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Cultivating nut tree species in urban community gardens in Germany: motivations, challenges, and opportunities

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Research Paper

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Abstract

The EAT-Lancet Commission recommends increasing the consumption of nut trees worldwide as part of a sustainable diet. Integrating more nut tree species in urban gardening initiatives could provide members access to locally grown nuts and provide ecosystem services to urban landscapes. This study investigated the reported presence and diversity of nut tree species in urban community gardens, as well as the motivations and challenges for adopting and expanding those trees. Based on an online survey with 111 responding projects from the urban community gardening network in Germany as our case study, we found that nut tree species exist in almost half of all responding projects surveyed, albeit in a few numbers of individual trees and producing low yields. Projects are motivated by the provisioning, regulating, and cultural ecosystem services they provide, such as the nutritional value of nuts, the provision of food for animals, and the potential for education of members about agroforestry and nut use. Yet projects are hindered by limited space, local laws and regulations, and the interaction of nut trees with other species in the garden. Although only 50% of projects plan to incorporate more nut tree species in the future, most recognize the importance of nuts as part of a healthy diet. Governmental leadership is necessary to secure long-term contracts for urban gardens, so that more nut trees can be planted, and city residents can exploit the benefits of the ecosystem services they provide.

Introduction

Maintaining food security in urbanizing cities is a global challenge (Fan, Cho and Rue, 2017). One way to meet sustainable urban development goals and food security is to design urban landscapes that integrate multiple ecosystem services including food production, a provisioning service (Clark and Nicholas, 2013). Urban agricultural systems, for example, can offer urban dwellers nutritious food production. Although not specific to urban areas, the EAT-Lancet Commission recommends healthier and more sustainable global dietary patterns through increased local food production, increased consumption of non-animal protein sources, and a planetary health diet (Willett et al., 2019). A planetary health diet calls for a 100% increase in healthy foods such as fruits, vegetables, and nuts globally. The concept of planetary health is centered around the understanding that human health is dependent upon flourishing natural systems. To maintain it, human activities should limit the use of the Earth's resources and avoid environmental degradation. The planetary health diet, then, focuses on and encourages foods that are healthy for humans and at the same time produced more environmentally friendly than meat-based diets (Whitmee et al., 2015). In this paper, we focus on nut trees integrated into urban agriculture as an important and potentially underutilized component of a planetary health diet.

Tree nuts including walnuts, hazelnuts, Brazil nuts, almonds, cashews, and chestnuts are nutrient-dense, protein rich, and contain primarily unsaturated fatty acids (Gonçalves et al., 2023). They also supply the human body with fiber, vitamins, antioxidants, and phytosterols (Gonçalves et al., 2023). Due to their unique composition, their consumption positively affects human blood lipids, oxidative stress, inflammation levels, visceral adiposity, hyperglycemia, and insulin resistance (Willett et al., 2019). The consumption of nuts is associated with significantly reduced mortality rates and reduced risk for non-communicable diseases (Clark et al., 2019). The EAT-Lancet Commission recommends a daily intake of 25 g of peanuts and tree nuts per adult worldwide, also recognizing that an increase in cropland would be needed to fulfill this new demand (Willett et al., 2019). Furthermore, as nut production can be energy intensive, more extensive, or traditional agricultural practices in nut production that utilize agroecological methods and lower water and chemical inputs is needed (Tapsell et al., 2023).

The integration of more nut trees into urban agricultural systems such as urban allotment or community gardens and urban food forests (UFFs) can be a way to increase local sustainable nut production and consumption. Urban community gardens can be described as green

spaces managed and operated by members of the local community, where food or flowers are cultivated. They are a location where agroecology is practiced as a more sustainable and just form of agriculture (Egerer and Cohen, 2021; Siegner, Acey and Sowerwine, 2020). Agroecology can be generally defined as a transdisciplinary, participatory, action-oriented systems-approach to transform food systems to reconcile economic, social, and environmental sustainability (Gliessman, 2020). Agroecology is both a science—integrating knowledge from e.g., ecology and agricultural sciences—as well as a portfolio of sustainable agricultural practices to manage agricultural systems (Wezel et al., 2009; Gliessman, 2020). One component of agroecology is agroforestry, the intentional combination of trees and crops that complement each other for greater cultural and ecological benefits (Wezel et al., 2014). Within an urban community garden, members can decide to grow different tree species, such as nut trees, along with more traditional crops such as annual vegetables and herbs. These plant combinations have the potential to infiltrate stormwater, conserve biodiversity, sequester carbon, contribute to soil formation, and mitigate urban heat islands through the integration of trees (Taylor and Lovell, 2021). Thus, nut trees and their integration into so-called food forests have the potential to supply various ecosystem services (Rockwell et al., 2022)—the benefits that people derive from ecosystems and ecological processes that include regulating, supporting, provisioning, and cultural services (MEA, 2005).

