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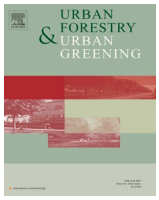

Original article

Exploration of the functions and potentials of urban forest gardens in Sweden

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ABSTRACT

Forest gardens are multilayered intercropped systems with perennial and mainly, edible crops. They have recently begun to be regarded as edible green infrastructure of cities in temperate regions. This study was aimed at: i) making a national inventory of Swedish urban forest gardens, ii) identifying the drivers that led to their establishment and iii) understanding their contribution to urban sustainability policies. A total of 30 forest gardens were identified in 10 different cities. Site visits and interviews to relevant stakeholders, highlighted the presence of three main types of origin of forest gardens initiated firstly by grassroot movements, followed by schools and municipal officials. These actors were informed and trained by so-called knowledge hubs, namely associations, education centres and professionals. A social network analysis emphasized that knowledge hubs were pivotal in supporting the establishment of forest gardens and circulate information, whilst few connections were found among other actors. More collaboration and integration among all stakeholders might be a key factor to increase the number of forest gardens and improve their quality. Stakeholders stressed the prominence of cultural ecosystems services provided by urban forest gardens by assigning high scores to education, enhancement of community building, recreation and aesthetic values (8.7/10) as compared with regulating services such as biodiversity and climate regulation (7.9/10) and provisioning services (6.5/10). Urban forest gardens were acknowledged to actively engage citizens in public green spaces management and planning, to improve environmental awareness and to promote intergenerational connections. However, the interviews underlined also the presence of legal burdens on land management and use, financial sustainability of both bottom-up and top-down forest gardens and lack of skilled labour. This study offers guidance to urban planners, public officials, education centres and activists on how highly multifunctional forest gardens could improve the green infrastructure thus contributing to cities' sustainability.

1. Introduction

Agroforestry systems are well acknowledged regarding their generation of products such as food, fiber and fuel alongside a range of social and ecological sustainability benefits (Jose, 2009; Burgess and Rosati, 2018; Sollen-Norrlin et al., 2020; Smith et al., 2022). In Europe, traditional agroforestry as various types of silvopastoral systems have been practiced in rural areas since 2 500 BC (Eichhorn et al., 2006; Nerlich et al., 2013), but they have been in decline since the breakthrough of industrial agriculture. In the search of more sustainable pathways and non-linear models of production, agroforestry systems have been suggested, among other models (e.g. regenerative, agro-ecological). In temperate regions novel forms of agroforestry practices have emerged such as modern types of alley cropping (Nerlich et al., 2013) or "multifunctional woody polycultures", systems focusing on the tree crops (Lovell et al., 2018). Also, new types of agroforestry have emerged in urban areas namely in the form of urban forest gardens or food forest and as such it constitutes one form of urban agriculture (Park et al.,

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2019; Albrecht and Wiek, 2021; Taylor and Lovell, 2021) (Fig. 1).

Forest gardens are multilayered intercropped systems with perennial and mainly edible crops, designed by humans to mimic young woodlands and are of low maintenance and low input models (Crawford, 2010). When located in temperate regions they are sometimes named edible forest gardens (Crawford, 2010; Björklund et al., 2019). The term food forest is also used by scholars (e.g. Park et al., 2019; Albrecht and Wiek, 2021) for a type of system similar to forest garden. Both forest gardens and food forest are closely related to the concept of urban food forestry, coined by Clark and Nicholas (2013), as all three concepts combine elements from urban agriculture, urban forestry and agroforestry. However, the multilayered and multispecies feature distinguishes forest gardens from urban food forestry as highlighted by Park et al. (2019). Regarding other similar terms in an agroforestry context, homegarden is used more often for tropical regions in the global south (Nair et al., 2021; Sharma et al., 2022) but is used also in Europe, including temperate areas (Mosquera-Losada et al., 2023). In the present study on both urban and peri-urban areas in northern Europe, temperate region, we use the term urban forest gardens (UFG). We included all forest gardens or food forests identified in urban contexts in Sweden that were of multi strata-model, thus one type of agroforestry and in line with Park et al. (2019).

The richness of edible perennial species is one of the main characteristics of forest gardens, both globally and in Europe, where a kitchen garden could have 100–400 species (Crawford, 2010; Schaffer et al., 2024). Therefore, several studies on forest gardens do include lists of species, without having a focus on the species per se rather than on their function in the system. For example, the energy and macro-nutrients of the edible perennials in an urban forest garden (UFG) were estimated by Nytofte and Henriksen (2019). Schafer et al. (2019) quantified the above and below ground carbon storage, while Lehmann et al. (2019) estimated the carbon storage of the understory of the same peri-urban forest garden in the UK and concluded that the amount of carbon stored is in parity with a temperate urban forest (Lehmann et al. (2019)).

Perennial vegetables, often used as understory in forest gardens, have higher nutritious values than annual crops (Toensmeier, 2022). Besides, perennial vegetables also contribute to both crop biodiversity and mitigation of climate change since often no tilling methods are used and most carbon could be bind in perennial systems compared to other agricultural practices (Toensmeier, 2022). Alongside healthy crops, for example fruits, nuts and berries, are generally produced from perennial systems (Lovell et al., 2023). Stoltz and Schaffer (2018) argued that forest gardens as an environment in the city, could be health promoting in several ways, for example by its aesthetic qualities, by reducing stress and/or by mitigation of urban heat islands effects. In addition, when UFGs are organized as community gardening multiple contributions to human health and wellbeing and sustainability could be reinforced (Stoltz and Schaffer (2018)).

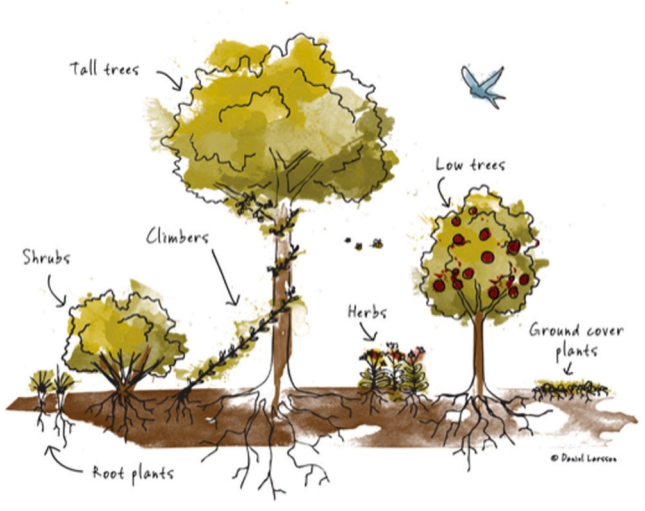

Fig. 1. A model of a seven-layered forest garden. The layers comprise large and small trees, shrubs, herbaceous perennials, ground cover plants, climbers and underground plants. Illustration by Daniel Larsson.

Some UFGs are also used for educational purposes (e.g. Park et al., 2019), for example for increase the ecological literacy in the era of urbanization (Hammarsten et al., 2019). Comparing conventional school yard gardening, field excursions and forest gardens, Almers et al. (2017) concluded the UFGs were better environments regarding accessibility, maintenance (less work input from teachers/staff/students) and provided opportunities to study the more complex natural systems. In addition, children were more involved in the creation and maintenance of the forest gardens (Almers et al. (2017)).

