SiEUGreen
Sino-European innovative green and smart cities

Sino-European Innovative Green and Smart Cities

Deliverable 1.4

Guidelines for a new interactive impact assessment approaches

Lead Partner: Nordregio
Lead Authors: Carlos Tapia, Luciane Aguiar Borges, Shinan Wang & Linda Randall
Due date: 31/12/2020
Version: 6.0

Co-funded by the Horizon 2020 programme of the European Union

Co-funded by the Chinese Ministry of Science and Technology

The project has received funding from the European Union's Horizon 2020 Research, and Innovation Programme, under Grant Agreement Nº 774233

Co-funded by the Horizon 2020 programme of the European Union

Co-funded by the Chinese Ministry of Science and Technology

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The project has received funding from the European Union's Horizon 2020 Research, and Innovation programme, under grant Agreement N 774233 and from the Chinese Ministry of Science and Technology.

Throughout SiEUGreen's implementation, EU and China will share technologies and experiences, thus contributing to the future developments of UA and urban resilience in both continents.

The project SiEUGreen aspires to enhance the EU-China cooperation in promoting UA for food security, resource efficiency and smart, resilient cities.

The project contributes to the preparation, deployment and evaluation of showcases in 5 selected European and Chinese urban and peri-urban areas: a previous hospital site in Norway, community gardens in Denmark, previously unused municipal areas with dense refugee population in Turkey, big urban community farms in Beijing and new green urban development in Changsha Central China.

A sustainable business model allowing SiEUGreen to live beyond the project period is planned by joining forces of private investors, governmental policy makers, communities of citizens, academia and technology providers.

Co-funded by the Horizon 2020 programme of the European Union
Co-funded by the Chinese Ministry of Science and Technology

Technical References

Project Acronym:	SiEUGreen
Project Title:	Sino-European Innovative Green and Smart Cities
Project Coordinator:	Dr. Sjur Baardsen, NMBU Phone: +4741515562 Email: sjur.baardsen@nmbu.no
Project Duration:	January 2018 - December 2022

Deliverable Nº:	1.4
Dissemination level [1]**:**	PU
Work Package:	WP1
Task:	T 1.3 Assessment of tools to measure the social and economic benefits and costs of UA
Lead beneficiary:	5 - Nordregio
Contributing beneficiar-y (-ies):	1 - NMBU, 7- AARHUS KOMMUNE; 8 – VILABS; 13 - HATAY MUNICIPALITY, 15 - SAMPAS
Due date of deliverable:	31/12/2020
Actual submission date:	09/02/2022

[1] **PU** = Public
PP = Restricted to other programme participants (including the Commission Services)
RE = Restricted to a group specified by the consortium (including the Commission Services)
CO = Confidential, only for members of the consortium (including the Commission Services)

Document History

Version	Date	Author - Beneficiary	Summary of Changes
1.0	07/12/2020	NORDREGIO	Initial Draft
2.0	11/12/2020	NORDREGIO	Revised draft
3.0	30/12/2020	NORDREGIO	Final version submitted
4.0	29/12/2021	NORDREGIO	First resubmission after improvement
5.0	03/02/2022	NORDREGIO	Second resubmission after improvement
6.0	09/02/2022	NORDREGIO	Third resubmission after minor editings

Executive Summary

What is the impact of urban agriculture (UA) on urban sustainability? What are the benefits and costs of UA for urban sustainability? How can we best measure the contribution (or otherwise) of UA to urban sustainability? This report addresses these questions, presenting a novel, indicator-based sustainability assessment tool - the SiEUGreen monitoring framework for UA.

Framework development

The tool provides a holistic account of the contribution of UA to urban sustainability and is structured around four pillars: (i) environmental resilience and resource efficiency; (ii) food security and income generation, (iii) inclusive society and (iv) sustainable urban development. These pillars – conceived as key dimensions or enablers for sustainable urban development – were defined based on the findings of previous SiEUGreen deliverables. They were the starting point for a comprehensive literature review that explores the most relevant benefits and costs of urban agriculture and the potential methods through which they could be measured.

Following the setting of the theoretical frame, the SiEUGreen monitoring framework for UA was operationalised by means of a **performance matrix.** The matrix includes three main components:

- **Impact chains** conceptualise the indicators within the theoretical framework of the model and include three elements: (i) *SiEUGreen Pillars* (the desired outcome, e.g. environmental resilience and resource efficiency, inclusive society); (ii) *Pathways* (actions through which to verify progress towards the desired outcome, e.g. climate regulation, community engagement.), and; (iii) *Specific aspects to monitor* (indicators through which to collect evidence of progress towards the desired outcome, e.g. GHG captured by UA, evidence of social interactions between gardeners).
- **Indicator descriptions** provide information about each indicator, including: name, definition, type of indicator (headline, standard, background), units, data type and origin, utility function (beneficial, detrimental), and complexity.
- **Reference frameworks** place each indicator in its broader sustainability research and practice context, including reference to ecosystem services and the SDGs, as well as the scientific literature.

This process resulted in the identification of 83 indicators across the four pillars. A straightforward scoring methodology was then developed to normalise the various units used to measure each indicator. Maximum and minimum values were defined for each indicator, and, based on these, all indicators were transformed to a-dimensional scores ranging from 0 to 100, where higher scores are preferable to smaller ones.