Examples of UFF and urban nut tree initiatives are proliferating worldwide (Castro et al., 2018; Riolo, 2019; Allen and Mason, 2021; Russo and Escobedo, 2022; Oncini et al., 2024). They are defined as 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). Initiatives such as City Fruit Seattle and the Portland Fruit Tree Project in the USA are examples of urban orchards that are planted and cared for by their initiators and the surrounding community, and produce is accessible to the public. In Europe, initiatives such as 'Waldgärten' (forest gardens) in Berlin and Kassel, Germany, blend permaculture and 'Tiny Forest' concepts in their food forest gardens designed collaboratively with city residents (see: https://www.urbane-waldgaerten.de/). In Parma, Italy, 'The Picasso Food Forest' provides one of the earliest case studies of urban community food forest worldwide, where benefits include resident engagement, educational opportunities, and agroecological practices and increases in biodiversity (Riolo, 2019). Other examples include the German project 'mundraub', a platform for utilizing edible landscapes. On the webpage, users can locate edible plants and trees in their surroundings that are grown on public land, to harvest seasonal fruit, herbs, and nuts (see: https://mundraub.org/). Thus, such nut and fruit trees integrated across urban landscapes are proposed as an urban planning and design strategy to enhance ecosystem service provision (Russo and Escobedo, 2022).

This study explores the cultivation of nut tree species in urban community gardens to supply different ecosystem services to the urban landscape, using community gardens in Germany as our case study. Germany is an excellent case study as a highly urbanized country, with more than 77% of Germans living in urban areas and cities in 2021 (World Bank, 2022). Despite new urbanization trends, the country has a long history of agroforestry practices, in particular traditional orchard meadows (in German, 'Streuobstwiesen'). Today, the number of urban community gardens is growing steadily (Winkler, Maier and Lewandowski, 2019), as is the popularity of vegetarianism—76% of Germans are looking to reduce their meat consumption (Consumer Intel 360, 2021). Most nut species are not currently commercially grown in Germany but imported from countries including the USA, China, and Turkey (USDA Foreign Agricultural Service, 2018). Hazelnuts, almonds, and walnuts are grown in many regions in Germany for self-consumption and local consumption but are not marketed and transported to other parts of Germany (Kötter, Walldürn-Rippberg and Lobitz, 2020). Even though most nut trees are not yet commercially established in Germany, they might play a bigger role in the future due to climate change as more species from warmer climates may be more productive. We provide an initial study on the investigation into which nut tree species currently are integrated in urban community gardens in Germany, in light of their ecosystem service potential in the future. We ask: (1) Which nut tree species are currently integrated in urban community gardens? (2) What are the motivations and challenges for nut tree species adoption, cultivation, and expansion? and (3) What is the potential of nut tree species integration in urban community gardens?

Methods

We designed a 10-minute online survey questionnaire to explore the cultivation of nut tree species in urban community gardens and learn about the motivations and challenges behind growing those trees (see Appendix 1a and b for both original in German and translated English version). The survey consisted of four sections: (i) general data about the project, such as the name, location, and garden size; (ii) the current integration of nut trees, their species, number of individual trees, and percentage of the total gardening area; (iii) motivations behind and challenges of growing certain species of nut trees; and (iv) which nut tree species the project plans in the future, and how much importance the respondent attributes to nut trees as part of a healthy diet. Participation was anonymous, voluntary, and questions could be skipped. The approval of an ethics committee is not required for such research in Germany and the study was conducted in accordance with the German data protection law.

The online survey questionnaire was sent to all community garden organizations in Germany registered in the anstiftung e.V. database, an organization that supports community garden projects with knowledge networks in Germany. At the time of this study (March 2023), 921 community garden projects were listed (for geographic locations across Germany, see: https://urbane-gaerten.de/urbane-gaerten/gaerten-im-ueberblick). After removing duplicates and incorrect email addresses, the survey was sent to 830 projects. Additionally, the anstiftung e.V. published an article about this research project in the news section of their webpage and included the link to the survey. The survey was accessible for 3 weeks and received 111 responses in that period. In our analysis, we removed duplicates by confirming the head management and removed projects that did not fit the definition of urban community gardens.