Trees are crucial for biodiversity in urban areas (Sousa-Silva et al., 2024) and are pivotal elements in UFGs. On landscape level, forest gardens could be a part of the edible urban landscape (McLain et al., 2012) and the edible green infrastructure in both rural and urban areas (Russo et al., 2017). Since landscapes are becoming more and more heterogeneous UFGs could be used for restoration and to counteract the monofunctions of landscapes (Park et al., 2019).

Riolo (2019) reported on the genesis and implications in terms of public engagement, educational opportunities, and environmental benefits of the "Picasso food forest" in the city of Parma (Italy). That study addressed the relationship between grassroot initiatives and the city administration and how urban agroforestry, to some extent, influenced the urban sustainability policies (Riolo (2019)).

UFGs are highly multifunctional and could contribute to a range of food products, alongside enhancement of biodiversity and several sociocultural benefits (Park et al., 2019; Nytofte and Henriksen, 2019; Moereels et al., 2024). On the landscape level, UFGs could contribute to the green infrastructure level including strategies to combat climate change (McLain et al., 2012; Russo et al., 2017; Park et al., 2019). In addition, UFGs as community gardens have become a way to involve citizens in urban planning to a greater degree (McLain et al., 2012; Riolo, 2019).

As stated by Taylor and Lovell (2021), research on UFGs is behind the practice.

Albrecht and Wiek (2021) conducted a worldwide study on 200 forest gardens, including UFGs, regarding their performances on sustainability. Moereels et al. (2024) described the main characteristics and the origin of forest gardens in a comprehensive study in Flanders (Belgium), providing information on species composition and functions of 23 forest gardens located in both rural and urban areas. Moreover, the literature concentrated on case studies and inventories on forest gardens located in urban areas more specifically on the country level have not been attempted, to our knowledge.

In Northern Europe – e.g., in Sweden – several UFGs have been initiated during the last decade. Such initiatives have come from various grassroot movements (e.g. Schaffer, 2016; Vlasov and Vincze, 2018). More recently, adult educational programs on agroforestry have also been initiated by public actors such as the County of Västra Götaland at Angereds gård (vgregion.se/), including other initiatives by municipalities for example the "edible public park" and playground in Örebro municipality (Örebro kommun, 2025) and the food forest in Västerås municipality (Västerås kommun, 2025). Despite the growing interest for urban forest gardening in the country, there is a lack of knowledge on the overall features of UFGs, their main characteristics and their functions and potential fulfillment of urban policies. In particular, the raising interest of municipalities for UFGs poses some questions about the motivations for their creation, their limitations and challenges according to the perceptions of local stakeholders such as urban forest gardens practitioners and the officials in municipalities where such gardens are located, the implication on urban planning/policies, the role and the benefits/functions that public officials assign them.

To fill the knowledge gap, the objectives of this study are to: i) conduct an inventory of all Swedish UFGs and to characterize them according to location, origin, management, size and activities carried out; ii) identify the main drivers that led to their establishment; and iii) understand the perceptions of 100 stakeholders about how UFGs could contribute to urban sustainability policies.

2. Materials and methods

2.1. Data collection

In a first step, we inventoried UFGs using multiple sources of information such as an online based interactive map of forest gardens in Sweden, newspaper articles, specialized gardening journals, local forest garden and permaculture groups on Facebook. We also used the personal knowledge and contacts of one of the co-authors who has been involved with forest garden community in Sweden for many years. We included in our study all forest gardens in urban areas in public green spaces that we found in Sweden regardless of size, purposes such as self-sufficiency or commercial. There might be more on private land and for private use only. In Sweden, allotment gardens are common in urban areas. They combine annual and perennial crops such as fruit trees and shrubs. They do not label their activities agroforestry, so we excluded further investigations in allotment areas.

In a second step, we performed a stakeholder analysis order to understand the typologies of actors who manage or interact in some ways with UFGs. The analysis was based on reference academic literature and findings from Step 1. Three main actors were then identified, namely practitioners (citizens and/or community-based organization members), schoolteachers and/or adult educators and officials in local municipalities.

Successively, we elaborated a questionnaire with the aim of collecting information from the selected actors. The questionnaire was divided into three sections: "Urban and peri-urban agroforestry", "Agroforestry and urban planning" and “Social Network Analysis” (Appendix 1–4).

The "Urban and peri-urban agroforestry" section aimed at understanding the main features of UFGs (size, year of foundation, people involved, activities), a general opinion about the importance of agroforestry in urban and peri-urban contexts and an assessment of main ecosystem services (ESs) provided. Not all ESs were included in the questionnaire, but ESs were selected in relation to their possibility to occur in both urban and peri-urban contexts as well as to their recurrence in literature on agroforestry. Successively we grouped some of them into macro categories according to i) belonging to the same typology; ii) contiguity of subject. The latest version of the CICES - Common International Classification of Ecosystem Services (Haines-Young and Potschin, 2018) was taken into consideration for this purpose.

The following "Agroforestry and urban planning" section sought to identify the main drivers behind the establishment of UFGs and their relation to urban sustainability policies. Most of the questions were open in order to give respondents the opportunity to freely express their point of view and provide information in a discursive manner. Some of the open-ended questions in this section were tailored around the type of respondent (e.g. specific questions to schoolteachers on the didactical approach with pupils in relation to the forest garden). Additionally, officials were also asked to fill in a S.W.O.T. analysis aimed at highlighting all aspects related to the introduction of agroforestry as management for UFGs.

The “Social Network Analysis” section investigated the relationships and the connections among different stakeholders dealing, in various ways, with forest gardens. This part was aimed at developing a conceptual framework on the centrality of certain actors for spreading urban forest gardening concepts and practices among other stakeholders.

Starting from June 2023, key stakeholders identified during the stakeholder analysis were contacted via email to set the site visits to inventoried UFGs. Field visits took place from August 2023 to January 2024, and they were coupled with semi-structured interviews with UFGs reference person. The questionnaire-based survey involved also those actors that may indirectly deal with forest gardens such as municipal officials employed in urban green/park units of the city where forest gardens were located. The questionnaire was sent to respondents before the interview. Face to face interviews were chosen as a priority since they provide richer and more detailed argumentations than computer-mediated interviews (Krouwel et al., 2019). Whenever a UFG reference person was unable to attend, the interview was conducted at another moment. In this latter case, site visits preceded the interview in order to obtain in advance knowledge about the main features of each forest garden. In a few cases, due to the unavailability of people for in-person meetings, on-line interviews were conducted. Web-based interviews took place between February to March 2024. During the survey, snowballing sampling (Goodman, 1961) made it possible to include in the study additional UFGs and interviewees. In fact, with this method respondents provide additional people to be interviewed, and previously unknown stakeholders are identified (Harrison and Qureshi, 2000; Paletto et al., 2015). The risk of the use of snowball sampling is to produce a bias toward stakeholder groups that are better structured, and this imbalance could lead to not considering those that are poorly organized or not present on social networks/other media. In our survey, this risk was smoothened by coupling facebook groups screening and websites search with direct interviewees’ indications. In this way, it was possible to identify some bottom-up FGs that otherwise would have remained unknown. During the survey, respondents highlighted the presence of a fourth category of actors, that can be labeled as “knowledge hubs”, who had not been immediately identified with the stakeholder analysis. Knowledge hubs can be described as actors that act in close collaboration with people who directly manage UFGs and provide technical support, bring innovation and circulate knowledge. Thus, a reduced version of the questionnaire was elaborated for them in order to collect their insights on the direction that Swedish urban forest gardening movement may undertake to further spread in the country.

