green infrastructures – or scale up existing ones – and investigate *simultaneously* their natural and social facets. Moreover, to truly understand their potential, it would be fundamental to gather empirical data on the available green spaces in different urban areas suitable for these activities. Such data would offer a more grounded framework for the application and scalability of these practices, and potentially permit to evaluate the pros and cons of the different approaches (e.g. foraging in wild environments vis-à-vis food forests). In fact, there are several ways and land use types to take

[3] See, for instance, the inventory of maps reported by Adrien Labaeye in the Edible city project. https://ediblecities.net/maps/

advantage of "wild", in particular perennial, edible species, from foraging in natural or planted forests to semi-wild cultivation (e.g. growing mushrooms on logs or inoculating trees with spores of edible fungi; Thomas and Vazquez, 2022) and to the design of food forests and polycultural agroforestry systems (Wolz et al., 2018). These land uses can be more or less efficient depending on both bio-physical (e.g. soil properties, climate, topography and biodiversity) and local socio-geographic (e.g. urban layout, population size, density) contexts. While there are no one-size-fits-all solutions, it is extremely important to identify, test, and streamline the most sustainable and productive ways to use wild foods in specific contexts. Consequently, this paves the way for an increased demand for studies quantifying the potential contributions of diverse foraging environments, particularly in terms of food production and carbon storage, as illustrated in Table 2. At the same time, it is crucial to investigate how different production scenarios can be socially organized so as to become part of cities' food supply chains – i.e. who will collect the harvest, how will it be distributed, when, where, and to whom? Comprehensibly, most studies focus on urban foragers, but a vast majority of the population is currently detached from this practice – and ultimately from the natural environment. Understanding how a practice conducted by a minority can have spillover effects on the entire urban population is of fundamental importance for scaling up wild food use and obtain tangible sustainability outcomes.

Second, while hardly mentioned in the works we reviewed, availability of labour should be a central concern if we wish to consider wild food as a serious complement to mainstream supply channels. Foraging is often a labour-intensive activity which involves walking, hiking, carrying equipment, as well as the time and effort to locate, identify and harvest wild plants. Clearly, when carried out for recreational purposes, people do not feel their labour input as an incumbency or an obligation. Yet, for some people foraging is an actual source of income, and in light of the high gastronomic value of certain species – e.g. truffles, morels, matsutake mushrooms – it is a profitable activity that can have competitive aspects often neglected by the scientific literature (e.g. Truffle trade in Italy).[4] Moreover, not all people want to forage, and some can be physically impaired or unable to do so. Conversely, within the current economic system, many who would like to forage lack the time to engage in the practice and the capacity to make it compatible with other means to their livelihoods. The scalability of any project involving wild food would then need to consider different ways to organize the collection and distribution of the harvest – i.e. the social division of wild food labour – so as to overcome the social and systemic barriers to fully benefit from it.

Third, the sustainability of foraging needs to be considered. It is possible that urban wild foraging could become so popular as to generate unintended consequences – i.e. a rebound effect (Hertwich, 2005). In this case, that would include detrimental influences of foraging on wildlife biodiversity and carbon storage capacity despite good intentions behind the use of local food sources for the provision of nutrients. Even though studies to date suggest that foragers are generally attentive and carry out the practice so as to minimize their impact, the mere increase in the number of gatherers that is needed to mainstream the practice could offset its intended benefits. Such risks can only be alleviated if upscaling foraging comes along with upscaling forageable urban green infrastructures designed for edible species. This, in turn, requires significant policy change. Moreover, while foraging and food forestry are different approaches, they should not necessarily be seen in space competition. Rather, food forestry practices could be applied to existing green spaces to deliberately increase public foraging opportunities. Competition rather occurs with urban green infrastructure that is predominantly characterised by decorative plants. While the design of parks and roadsides indeed still mostly follows recreational and aesthetic principles, there is no inherent reason not to integrate edible species into these spaces. That said, any significant change to the way things are, can be expected to be met with resistance and local authorities may thus require ideational and financial support backed by policy.

Fourth, there is a need to decouple food insecurity and foraging when developing projects. At present, the literature indicates that some foraging is part of urban poor households' strategies to counter food insecurity. Projects such as Hidden Harvest donate part of the food rescued to food banks, that in turn distribute it to people in need (Ballamingie et al., 2019). While food support provision represents a crucial safety net that prevents people from falling into greater hardship, it is important to differentiate between (wild) food loss/surplus and food poverty as two distinct issues that require unique solutions. The former relates to the environmental sustainability of our food supply chain, whereas the latter pertains to the social sustainability of income and wealth distribution. Treating them as interrelated concerns does not effectively address either issue, as it fails to bring about significant improvements to the overall food supply chain and consumption habits, while social inequalities and suffering persist (Hirth et al., 2022; Oncini 2023a, 2023b; Oncini & Ciordia, 2023). That said, more food sovereignty could play a role in alleviating poverty, even if that does not exhaust the necessary steps to overcome poverty.

Finally, imagining sustainable food in cities requires policy efforts to lead urban green infrastructure and to interlink it with other domains such as mobility. In this light, the ongoing electrification of public and private transport and the implementation of clean air zones are opportunities to reduce pollution loads and make tree crops and herbaceous plants and fungi (but also raised vegetable beds for urban gardening) along roadsides a more safe and appetizing option. In addition, the targeted reduction of private mobility and a shift towards cycling can free up space for urban greening. Another opportunity is the use of sustainable technology to support the creation of urban green infrastructure and enable and encourage urban foraging. For example, emerging biotechnologies such as the inoculation of trees with mycorrhizal fungi could support the design of urban forests that combine tree crops with edible mushrooms Guerin-Laguette, 2021; Thomas and Jump, 2023; Thomas and Vazquez, 2022). Further to this, local community infrastructure, including tools and spaces for food processing that can support urban foraging and gardening, can enhance access and involvement. All these measures will only be possible if there is genuine will to transform cities, provide the necessary funds to do that, and shift to economic models based on sharing and access rather than resource exploitation and private capital accumulation.

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CRediT authorship contribution statement

Filippo Oncini: Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing. **Steffen Hirth**: Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing. **Josephine Mylan**: Conceptualization, Funding acquisition, Writing – review & editing, Supervision. **Clare H. Robinson**: Conceptualization, Funding acquisition, review & editing, Supervision. **David Johnson**: Conceptualization, Funding acquisition, Supervision.

[4] The lucrative scene of truffle trade in Italy is a patent example of how foraging competitive dynamics can be at the basis of violent rivalries between foragers and animal cruelty. See, for instance, the Atlantic article *The dark side of the truffle trade*, by Ryan Jacobs (2014) and the Wall Street Journal article *Dogs pay the price in Italian truffle war* by Margherita Stancati (2022).

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ufug.2024.128216.

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