We conducted summary statistics of multiple-choice questions. The survey's open-ended questions were coded manually. The coding was done by one researcher and is based on the concept of content analysis. The researcher studied all surveys and started taking notes of emerging themes and topics. She then created labels (codes) to be applied to the data to classify it into meaningful categories. The categories that naturally emerged, based on survey responses, represented the four ecosystem services: provisioning, regulating, supporting, and cultural. These

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categories were later analyzed and interpreted, and form the base of our discussion, alongside the challenges and motivations for nut tree integration reported by our respondents.

We used an 'emergent coding' approach, where codes were drawn from the survey responses, and are therefore tailored to our data collection. Following the concept of open coding suggested by Strauss and Corbin (1998, p. 12), we grouped 'conceptually similar events/actions/interactions'. We recognize, however, that the process of open coding can be highly subjective, and that the researcher will likely be influenced by his own epistemological and ontological assumptions (Mauthner and Doucet, 2003). For that reason, all codes were later cross-checked by a second researcher and discussed and verified with the first researcher in an analysis triangulation process.

In order to establish reliability and trustworthiness in this qualitative research, several measures have been taken, alongside respecting the Standards for Reporting Qualitative Research (O'Brien et al., 2014). To address the question of credibility, the researchers used triangulation—involving the integration of data sources and approaches—to best accurately understand patterns and to validate findings and their credibility (Ahmed, 2024). The three forms of triangulation included data triangulation (accessing a variety of people from the community garden network), analyst triangulation (having a second researcher review results of qualitative coding), and some environmental triangulation in that the data comes from a variety of locations. Additionally, the researcher engaged with several participants via email, receiving follow-up questions and suggestions for future research, thus creating a higher level of trust. For transferability, sampling strategies and a general description of the study setup are given. In terms of dependability, the researcher involved in data collection leaned upon her research diary for interpretation and to make sense of, and give meaning to, the data collected. This naturally led to creating an audit trail, in which the decision-making process of the researchers can be retraced. Dependability was further enhanced through regular meetings and discussions between the two researchers. Occasionally, other students were presented the state of the research in an informal setting and commented on its methods and progress. This also enhances the confirmability of the research through peer debriefing, by inviting alternative perspectives (Ahmed, 2024).

Results

Summary statistics

We received 111 responses (13% response rate). After removing duplicates in organizations, 91 responding projects identified their project as an urban community garden, three identified themselves as UFFs and 11 as hybrids (both UFFs and community gardens) (Appendix 2, and see: https://urbane-gaerten.de/urbane-gaerten/gaerten-im-ueberblick for geographic distribution). Various sizes, ages, and motivations of projects are represented in the sample: 34% of all projects are between 101 and 500 m^2, 60% of all projects were established in 2016 or later, 75% report organic cultivation, and 55% focus on education. Most projects are relatively young, with 60% of projects founded in the last 10 yrs.

Nut tree species

A total of 44% ($n = 47$ projects) have at least one nut tree integrated in the garden, while the remaining 56% (60) do not currently have any nut trees. Of the three UFFs, all have planted nut trees. Of all hybrid projects, 60% report the existence of nut trees. Of the community gardens, 41% have at least one nut tree, and 34% of those with nut trees only have one nut tree planted in the garden while 42% have two to three trees planted. Only one project reported to have more than five individual trees, with a total of 12 nut trees. Approximately a quarter (27%) of these gardens only have walnut trees (genus *Juglans*), whereas 18% have only hazelnut trees (genus *Corylus*), and thus across these gardens both walnuts and hazelnut trees are currently grown in half of all the projects surveyed that have nut tree species. One project has chestnut trees (genus *Castanea*) and one gardening project in Edingen-Neckarhausen stated that 'we are currently germinating two pecans, because in our region most walnuts suffer from fungal infection'. Three other projects have plans to incorporate chestnut trees, where one respondent from Berlin reported that they are propagating chestnut trees to plant.

In 18% of projects, walnut trees occupy less than 1% of the total area. In 73% of projects, they occupy between 1 and 5% of the total area. Similarly, hazelnut trees occupy less than 1% of the total garden area in 26% of all projects where they are present. In 68%, they occupy 1–5% of the total area. In accordance with the small space that nut trees occupy, the reported yields are also meager. For walnuts, 54% of projects do not harvest any nuts from their trees because the trees are 'too young' to bear fruit (Zwickau), or that 'squirrels benefit [the most]' (Berlin). In Hamburg, one project is 'not harvesting any hazelnuts at all, because the squirrels are quicker'. In Berlin, a project reported that 'walnut kernels are surrounded by a black substance. [It is] probably a disease'. A project from Stuttgart explained that 'almost 100 percent of the harvest [of hazelnuts and walnuts] belongs to the animals'. Twenty-nine percent of participants can harvest between 1 and 5 kg of walnuts per year. One project, the Mitmachgarten in Leipzig, reports to collect more than 50 kg annually from their *Juglans nigra* (black walnut) tree. Even though the project was founded in 2019, the tree has existed since long before and therefore is mature and bearing more fruit than younger trees.