Of the 53 people contacted, 37 accepted to participate in the interviews with a respondent rate of 70 %. Interviews were conducted in English, lasted approximately an hour and were mostly face-to face (77 %). The most represented category were municipal officials (13 interviews) followed by practitioners belonging to grassroot organizations (10), and both schoolteachers/adult educators and knowledge hubs (7). Of the 30 inventoried UFGs’, 19 were visited and additional 2 provided information via email. In particular, for the city of Gävle, who accounted for 13 forest gardens located in primary and pre-schools, a subsample of 4 gardens was visited and face to face interviews to schoolteachers were conducted accordingly. In order to ensure representativeness, the schools were chosen according to the grade (two pre-schools and two primary schools), size of forest garden and typology of activities.

In Fig. 2 a resume of data collections steps is presented.

2.2. Data analysis

Qualitative data deriving from open-ended questions were elaborated with the thematic analysis method (Braun and Clarke, 2006) by identifying patterns to derive the main themes. Close-ended questions were collected on a series of Likert scales ranging from 1 to 10 or 1–3 and analyzed with descriptive statistics that included means and percentages. Statistically, the Shapiro-Wilk test and the Anderson-Darling test showed a non-normal distribution of data (Shapiro-Wilk test: $W=0.701$, $p = 0.006$; $A2 =0.905$, $p = 0.008$), therefore non-parametric tests were applied rather than parametric ones. In particular, the non-parametric Kruskal-Wallis test was performed to detect and compare statistical differences among the four main typologies of actors (i.e. municipal officials, practitioners, schoolteachers, knowledge hubs). The Kruskal-Wallis test was applied considering a minimum sample size of

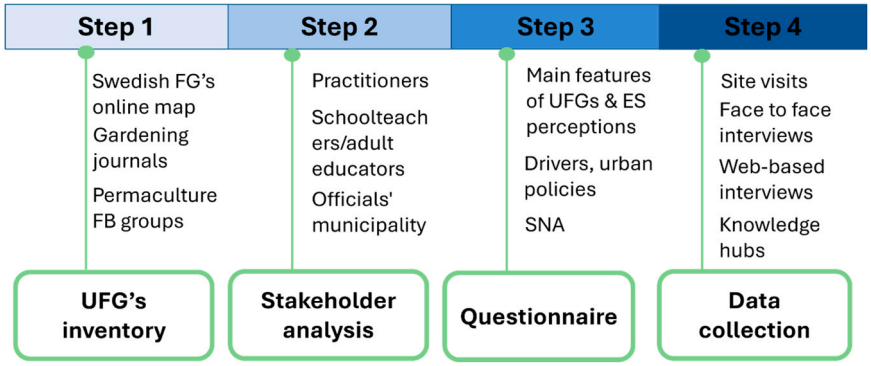

Fig. 2. The flowchart illustrates the four methodological steps followed in the study.

five respondents per group (i.e. typology of actors). After rejecting the null hypothesis (H0) of the Kruskal-Wallis test, a pairwise multiple comparison for stochastic dominance was conducted using the Dunn's test. The Dunn's test was used with Bonferroni adjustment, which can modify the rejection level for any test by dividing α by the total number of tests and requires a much smaller p-value to reject any test. Statistical analyses were performed using XLStat 2020.

Eventually, a social network analysis (SNA) was conducted in order to identify the network of collaborations among different stakeholders. Theoretically, a social network is a structure that consists of nodes (stakeholders) and ties (relationships between stakeholders). The SNA is an effective tool to analyze the relationships between stakeholders in a multi-actor context with the aim of improving the collective action (Harshaw and Tindall, 2005, Bodin and Prell, 2011). Formal professional cooperation between stakeholders was highlighted, distinguishing between strong and weak ties. Strong ties are considered those in which there is frequent and intense communication between stakeholders (Granovetter, 1973), while weak ties are the least frequent and understood, but they can give access to a wide variety of information (Vennesland, 2004). The strength of ties was measured in a Likert scale ranging from 0 (no interaction) to 5 (monthly collaboration). A sociogram – a visual model that displays all the personal connections within a network – was elaborated for each group of stakeholders. The role of each stakeholder in the network was analyzed using the Degree Centrality (D_c) that is the most widely adopted measure of centrality, and it represents the measure of the social status, power and prestige of a stakeholder in a network. Freeman's formula for D_c is applied to this study (Freeman et al., 1979):

$$Dc(n_i) = \sum_{k=1}^{n} a_{ik}(n_i, n_k)(N-1)^{-1}$$

Where:

Dc = Degree centrality

a_{ik} = arc between nodes (1 when there is a connection between n_i and n_k; 0 when there is no connection between n_i and n_k)

The Dc values and the graphic elaborations of the SNA were elaborated through the software UCINET 6.0.

Prior to the interview confidentiality and anonymous surveys with aggregated data processing were assured to respondents by the authors. The authors declare that they obtained informed consent from human participants involved in the study.

3. Results

3.1. Inventory of UFGs in Sweden

By our inventory of UFGs in Sweden in total 30 UFGs were identified in the country, located in 11 different cities. Most of them were geographically concentrated in three areas of the country, in the South (Malmö and Lund), in the West (Göteborg) and in the Center (Stockholm and surrounding areas). All UFGs were comprised between 60°40'28.27"N and 55°36'21.13"N latitude, the northernmost forest gardens being located in the city of Gävle and the southernmost in the city of Malmö (Fig. 3).

The size of UFGs in Sweden varied significantly ranging from around 30 m^2 of mini forest gardens located in pre-schools up to 5.000 m^2 in public parks. The average size was around 850 m^2.

According to the categories of actors who had initiated and managed the sites, we grouped the forest gardens into the following groups: (i) "bottom-up UFGs", run by associations or informal group of citizens; (ii) "educational UFGs", managed by schools or adult education centers; and (iii) "top-down UFGs" established by municipalities. A synthesis of the inventoried FGs is presented in appendix 5.

The nine bottom-up UFGs were initiated by spontaneous initiative of citizens interested in permaculture. They were evenly distributed in the central-southern part of the country. The totality was developed on public land provided by the municipalities. The first UFG was founded in 2009 (Rågdalens permakultur, city of Stockholm), the last one (of those identified in this study), in 2019 (Ätbara Lund, city of Lund). Over this period, the number of new forest gardens increased steadily and then, from 2020, the establishment slowed down. Five out of nine were run by associations, the remaining four by informal groups of citizens. They were all open for visits and hang out to harvest fruits and vegetables for free. Additionally, most of them organized open theme days such as courses and workshops on permaculture principles (66 %), planting, clean up, and harvesting days (55 %), and educational activities for children (33 %).

A second group we identified and named as "educational urban forest gardens". They did not have one unique origin, being initiated by several different actors such as schoolteachers, universities, officials in municipalities, parents of pupils, technical officers or non-governmental organisations (NGOs). Overall, 18 forest gardens were recorded, 13 of them (72 %) located in the city of Gävle. Stockholm University created the first one in 2012 (Stockholm's universitets Skogsträdgård), the Municipality of Gävle the last ones at five primary/pre-schools in 2023. The majority (56 %) were established at pre-schools, secondly at primary schools (33 %). The remaining 11 % were forest gardens who address their activities to adults (Angereds Gård, city of Göteborg and Stockholms universitet Skogsträdgård, city of Stockholm).

All educational UFGs allowed free picking of products, and some of them had more structured activities with children such as cultivation and maintenance of the site, scientific observation and also "food education activities" such as cooking sessions of fresh vegetables and fruits harvested in the garden. Forest gardens for adult education focused mainly on providing courses and workshops. From a didactical point of view, most educational gardens followed a "learning by doing" approach. Especially pre-school focused also on the "Reggio Emilia" methodology (Hewett, 2001), a didactical approach that encourages the relationship with the environment through practical activities.