For hazelnuts, 60% of projects cannot harvest any nuts from their trees due to similar animal- and disease-related reasons as mentioned above. In total, 25% of projects yield between 1 and 5 kg of hazelnuts annually. A yield of 0 kg yr^{-1} has been reported for both urban community gardens growing chestnuts, as the trees have been planted recently and are not matured yet.

Perceived and reported benefits of nut tree species and motivations to grow nut tree species

Ninety-seven percent of all projects report that nuts are either an important, very important, or extremely important part of a healthy diet (Fig. 1). Of the 15 projects that think that nuts are extremely important, only five are members of a garden that grows nuts. One project reported high retail prices of nuts and said they would suggest planting a nut tree for subsistence in the project she belonged to. Another project stated that 'native nuts [like walnuts, hazelnuts or chestnuts] should be integrated more into our diet'. In 13% of projects the trees already existed on-site; while some respondents saw them positively, while others reported the pre-existence of nut trees on the properties negatively.

Motivations to grow nut trees varied (Table 1), and we categorized these motivations in relation to ecosystem service benefits. A total of 26% of projects value nuts as part of a healthy diet for

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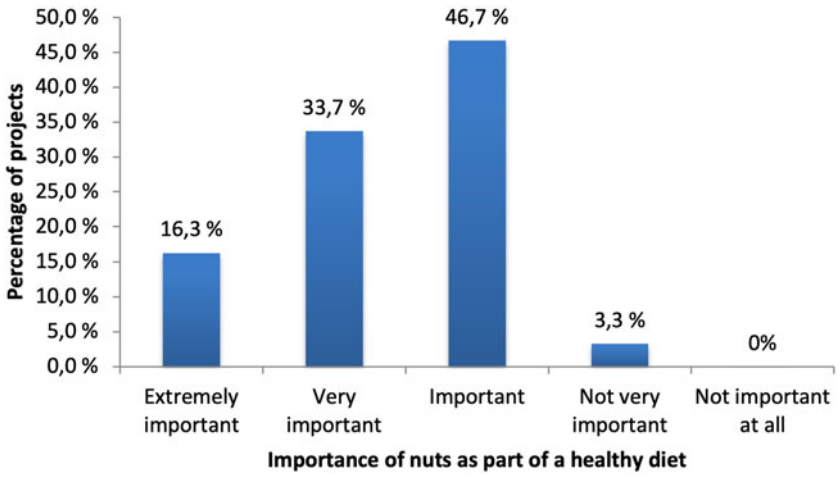

Fig. 1. Reported importance of nuts as part of a healthy diet.

humans, while 13% grow nut trees, amongst other reasons, for animal feed (provisioning services). Furthermore, 7% valued nut trees for the generation of biomass, and one project mentioned their beneficial medicinal properties.

Six percent of projects welcome the shade that the trees cast in summer (regulating service), although the shade was reported to negatively affect crop cultivation in other gardens. Evaluating cultural ecosystem services generated through the integration of nut tree species, 11% of projects mentioned the aspect of education. Only a few projects (4%) grow nut trees for their cultural significance in the area, as walnuts are native to the area, and have been used for centuries for food, medicine, dyeing, etc. Supporting services included the increase of biodiversity of species, structures, and animals (17%) and their robustness and low maintenance once established (4%).

Overall, 57% of projects feel that integrating nut trees now or in the future would help them achieve their overall vision. Several projects in Berlin, Zwickau, and Göttingen want to showcase the variety of edible plants in their garden, explaining that part of their vision is to 'present an array of different plants [and to] educate visitors on them' (Zwickau). Projects in Regensburg and Mainz strive to become 'edible gardens' and incorporate nut tree species for their many harvesting seasons and low maintenance. Similarly, gardens in Lindlar and Berlin appreciate nut trees for their longevity, and for fulfilling the criteria of permaculture which is part of their vision. Gardens in Landau, Karlsruhe, and Aachen are interested in sustainable and locally grown food, and therefore value native species of walnuts and hazelnuts. One project in Göttingen is focused on self-sufficiency. They say that 'growing nuts in sufficient amounts could cover the demand of all members of the project. […] This could lead to the learning outcome that partial subsistence is possible. In that way, we hope to empower members to participate in the fight against climate change and long transport ways'.

On the other hand, 24% of projects stated that growing nut trees does not contribute to fulfilling their overall vision.

Challenges to grow nut tree species

Nearly a quarter (23%) of projects stated that they did not encounter any challenges to grow nut trees. Amongst the ones that do, limited space is the biggest challenge (19%), as well as tree care and the disposal of leaves in fall (15%) (Table 1). Related to regulating ecosystem services, sunlight is of concern as well. Fifteen percent of all projects worry about the interaction of nut trees with other plants. Related to cultural ecosystem services, 19% said that they are motivated to grow nut trees but are restricted to plant trees due to local laws and regulations. Other projects were not motivated to grow nut trees but were dealing with already existing trees. One project reported that some members of the community do not like the walnut that already existed, and that it is a topic of recurring debates. Others would like previous trees removed but are prohibited from doing so by laws and regulations protecting these old-growth trees. One project worries about the cost of removal they might face in the future, when the tree is growing too big for their purpose. One reason why people struggle with pre-existing nut trees is because they feel restricted by their existence. They now need to adapt their planting design around the old tree and might lose gardening area due to its shading effect, release of juglone, or the extent of its root network. Juglone is a phenolic organic compound produced by *J. nigra* (black walnut) and other related trees that can inhibit the growth of other plants including vegetables in the Solanaceae family, apples, and berries.

To overcome challenges (Fig. 2), 37% prune their trees to reduce shading and keep them contained. Other projects consider the planting design of their beds, and therefore avoid having vegetable beds near their walnut trees. One project created a lounge area underneath their nut tree, which is valued by gardening members on hot summer days. Another 21% of projects removed the nut trees or indicated that they would not plant new trees in the future. Some projects (11%) address issues such as species interactions or vandalism through communication and education. This can take the form of community evenings where experts are invited to talk about the specifics of nut trees. One garden also created a godparent system, where individual members can sign up to be responsible for the care of a certain tree.

The potential of nut tree species

There is limited potential for new or further nut tree species integration. Of all projects surveyed, half (51%) have no plans of growing (more) nut trees in the future. While many of them did not elaborate further, seven projects explained that this decision is due to local laws and regulations, e.g., the limit German cities set for the height of trees in allotment gardens. Other projects (7%) said that space limitations will prevent them from integrating (more) nut trees in the future. Some projects (11%) do

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Table 1. Motivations and challenges associated with growing nut tree species, coded by main trends and classified as ecosystem services

Ecosystem services	Motivations	Examples	Challenges	Examples
Provisioning	• Healthy diet for humans (26%; *n* = 14) • Feed for animals (13%; *n* = 7) • Generation of biomass (7%; *n* = 4) • Medicinal purposes (2%; *n* = 1)	• Nuts contain 'protein, omega 3, many vitamins, and minerals' (Berlin) • '[Nut tree species] attract animals for observation' (Göttingen) • Use of hazelnut as 'hedge in an agroforestry system' (Berlin) • 'Healing properties of extracts [made from] fruits and leaves' of some nut tree species (Wilhelmshaven)	• Limited space (19%; *n* = 5) • Disposal of leaves (15%; *n* = 4)	• 'Space would be a challenge. Tree nuts grow quite tall, and we are running out of space […]' (Berlin) • 'The leaves [of the hazelnut] are inconvenient as mulch, because they are too acidic' (Hamburg)
Regulating	• Provides shade (6%; *n* = 3)		• Provides shade (6%; *n* = 3) • Negative interactions with other plants (15%; *n* = 4) • Fungal infestations (8%; *n* = 2)	• 'Nearby plants do not grow as well because of the walnut releasing juglone' (Wettringen) • 'Roots spread far into the garden, [so] very little is growing in the area where roots are' (Radolfzell)
Supporting	n.a.		n.a.	
Cultural	• Feed for animals (13%; *n* = 7) • Education (11%; *n* = 6) • Cultural significance (4%; *n* = 2)	• 'Nuts are not only edible to humans but also to animals which we welcome in our garden' (Berlin) • '[Our vision is to] present an array of different plants [and to] educate visitors on them' (Zwickau) • 'We are growing walnuts because they are a native tree [to the area], but there are not many left' (Göttingen)	• Local laws and regulations (8%; *n* = 2) • Vandalism (8%; *n* = 2)	• 'The community garden is […] subject to the federal law for allotment gardens. For that reason, nut trees are not allowed' (Markkleeberg)
Other	• Biodiversity (17%; *n* = 9) • Tree existed already (13%; *n* = 7) • Robust, low maintenance (4%; *n* = 2)		• No motivation (15%; *n* = 8) • Tree existed already (13%; *n* = 7)	• 'We do not have the necessary funds and [do not see nut tree species as a] priority' (Quadrath-Ichendorf)

Percentages and example quotes from open-ended text are included.