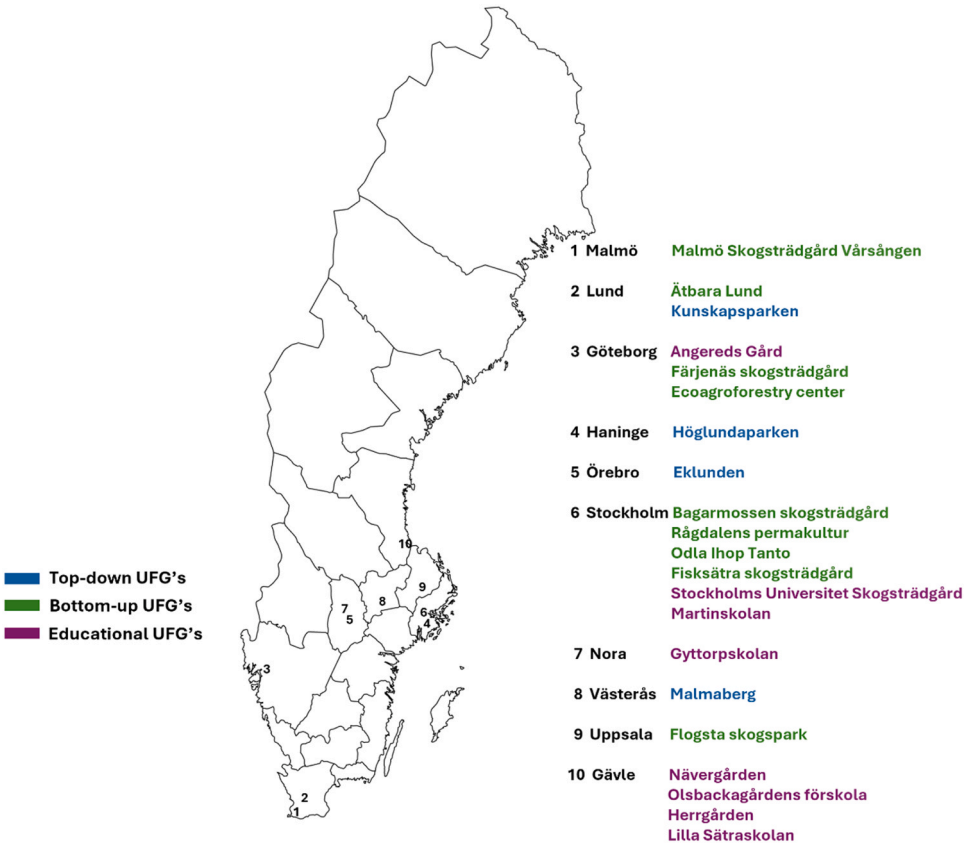

Fig. 3. Map of Sweden with national and counties borders illustrating the distribution of urban and peri-urban forest gardens identified in the study. Top-down FGs are indicated in blue color, bottom-up FGs in green color and educational FGs in purple color.

The category by us named "top-down forest gardens" were initiated by municipalities and located in public spaces such as parks or derelict green corners that have been converted and redesigned into edible green areas. The four identified UFGs were created in the period 2022–2023, thereby representing a novelty both considering history and origin in the Swedish forest gardening movement. Due to their recent establishment, few activities have been carried out at the time of our investigation. According to their initiators all UFGs had multiple purposes, for example they were all open for visits and accessible for all inhabitants for free picking of fruits and nuts. The purpose was also to connect citizens to local food production besides the provisioning of aesthetic qualities. Västerås municipality, for instance, introduced flower beds in the forest

Fig. 4. Examples of urban forest gardens visited during the study. A) Bottom-up FG, Bagarmossen skogsträdgård, Stockholm. B). Top-down FG, Eklunden park, Örebro. C) Educational FG, Gyttorpskolan, Nora.

garden in order to enhance the aesthetic qualities. In 2023, the Västerås municipality received a national award among municipal city gardeners (Fig. 4).

3.2. Motivations and drivers of UFGs

We have identified that urban forest gardening in Sweden followed three "foundation waves". Associations and/or informal groups of citizens started in 2009 with what in this study is named bottom up UFGs. Forest gardening firstly originated in a rural context at Holma Folk High School, a permaculture centre located close to the town of Höör, south Sweden. Practitioners who attended courses in this educational centre funded the first community-driven forest gardens in urban contexts. Over time, other educational centres emerged and contributed to mainstream UFGs in cities and, successively, in schools. More recently, from 2022 to 2023, also municipalities started to establish "top-down UFGs" in public urban green spaces. In general terms, UFGs have constantly increased over the last 15 years, showing an exponential growth after 2020, mainly due to the occurrence of educational forest gardens and, secondly, to the top-down ones (Fig. 5).

According to respondents, urban forest gardening in Sweden started as an "underground movement" run by volunteers inspired by permaculture principles and ethics. The interest in producing and consuming healthy food coupled with concerns on the development of sustainable lifestyles and city designs were the major drivers. These ideas, in turn, were spread and seen as fruitful in educational contexts and eventually institutionalized by some municipalities. According to most respondents, a pivotal role in this process was covered by so-called "knowledge hubs".

A total of six knowledge hubs were identified by the interviews. They had heterogeneous composition ranging from adult education centres (2) to universities (2), formal NGO (1), and network of entrepreneurs/professionals/activists (1). Two of them acted at local level only, while the others carry out their activities and have contacts with UFGs not only at local but also at regional and/or national scale. The first one, Holma Folk High School, started its activities in 2004, the latest one, Angereds Gård, in 2018. All of them combine theoretical with practical knowledge, thereby approaching various contexts and actors in a comprehensive manner. These hubs can be defined as innovation brokers that first introduced forest gardening concepts through practical courses, academic programs, applied research, workshops, seminars etc. In addition, they also assisted participants, after finishing an educational event who wanted to apply the knowledge of forest gardening elsewhere, for example by designing, initiating or by technical support (Table 1).

Overall, 77 % of interviewees mentioned knowledge hubs to various extents. Almost half of bottom up UFGs (55 %) practitioners reported that they attended courses and workshops organized by them as well as received technical assistance and advice once their UFG was established. The large majority of educational UFGs (88 %) were initiated because of the drive of knowledge hubs. In 19 % of these cases, they directly intervened in designing and technically assisting along all phases of UFG establishment and management, while in the remaining 69 % they had both an indirect role in providing knowledge and motivation to the initiator of a new UFG and had a direct role in giving technical assistance during the implementation phase. Similarly, 80 % of top-down UFGs were influenced by these actors. For this category, their contribution covered all phases, from the design to the implementation one. Additionally, officials of municipalities reported the relevance of the forest garden handbook released by the Stjärnsund knowledge hub (Weiss & Sjöberg, 2018) This book was seen as a milestone, since forest gardening hereby was perceived to be based on science, and thereby also making the adoption of UFG justifiable for decision makers.

The SNA provided manifold indications on the level of integration among different stakeholders.

The ego-network size of each actor indicated that the most important player was Stjärnsund knowledge hub with 27 % of degree centrality, followed by Holma Folk Highschool knowledge hub (20 %), Municipality of Gävle (16 %), Stockholm University knowledge hub (13 %), Municipality of Stockholm at district level (11 %), and Rågdalens permakultur and Odla Ihop Tanto bottom-up forest gardens (9 %) (Fig. 6).

SNA provided also interesting information about relationships among different actors. Municipalities acted as decision makers who provided land and other support and collaborated thereby often with grassroot organizations and with knowledge hubs who provided technical advice and support. In both cases, they had a strong level of interaction, with an average value of 3 (3–4 times/year collaboration). A similar pattern could be shown for grassroot organizations, although the strength of collaboration with knowledge hubs was lower (average score of 2-yearly basis collaboration) with respect to that one of municipalities. Educational actors (schools and adult educational centers) collaborated firstly with knowledge hubs and, secondly, with

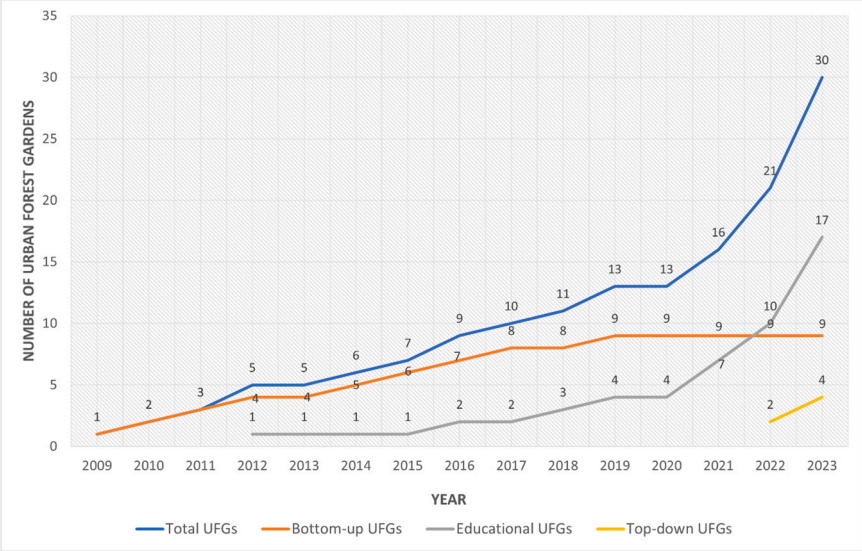

Fig. 5. Chart showing Swedish UFGs' foundation over time. The first forest garden was recorded in Stockholm in 2009 (Rågdalens permakultur, bottom-up FG). In 2012, the first educational forest garden was founded at the campus of the University of Stockholm. Top-down forest gardens firstly appeared in 2022 (Kunskapsparken, Lund; Eklunden, Örebro).

Table 1
Resuming features of knowledge hubs. The "starting year" column indicates the time in which the knowledge hub began to organize courses or other training activities related to forest gardening. The "scale of activity" column describes whether the knowledge hub's activity was restricted to the FG's geographically situated in the same municipality, in the same county or in different counties all over the country.

Name	Location	Starting year	Typology	Scale of activity
Holma Folk Highschool	Höör	2004	Education center	Local/regional/national
Stjärnsund	Stjärnsund	2011	Professional	Local/regional/national
Stockholm University	Stockholm	2012	University	Local/national
Svenska Naturskyddsföreningen	Nora	2014	NGO	Local
Jönköping University	Jönköping	2016	University	Local
Angereds Gård	Göteborg	2018	Education center	Local/regional

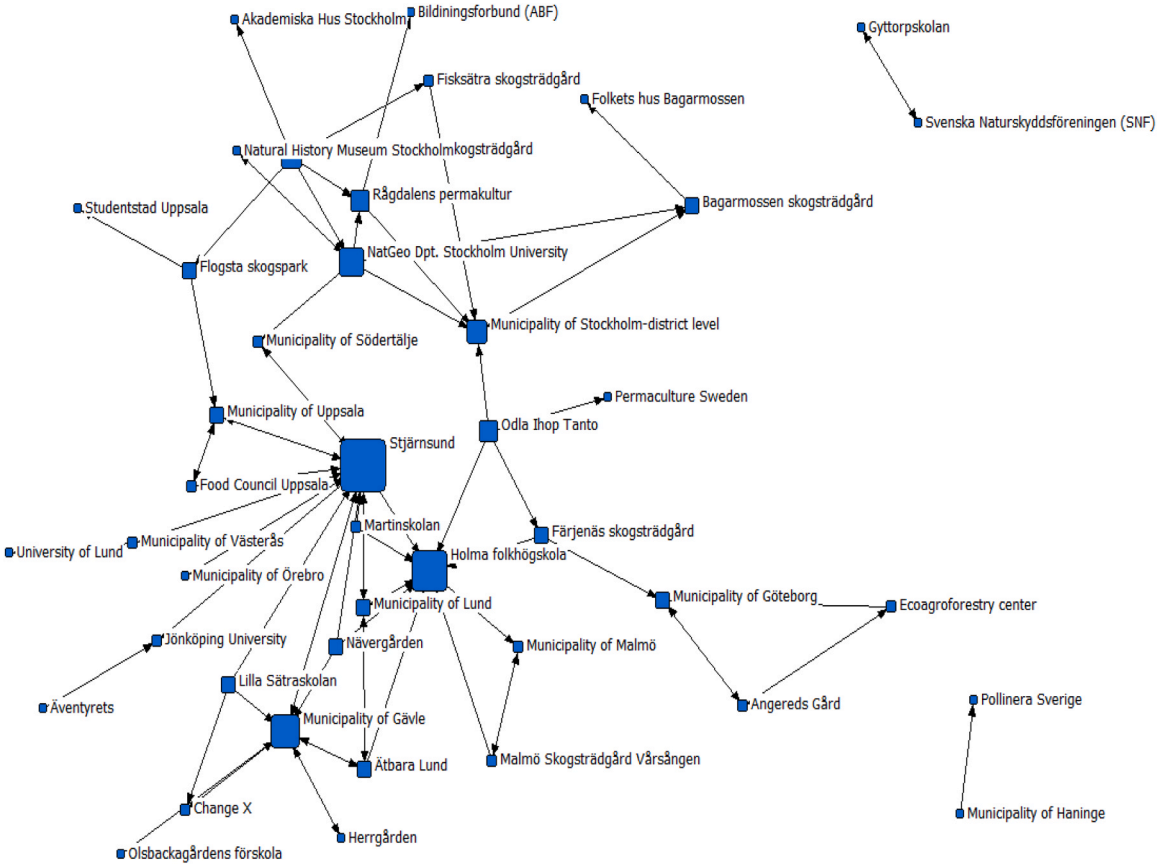

Fig. 6. The sociogram illustrates the social network of urban forest gardening community. The size of blue squares is directly proportional to the actors' centrality.

municipalities. The average strength was 3 (3/4 times per year) and 2 (once per year), respectively. Knowledge hubs had a high number of interactions compared with the other three categories of actors. They tended to have more connections with municipalities (10 ties), compared with educational actors (7 ties) and grassroot organizations (6 ties). This preference is reflected also in the strength of the tie, 3 on average with municipalities and 2 with the other actors. Actors belonging to the same typology tended to not collaborate with each other. Municipalities and educational actors did not indicate any interactions with their homologues, grassroot organizations and knowledge hubs only one and two collaborations, respectively. In both cases they have weak contacts (average score 1-occasional) (Table 2).

Table 2
Social network analysis. Relationship between typology of actors in the Swedish urban forest gardening community. The number of ties is directly proportional to the centrality of the actor within the network. The average strength indicates the collaboration/interaction between two typologies of actors: 1 (less than once per year), 2 (2–3 times per year), 3 (every month), and 4 (every week).