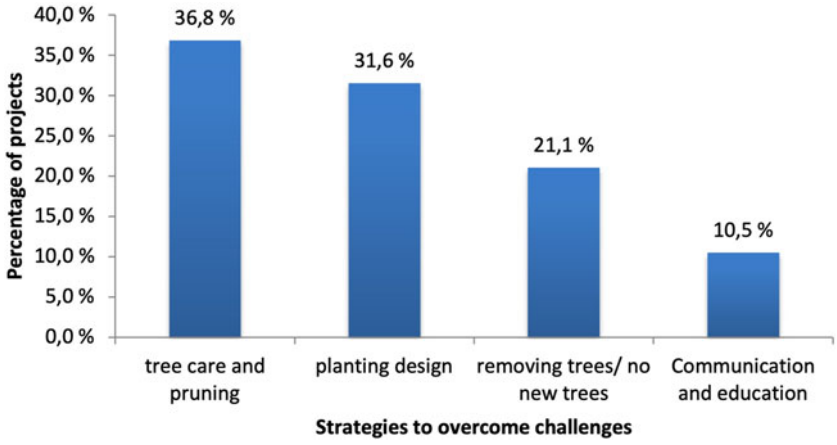

Fig. 2. Reported overcoming of challenges around nut trees, coded by main trends.

have firm plans for nut trees in the future, and mentioned chestnuts, hazelnuts, and pecan nuts as potential species. A few (7%) projects were still undecided on the matter and stated that 'nut trees have not been on the agenda so far, but I will propose it to our urban gardeners'. One project said that decision will be taken 'in a discussion with the group, after evaluating the success of nut trees already planted'.

Discussion

Nut trees are currently integrated in urban community gardening and food forest projects in Germany, but challenges are prevalent to integrate more nut trees, thus limiting their potential. Our case study revealed three main trends in nut tree integration: (1) nut trees are common in community gardening projects and valued for many benefits, but overall the abundance and diversity is low within a garden system; (2) challenges including limited space, longevity of leasing contracts, and local laws and regulations can limit (more) nut tree integration; and (3) there is high potential for further nut tree integration in urban community gardens and increasingly popular 'food forests', but more technical and policy support is needed. For example, more technical knowledge is required from horticultural experts around tree care and maintenance including topics such as pruning, pest, and disease management. In addition, more support to understand policies and regulations around trees and their cultivation, or changes in policies are needed to allow for tree growth. We elaborate on these trends.

Nut trees are common and benefits are recognized, but overall the abundance and species diversity is low

Nut tree species play an important role in these community gardens and food forest projects, offering both nutritional benefits and opportunities for education and biodiversity enhancement, in line with other studies (Taylor and Lovell, 2021; Oncini et al., 2024). Our research reveals a high occurrence of nut tree species in these gardens, yet their overall abundance and diversity remain low. Additionally, nut trees occupy a small fraction of the total gardening area in many projects. This suggests that space could be better utilized or optimized for nut growing and integration. Walnuts and hazelnuts emerge as the dominant nut tree species in these gardens, in line with recent literature. Notably, almonds or pistachio, although suggested as relevant by some studies particularly under climate change where hotter and drier summers are more common (Kötter, Walldürn-Rippberg and Lobitz, 2020), were not reported in any survey results. However, there are emerging trends, with two projects experimenting with incorporating pecan nuts (genus *Carya*), which are native to North America and require warmer temperatures, suggesting a potential diversification of nut species from species that are not native to Germany.

The various reported motivations as well as challenges for growing nut tree species provide insight into the ecosystem services as well as disservices that nut tree species are providing in these projects. These include a desire for nutritious food, increased biodiversity, educational opportunities, and the shade provided by nut trees during summer months. Nut tree species are reported to contribute to biodiversity and ecosystem services by attracting wildlife, creating habitats for insects, and stabilizing ecosystems as perennials. Nut trees are a means to engage the community in environmental education and generate knowledge and promote awareness of nuts in sustainable diets, as well as practical experience with agroforestry practices in some projects through learning-by-doing. Practical experience with nut trees can foster a deeper connection to food and agricultural practices, and in turn change the way humans relate to the food they eat (Garcia et al., 2017). Embracing agroforestry as a social movement can also go hand in hand with inviting outsiders of the community to participate in workshops around the topic (de Souza et al., 2012; Mier y Terán Giménez Cacho et al., 2018). As shown in the varied responses from projects, nut trees can open the doors to numerous discussions, from urbanization, agricultural practices, and climate change, as well as to the issues of under- and malnutrition in society.