Actor typology	Municipality		Grass root organization		Educational actor		Knowledge hub		Other actor	
	N. ties	Av. strenght	N. ties	Av. strenght	N. ties	Av. strenght	N. ties	Av. strenght	N. ties	Av. strenght
Municipality	0	0	9	3	5	3	10	3	3	3
Practitioner	9	3	1	1	3	1	6	2	3	3
Educational actor	5	3	3	1	0	0	7	2	3	2
Knowledge hub	10	3	6	2	7	2	2	1	1	2

3.3. Perceptions of ecosystem services and the role of UFGs in urban planning

On average, respondents assigned high values to agroforestry in urban and peri-urban areas. On a scale of 1–10, the overall score was 8.4/10.

In general terms interviewees underlined the relevance of cultural services (8.7/10) compared to regulating (7.9/10) and, especially, compared to provisioning ones (6.5/10).

Further, each category was explored in more detail. Regarding the category cultural services, the following options of values were ranked the highest "Educational and cultural value" scored (8.9/10), followed by "Recreation and aesthetic enjoyment" (8.8/10) and "Promotion of physical activities and psycho-physical well-being" (8.5/10) (Table 3).

Within the category regulating services, "Microclimate regulation and heat islands mitigation" obtained the highest score (8.5/10) followed by "Preservation of natural habitat, conservation of genetic diversity" (8.2/10), "Contribution to CO2 absorption" (8.0/10), "Erosion control, wind control and water cycle regulation" (7.8/10), "Soil conservation and improvement" (7.6/10), and "Filtering/accumulation of pollutants and reduction of pollution" (7.5/10).

Regarding the provisioning services, they received the lowest scores, with "Cultivation of domesticated and wild plants for production of food, energy and materials" (7.1/10) and "Cultivation of domesticated and wild plants for reared animal nutrition" (6.0/10).

About all ecosystem services from UFGs, the groups of respondent's schoolteachers and adult educators assigned the highest scores, 8.6/10 on average, compared to practitioners and knowledge hubs (8.1/10 and 8.0/10) and officials (7.0/10).

The non-parametric Kruskal-Wallis test (α=0.05) showed statistically significant differences among the four groups of actors for the following six ecosystem services: filtering/accumulation of pollutants ($p = 0.011$), erosion control ($p = 0.035$), carbon dioxide (CO_2) absorption ($p = 0.014$), microclimate regulation ($p = 0.019$), value of recreation ($p = 0.033$). The Dunn's test showed statistically significant differences in the pairwise comparison between groups for the following ecosystem services: filtering/accumulation of pollutants between practitioners and municipal officials (p = 0.005) and schoolteachers and municipal officials (p = 0.005); erosion control between practitioners and municipal officials (p = 0.005); carbon dioxide (CO2) absorption between practitioners and municipal officials (p = 0.002); microclimate regulation between practitioners and municipal officials (p = 0.003); and value of recreation between practitioners and municipal officials (p = 0.008). Therefore, differences of opinion are particularly evident between two groups: the practitioners on the one hand and the municipal officials on the other.

The open-ended questions regarding relationships, perspectives, and challenges of UFGs with city administration, planning and existing policies provided a heterogeneous picture among actors.

The totality of bottom-up UFGs respondents believed that their forest garden could be a model to influence decision makers in including forest gardening into city policies. To increase the adoption of UFGs, respondents suggested a need for a dedicated budget to urban agroforestry, both in terms of direct funding to bottom-up experiences and employment of people for managing public forest gardening sites. In relation to this, they also perceived a need to fill a knowledge gap regarding the lack of skilled labor. Interviewees stated that decision makers were not enough aware of the benefits of UFGs. The latter was confirmed by the relatively low percentage of respondents (56 %) who were satisfied with the municipality. Most frequent issues regarded the request for financial support (44 %), followed by problems with the agreement to use the land (33 %) both in terms of duration of the contract and flexibility of some rules (e.g., permission to plant trees, accessibility) and request of support to practically manage the site (22 %). Eventually, one third of them considered more connections with other categories of actors, particularly schools and marginalized groups

Table 3
Scores of ecosystems services provided by UFGs assigned by interviewed stakeholders. The lowest value (4.3/10) was given to food production for animals by officials of municipality. The highest score was assigned to recreation and aesthetic enjoyment (9.4./10) by educational actors.

Actor typology	Provisioning services				Regulating services										Cultural services							
	Cultivation of plants for production of food, energy and materials		Reared animals for nutrition		Filtering/ accumulation of pollutants and reduction of pollution		Erosion control, wind control and water cycle regulation		Preservation of natural habitat, conservation of genetic diversity		Soil conservation and improvement		Contribution to CO2 absorption		Microclimate regulation and heat islands mitigation		Value of recreation and aesthetic enjoyment		Promotion of physical activities and psycho-physical well-being		Educational and cultural value	
	Mean	Stand. Dev.	Mean	Stand. Dev.	Mean	Stand. Dev.	Mean	Stand. Dev.	Mean	Stand. Dev.	Mean	Stand. Dev.	Mean	Stand. Dev.	Mean	Stand. Dev.	Mean	Stand. Dev.	Mean	Stand. Dev.	Mean	Stand. Dev.
Practitioner	6,7	0441	5,9	3504	7,9	1787	8,4	1658	8,3	1202	8,2	1691	8,7	0707	8,9	0333	8,8	0667	8,2	1364	8,8	0441
Official	6,2	1557	4,3	2379	5,5	2393	6,5	2646	7,9	2193	6,1	3204	6,9	2314	7,8	2179	8,4	0124	8,3	2015	8,7	1557
Educational actor	7,9	1134	7,7	2582	8,9	2268	8,7	1751	8,4	3047	8,0	3215	8,6	1813	9,0	1265	9,4	0976	8,7	1890	9,4	1134
Knowledge hub	7,6	1380	6,3	2812	7,9	2340	7,6	2299	8,0	1528	8,1	1773	7,9	1574	8,3	1380	8,6	1397	8,9	1215	8,7	1380
TOTAL	**7,1**		**6,0**		**7,5**		**7,8**		**8,2**		**7,6**		**8,0**		**8,5**		**8,8**		**8,5**		**8,9**	

such as disabled people and immigrants as important and that this was enabled by UFGs in public urban green spaces.

According to all schoolteachers, forest gardens may contribute to promoting agroforestry in urban policies thanks to their didactical value, especially by forming a new generation of citizens and decision makers who will have, in the next future, a positive attitude towards agroforestry and urban green policies. 50 % of the respondents evidenced that signs of increased awareness had already been observed in behavioral changes of parents of the pupils and people living about the schools. The relation with the municipality consisted in direct funding for the activities related to the forest garden (67 %). It is also worth mentioning that the large majority of these UFGs (13 out of 18) was located in the city of Gävle, where the municipality initiated them and provided the funds for their creation through the support of an international NGO. In addition, representatives for adult educational forest gardens underlined the potential influence on decision makers during their visits to the site. They believed that the visiting decision makers, such as planners, might transfer this model of land use to urban or regional planning scale.