Yields from nut trees were generally low, falling short of those discussed in scientific literature (e.g., Nytofte and Henriksen 2019). This could be attributed to the young age of many trees, with most projects established recently. Most respondents reported no usable harvest for walnuts at all, and only 29% could collect between 1 and 5 kg yr^{-1} likely due to the age of the trees (black walnuts [*J. nigra*], e.g., will start producing fruit after 7 years [Van Colen, 2019] or 8–12 years [Dana, 2001]). It is therefore possible that the harvest will be more bountiful in the future, when trees are sexually mature (however this means that gardens must invest in the future, see below). This assumption is supported by one project whose tree existed already before the establishment of the urban garden. A member reported annual yields of more than 50 kg for their inherited black walnut. Thus, there is optimism that yields may improve as trees mature

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or through investment in nut tree cultivars. Furthermore, as the best producing trees were inherited with the site long ago, it would benefit from stronger policy protection of these old(er) trees to maintain and conserve ecosystem service provisioning into the future.

Beyond their nutritional value, nut trees offer various other uses, including timber production, dye extraction from leaves and bark, and potential medicinal applications. For example, the therapeutic and preventative effects of walnuts are recorded in Chinese medicine, Indian medicine, and Western folklore medicine (Milind and Deepa, 2011), centered around the chemical compound juglone, which can be extracted from the leaves and bark of the walnut tree and the husks surrounding the nuts. Juglone has antifungal and antibacterial properties and could be used especially in cases where bacteria already developed a resistance to common treatments (Strugstad and Despotovski, 2012).

While the abundance and diversity of nut tree species in these projects are currently limited, their presence offers numerous opportunities for improving food security, enhancing biodiversity, and fostering community engagement. Through continued experimentation, education, and investment, urban community gardens and UFFs can harness the full potential of nut tree species to address environmental and social challenges.

Challenges of nut tree cultivation include limited space, leasing contracts, and local laws and regulations

Limited space, temporary leasing contracts, and federal and local laws and regulations often stand in the way of nut tree integration in urban agriculture (Taylor and Lovell, 2021), and this is the case in our study. Challenges and disservices include limited shade coverage, negative perceptions of tree shade, and the management of tree litter. Indeed, 50% of all projects are ≤500 m^2. Using a tree spacing calculator and applying the recommended spacing of 5 × 5 m^2 between each walnut tree, a 500 m^2 site could host around 15 walnut trees (Treeplantation, 2023). Lovell (2010) states that many community gardens are established on lots that are temporarily vacant or underutilized without a long-term contract with the landowner. This has been confirmed by several projects who stated that their contract with the landowner is only temporary, and therefore trees cannot be planted. As described above, nut trees need several years to grow and sexually mature before they start bearing nuts, and the yield usually gets better with increasing age and size. Black walnut starts bearing after 8–12 years and has a lifespan of around 80 years. The Chinese chestnut bears after 7 years for 40–50 years (Dana, 2001). These numbers show that investing in nut trees is, in fact, an investment in the future. Therefore, projects should secure a contract that is either indefinite or spans at least 10–20 years and one where tree size is not limited or reduced, as larger and older trees are most productive. This is difficult to achieve in an era where space in cities is rare and highly priced.

Another issue that has not gotten a lot of attention in recent literature is the inflexibility of laws and regulations toward nut trees, particularly in Germany, which has strict planting regulations for gardeners. In the Bundeskleingartengesetz (federal law for allotment gardens in Germany) the existence of species naturally growing taller than 3 m is prohibited in German allotment gardens (Szczepanska et al., 2021), likely due to shading and leaf litter produced from trees that may inhibit food production or recreation. For example, in Saxony, allotment garden regulations include a stipulation that:

> The planting of trees and shrubs (except fruit trees) that are naturally taller than 3 m is not permitted. Only half-height species and varieties of ornamental trees of a maximum height of 2.5 m are permitted. However, with the new framework allotment garden regulations, which came into force on January 1, 2020, all coniferous and coniferous species were banned from allotment gardens. This applies to single trees and shrubs as well as hedges. Only ornamental trees and shrubs that can be kept at a maximum height of 2.5 m naturally or by pruning may be chosen—Landesverband Sachsen der Kleingärtner e.V n.d. (translated from the original German text)

Even though some exceptions are made for fruit trees, nut trees are not yet exempted from laws and regulations. Federal, regional, and local laws as well as specific rules from landowners often prevent urban garden members from integrating more nut trees into their projects.