In the S.W.O.T. analysis conducted with officials of municipalities, positive and negative effects of introducing agroforestry in urban planning were highlighted. Their considerations included the creation of single agroforestry-oriented interventions such as forest gardens in public urban green spaces as well as more general actions aiming at making the cities' green infrastructure more edible through the integration of perennial crops. In this sense, the city of Södertälje municipality elaborated a city food strategy (Södertälje food strategy, 2018) and the Skarpnäcks district in Stockholm city made an inventory of edible trees in the green plan. Around 50 % of the responding officials indicated the "relation to nature", "community engagement", and "involvement of different municipal offices and local politicians" as the most important strengths of including agroforestry in urban policies. 25 % mentioned "food production" and "biodiversity conservation". The most relevant weaknesses were "continuity of funds", indicated by 60 % of respondents, followed by "impermanence of officials coordinating agroforestry actions" and "lack of skilled labor to manage agroforestry", 25 % and 17 % respectively. Especially forest gardens in public parks were considered the best opportunity as "a model to promote permaculture and agroforestry in the city" as well as "to intensify collaboration among actors". Major risks were related to the exploitation of new land and lack of support from decision makers (Fig. 7).

Based on the interviews, knowledge hubs gave priority, in general terms, to the collaboration among different stakeholders to create an enabling environment for spreading agroforestry in urban and peri-urban areas. The circulation of information, especially among decision makers and key officials interested in agroforestry – e.g., the sharing of best practices and training opportunities – was considered key factor in this regard. In addition, municipalities should dedicate specific budgets

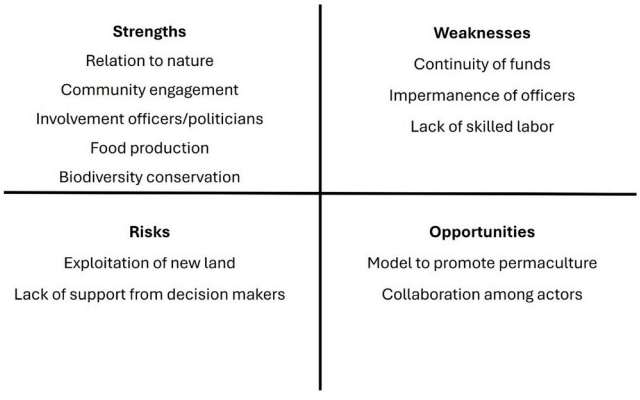

Fig. 7. S.W.O.T. analysis done by the officials of municipalities regarding positive and negative effects of introducing agroforestry in urban planning.

to both making urban green infrastructure more edible and raising awareness among citizens through direct funding to grassroot movements who implement forest gardening, participative processes, and by supporting harvesting days and/or festivals and similar events. Edible green infrastructure with focus on agroforestry should be kept simple, for example by reducing the multi-layer model to two-layer models (one tree layer and one bush layer) to overcome constraints related to management and skilled labor. Moreover, particular attention should be paid also to educational forest gardens in order to train new generations to a different relation to food production and nature. Eventually, knowledge hubs envisioned the improvement of UFGs by increasing their number in public parks, by complementing allotment gardens with community forest gardens for creating more socializing opportunities, and by collaborating with municipality-owned housing companies who might adopt forest gardening in common green spaces.

4. Discussion

Our study showed that the numbers of UFGs have increasingly grown in Sweden since 2009 and this raising trend follows a similar tendency in temperate regions over the last decades (Albrecht and Wiek, 2021; Allen and Mason, 2021; Moereels et al., 2024). Our inventory highlighted that seventeen out of thirty UFGs were located in the three major urban regions Stockholm, Göteborg and Malmö-Lund. The exception was the location of thirteen UFGs in the city Gävle (mid-size city), all of them were part of the same project, established at preschools and primary schools. Since the population is growing in these major urban areas in Sweden (SCB, 2025), UFGs might be under pressure and their existence compete with the development of new housing areas as well as with other more conventional green spaces (Coffey et al., 2021).

Similarly to other studies, the inventoried forest gardens offered several different activities. In particular, the forest gardens in our study all shared the possibility for people to hang out and freely harvest fruits and vegetables. Educational activities both for children in schools and for adults, theme days, courses and workshops in permaculture were carried out in the majority of UFGs (Allen and Mason, 2021; Albrecht and Wiek, 2021; Riolo, 2019). This enhanced their social function and the prominence of cultural ESs as compared to regulating and provisioning ones, which was confirmed by the high scores that stakeholders assigned to educational, aesthetics and psycho-physical well-being functions associated to UFGs.

There are seemingly contradictory reasons for the creation of these gardens. Respondents in our study stressed food production as one of the main reasons to start or get involved in forest gardening but at the same time mentioned the social, health and educational aspects of UFGs. Similar contradiction can be found also in other studies in which the importance of food security has been emphasized even though little food is produced (Clark and Nicholas, 2013, Albrecht and Wiek, 2021; Allen and Mason, 2021, Moereels et al., 2024, Riolo, 2019). Public harvesting days organized by bottom-up forest gardens, food festivals suggested by knowledge hubs and food-related activities in schools may overcome this dichotomy, thus linking food production to community engagement.

Indeed, fruits, nuts and vegetables harvested in the forest gardens are appreciated crops in UFGs in Sweden. Calories and nutrients from such gardens could be sufficient (Nytofte and Henriksen, 2019) but these values should not be separated from primarily social, cultural and educational aspects.

Educational forest gardens represent a great opportunity in this regard as the production and processing of food is functional to promote ecological literacy (Hammarsten et al., 2019; Almers et al., 2017), thus developing among pupils a sense of connection with natural ecosystems and responsibility for actively preserving life on earth (McBride et al., 2013; O'Brien and Murray, 2007). Similar benefits were provided by bottom-up forest gardens where the creation of social ties among volunteers and citizens frequenting the sites (Riolo, 2019) were effective in

conveying the concept of edible city among citizens.

The raising of educational forest gardens was probably facilitated by the presence, in most Swedish preschools, of methodology resembled of Reggio Emilia (Vallberg Roth and Månsson, 2011), from respondents' own description, however not pronounced as such, but principles and practices match with those of forest gardening.

Top-down UFGs represent a novelty for Swedish cities whose effects in the long term could not be valued because of their recent establishment. In spite of this, Västerås municipality received an award for best city gardening in Sweden already during its first year 2023. Which could indicate the fulfillment of something missing by UFGs. Nonetheless, some open questions arise about their ability in providing comparable social and cultural services comparable with what bottom-up and educational forest gardens could offer, although the top-down forest gardens were created following a participative process aimed at collecting ideas and consensus from local communities. For instance, while the maintenance of bottom-up and educational forest gardens was demanded to the personal effort of volunteers or of schoolteachers together with students, the maintenance of top-down forest gardens was carried out by workers paid by the municipality. Recognizing the significance of bottom-up processes in sustainable development—particularly for fostering innovation and enabling the articulation of alternative environmental values (Seyfang and Smith, 2007)—it is crucial to leverage this form of civic participation. Engaging citizens as co-creators of urban green spaces, through tactical or do-it-yourself (DIY) urbanism (Finn, 2014), offers a valuable mechanism for enhancing the social and cultural ecosystem services associated with urban food gardens (UFGs). Indeed, the balance between municipality-led interventions and grassroot approaches is an open issue, as confirmed also from bottom-up forest gardens side of respondents. Practitioners reported the difficulties of the every-day forest gardens maintenance claiming the support of city's authorities for mowing the grass and providing manure. Fox-Kämper et al. (2018) suggest that the dichotomy between top-down and bottom-up managed models in urban gardening as frequently presented in the international literature should be overcome to a continuum of top down and bottom-up governance approaches. In reviewing diverse community gardens models in Germany and New Zealand, the authors envisage that hybrid models in which bottom-up forest gardens are supported by professionals paid by municipalities were appreciated by all actors involved.