More support is needed for increased nut tree integration

Nut trees are not on the agenda of most urban community gardening projects, and many are not planning on growing nut trees in the future, even though individual members clearly understand the dietary benefits of nuts. Indeed, although nearly all (97%) of projects reported nuts to be an important part of a healthy diet, only 11 projects have concrete plans of integrating more nut tree species in their projects. It seems that there are too many challenges that prevent community garden projects from growing nut trees and probably maintaining larger and older stands of nut trees. By organizing workshops and events, and by publishing information materials about the importance of, and care for, nut trees, public organizations and the Ministry of Agriculture in Germany could stimulate the planting of more nut trees in the future.

Gliessman (2018) states that one purpose of agroecology is to re-establish the relationship between people who grow food and the ones eating this food. Thus, although nut tree species in urban community gardens in Germany are more common than expected, they often appear in few numbers and are often unplanned and even unwanted. This poses an opportunity to focus on nut trees, and to educate members about the different species and their properties. Urban gardens could put an emphasis on growing nuts regionally and on stressing their dietary importance according to the EAT-Lancet Commission; this would significantly improve the health of their members and other stakeholders of the community. Different species of nut trees could be grown in Germany in the future and with progressing climate change. A promising project for future knowledge generation is the project 'Urbane Waldgärten' (English: urban forest gardens; Urbane Waldgärten 2024). In collaboration with several governmental agencies, researchers from the University of Potsdam are building three new urban forests in the German cities of Berlin and Kassel. The project started in 2021, and researchers plan to closely monitor and analyze the ecological and social effects and climatic changes related to these new forest gardens (Schulz et al., 2022).

Government support in different research and praxis projects could scale up nut production from a local to a federal level in Germany. As an example, the government agency for agriculture in Bavaria (Bayerische Landesanstalt für Landwirtschaft; English: Bavarian State Institute for Agriculture) is currently experimenting with the commercial cultivation of hazelnuts (Demmel, 2012). Preliminary results show potential, and researchers said

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that the biggest challenges are not related to climatic conditions in Germany, but the availability of high-quality seeds (Bayrische Landesanstalt für Landwirtschaft, 2018). Other experimental projects on hazelnuts in Germany grew 15 different European varieties in experimental orchards and examined the nutritional profiles of each to see which varieties may make the best candidates for future cultivation in Germany based on nutritional quality (Müller et al., 2020). Thus, new experimental trials and eventual products on the market that are fit for garden conditions and future climate conditions may support the integration of nut trees into community garden projects, especially if the appropriate knowledge resources are also provided. Lastly, studies like this one are needed to establish a connection between theory and practice in urban community gardens. While this study can be seen as a starting point, more research is necessary that should also include the demographics of respondents and could examine aspects of household and community food security.

Conclusions

Nut trees can provide the urban landscape with ecosystem services and contribute to landscape multifunctionality and healthy diet initiatives. Warmer current and projected climates in cities may offer new opportunities for nut tree cultivation, especially in temperate regions. Our case study in Germany shows that many urban community gardens and food forest initiatives are motivated to integrate nut trees into their systems, and some projects are already experimenting with new and uncommon varieties and species in their regions. In addition, established trees can provide habitat for biodiversity, many food and fiber provisioning and climate regulating benefits. This suggests that especially long-standing older trees should be protected where possible. Yet our work also shows that many challenges remain around nut tree integration and cultivation, such as short land tenure arrangements and spatial constraints that limit plant growth, as well as pest and disease management. Although urban gardening is gaining popularity in German cities and cities worldwide more experimental work on nut tree cultivation in Germany, especially in urban contexts, is needed, as is adequate policy and planning support to activate the full potential of urban community gardens and UFFs as suppliers of all ecosystem services and as source of nutritious, protein-rich foods at the same time.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S1742170524000322.

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Ethical standards. Participation in the study did not cause any physical or mental harm or discomfort beyond the participants' everyday experiences. Participation was anonymous, voluntary, and questions could be skipped. The results do not allow any conclusions to be drawn about the individuals. The approval of an ethics committee is not required for such research in Germany and was therefore not obtained. The study was conducted in line with the German data protection law.

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