For the bottom up UFGs in Sweden, permaculture showed a pivotal role in both providing theoretical knowledge and inspirational values, as also documented in other urban agroforestry projects (Albrecht and Wiek, 2021; Allen and Mason, 2021). Indeed, interest in forest gardening has emerged in social movements such as in permaculture (McKay, 2011; Ferguson and Lovell, 2014) and in transition town/-transitioning movements (Hopkins, 2008; Vlasov et al., 2018), and from the broader trend of urban agriculture which is in line with our results.

While permaculture provided the technical and ethical base for implementing UFGs, the so-called knowledge hubs were recognized as the most important drivers for concretely turning forest gardening into a well-established movement. Courses on agroforestry and/or permaculture, workshops, events and the release of the forest garden handbook for a Swedish context by Weiss and Sjöberg (2018) have initially trained activists and, in the long term, also a new generation of schoolteachers and officials. Our results indicate they have brought their personal interest in permaculture into new arenas, their respective organizations as professionals. Thereby they have also contributed to institutionalisation of agroforestry as management option for green infrastructures in urban and peri-urban contexts.

This centrality was confirmed in the social network analysis, where knowledge hubs acted as focal points for circulating and sharing information and for providing interconnections among all nodes. Nonetheless, the network showed also some weaknesses. The force position occupied by knowledge hubs has created a sort of "monopoly of knowledge" with homologues actors seldom communicating each other. In particular, municipalities seem to be more dependent of knowledge hubs than the other actors. In fact, as reported by the officials, this implied that knowledge hubs were involved in all phases, from design to implementation of UFGs.

Our study showed, even if only for 15 years, that urban forest gardening has travelled from a grassroot movement to formal educational context to becoming a part of municipalities agenda. As stated by practitioners, schoolteachers and knowledge hubs, UFGs acted as models for inspiring decision makers to actively introduce forest gardening into urban green infrastructures. As community gardens, they have become a way to involve citizens in urban planning to a greater degree (McLain et al., 2012; Riolo, 2019). As educational gardens they created more environmentally literate citizens, thereby contributing to the city's sustainability efforts (Fisher-Maltese et al., 2018). The case of Gävle municipality showed the importance of the synergies among public-private actors to reach a wide impact in terms of number and typology of schools involved, thus indicating a possible pathway for replicating in other cities. According to officials' opinions, top-down forest gardens were created with the aim of bridging multifunctional services of forest gardening in public spaces (Taylor and Lovell, 2021) such as contact with nature, sense of belonging, intergenerational connection and of raising the awareness that urban spaces need a healthier and more environmentally friendly way of producing food.

However, the large-scale integration of forest gardening into city policies requires the removal of the many barriers reported by respondents. In line with Bukowski and Munsell (2018), Riolo (2019), Albrecht and Wiek (2021), and Allen and Mason (2021), practitioners mentioned legal issues on land management and use, financial sustainability, and access to formation and technical training. According to Sartison and Artmann (2020), these criticalities call for the active role of municipalities who could assist grassroots initiatives with financial and material support. A similar pattern may be followed for educational FGs. For officials, financial constraints and continuity of funds may hamper the adoption of agroforestry measures. Stoltz and Schaffer (2018) underlined that low input and low maintenance-models such as forest gardens could suit municipalities with tight budgets. Introducing simplified forest gardens structures with two or three layers and a reduced number of edible species (Björklund et al., 2019), as suggested by knowledge hubs, may also overcome the burden of training the labor employed in the management of this new type of green infrastructure. Additionally, since many Swedish cities faces ethnically based residential segregation (Malmberg et al., 2013), UFGs could contribute to improve the sense of place in underprivileged districts (Stoltz and Schaffer, 2018) by encouraging immigrants to grow crops belonging to their countries of origin. Ultimately, the integration of forest gardening into urban policies may pass from co-design through community and expert engagement and institutional partnerships (Taylor and Lovell, 2021), as argued by knowledge hubs.

The findings of this study highlight the need for further research to deepen our understanding of the drivers and potential of urban food gardens (UFGs) in contributing to urban sustainability in Swedish cities. This research did not examine the factors influencing the geographic distribution of UFGs across the country's three major urban areas. Investigating the reasons behind this concentration could yield insights for promoting UFGs in smaller or less populated regions. In addition, interviews with key stakeholders did not include representatives from UFGs that had ceased operations, due to challenges in identifying contacts and obtaining relevant information. However, examining cases of failure would offer valuable insights into the barriers hindering the establishment and long-term viability of UFGs, and could inform strategies to support future initiatives. Finally, the study did not capture perspectives from individuals not directly involved in UFGs, such as park visitors, parents of participating students, or occasional users. Including these voices could provide a more comprehensive understanding of the perceived benefits and limitations of UFGs among the broader public,

thereby supporting their integration into urban sustainability strategies and policies.

5. Conclusions

The inventory of UFGs in Sweden have highlighted the presence of 30 forest gardens in 10 different cities. Three main types can be categorized, namely bottom-up (initiated by citizens), top-down (initiated by municipalities) and educational (initiated by different actors such as schoolteachers, NGOs and municipalities). Their numbers increased over the last decade, showing that firstly bottom-up FGs were funded in public green spaces, followed by educational and top-down FGs. The study enhanced the centrality of so called "knowledge hubs", actors such as education centers who provide technical support, bring innovation and circulate knowledge. Knowledge hubs have supported grassroot initiatives for implementing FGs in public urban green spaces as well as in various educational contexts and have functioned as a bridge and practical implementation of top-down FGs for municipalities. The growing number of UFGs in urban areas could serve as a model and an entry point to include agroforestry into urban policies. A possible pathway to foster the creation of more edible cities should include all typology of UFGs. Municipalities may support bottom-up forest gardens in removing legal barriers such as land tenure agreements, planting permissions, and in easing volunteers from some maintenance or financial uncertainty. This, in turn, may free the workload and time that could be spent strengthening ties among other bottom-up UFGs, sharing knowledge and experiences, thus supporting a strong grassroot movement. For educational forest gardens, a virtuous model, where officials of school office collaborate with knowledge hubs and schools, may be the key for wide spreading in Swedish schools. The stakeholders engaged in the study highlighted the prominence of cultural ecosystem services provided by UFGs. Their impact may be improved by involving new typologies of users such as marginalized groups and disabled people. Top-down FGs are newly emerging as forest garden typology and need to pass from dispersed experiences to a more organized movement. Hence, more knowledge sharing is required among officials together with more public debate in order to raise interest among local authorities and mitigate, at the same time, possible competition with other land uses using green spaces owned by city housing companies or abandoned green spots. In this way, forest gardening may structurally become part of urban green policies, thus contributing to promote sustainability in Swedish cities.

Author agreement statement

We the undersigned declare that this manuscript is original, has not been published before and is not currently being considered for publication elsewhere.

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

We understand that the Corresponding Author is the sole contact for the Editorial process. He/she is responsible for communicating with the other authors about progress, submissions of revisions and final approval of proofs

CRediT authorship contribution statement

Salbitano Fabio: Writing – review & editing, Writing – original draft, Supervision, Methodology, Conceptualization. **Paletto Alessandro:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis. **Focacci Marco:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **De Meo Isabella:** Writing – review & editing, Writing – original draft, Methodology. **Schaffer Christina:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Marco Focacci reports financial support was provided by University of Florence Department of Agricultural Food Environment and Forestry Sciences and Technologies. Marco Focacci reports a relationship with University of Florence Department of Agricultural Food Environment and Forestry Sciences and Technologies that includes: travel reimbursement. If there are other authors, they 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.2025.128990.

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