Framework implementation

Initial testing of the tool took place in 2020 using two gardens from the Taste Aarhus program, Fællesgartneriet Brabrand (Brabrand) and Pier 2. Brabrand, a large garden on the outskirts of the city, was selected due to its role in the SiEUGreen project (testing the solar-driven toilet). Pier 2 was deemed a good candidate for comparison to Brabrand as it is similar with respect to the number and engagement level of members but is located in the centre of the city and provides much smaller plots.

Data was collected from garden managers and planners from Aarhus Municipality using online semi-structured interviews, as well as from garden members through an online survey addressing a range of issues relating to their participation in the garden. This data was complemented by GIS analysis and information about the gardens collected in previous SiEUGreen deliverables. Twenty-four headline performance indicators were selected for the test, six from each pillar. The data was then processed according to the scoring system and presented in a series of individual and comparative plots.

The assessment highlighted the different strengths of the gardens. From an environmental perspective, Pier 2 outperformed Brabrand on five of the six indicators. This is primarily explained by its location in the inner city on previously unutilised land. A similar picture emerges on the urban development pillar – Pier 2 performs better primarily due to its inner-urban location. When it comes to food security and income generation, although Pier 2 does better on the financial indicators, Brabrand performs far better on food security. Members of Brabrand are much more likely to report satisfying all or most of their needs for different products with the food they grow in their garden and are more likely to do this consistently year-to-year. Brabrand also outperforms Pier 2 from a societal inclusion perspective. This is likely a result of the greater amount of time members report spending in the garden.

Further testing of the tool took place in 2021. This included the full assessment process in the case of Turunçlu greenhouse in Hatay Municipality. It also included a comprehensive and interactive process leading up to the application of the tool in a private company (Company X). Unfortunately, it was not possible to complete the assessment of Company X due to data sensitivity concerns. Nevertheless, through the process of developing the assessment tools, the research team were able to determine the adjustments necessary to make the tool responsive to this type of UA initiative.

Conclusion

The SiEUGreen UA monitoring framework for UA is a valuable tool for analysing the contribution of activities to urban sustainability. The tool delivered a comprehensive overview of the sustainability performance of two gardens in Aarhus, Brabrand and Pier 2, as well as Turunçlu greenhouse in Hatay Municipality. The main strengths of the tool include:

- **Comprehensiveness.** Incorporation of the four pillars allows for a multidimensional assessment approach that takes into account the contribution (or otherwise) or UA to all aspects of urban sustainability.
- **Comparability.** The transparent and stable scoring system allows for comparisons between gardens and even between dimensions within a single garden.
- **Flexibility.** The tool incorporates a broad range of indicators within clearly defined pathways allowing the user to adjust the headline indicators according to the specific context (e.g. data availability, policy goals).
- **Multiple applications.** Criteria, processes, and monitoring methods can be determined in consultation with the relevant stakeholders, accommodating perspectives from different groups as appropriate.
- **Alignment with accepted sustainability appraisals**. All indicators are linked to the relevant SDGs and ecosystem services.

Of course, as with any such framework, there are also weaknesses to be considered. Allowing users to adapt the tool to their own specific context means that, in a scenario where the tool becomes widely used, it would be difficult to synthesise all the results in a meaningful way. It is also important to acknowledge that, despite our considerable efforts to assure flexibility and ease of use, the application of the tool does require a certain degree of expertise. Of particular importance is the need for domain-specific knowledge (e.g., knowledge of the UA initiative, familiarity with the urban context in question) to ensure accurate and meaningful interpretation of the results.

Despite these shortcomings, the SiEUGreen monitoring framework for UA is has proved to be a robust tool to support city planners, community garden managers and other decision-makers to understand and communicate the value of UA for sustainable urban development. The framework is also expected to contribute to ongoing academic debates about, among other things, the role of UA in increasing environmental and community resilience, the significance of the various expressions of UA for 'sustainable city making', as well as the challenges surrounding the monitoring and evaluation of sustainability goals by means of indicator-based frameworks.

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Abbreviations

FAO	Food and Agriculture Organisation
GHG	Greenhouse Gas
GIS	Geographic Information System
LCA	Life Cycle Assessment
MDG	Millennium Development Goal
SDG	Sustainable Development Goals
UA	Urban Agriculture

1) Introduction

Urban agriculture (UA) is widely recognised as making a significant contribution to sustainable urban development (Russo & Cirella, 2019) and agri-food sustainability (Caputo et al., 2020). It is a type of urban green space that provides various ecosystem services and can contribute to urban sustainability in a range of ways (Menconi et al., 2020), including reinforcing food security (Edmondson et al., 2020a; Ma et al., 2020), providing health benefits (K. H. Brown & Jameton, 2000; Van Den Berg et al., 2010), enhancing perceived wellbeing (Mayer & Frantz, 2004), and fostering social inclusion (Batitucci et al., 2019). Further, UA can also make a significant contribution to urban regeneration and promote social and other types of innovation (Ghose & Pettygrove, 2014; Sanyé-Mengual et al., 2019).

Alongside these benefits, however, a number of undesirable effects of UA have also been documented. These mostly relate to potential environmental impacts and risks, for example, excessive water consumption (Dalla Marta et al., 2019a), potential contamination of aquatic ecosystems and water quality (Harada et al., 2018), and maintenance concerns (e.g. irrigation, fertilising, weeding, pest control, pruning, and harvesting) (Lee et al., 2019). A number of studies have found problematic concentrations of organic toxins, including microbial contamination, and inorganic pollutants, like pesticides and heavy metals, in plants, soil and irrigation waters (Graefe et al., 2019; Perrin et al., 2014; Taylor & Lovell, 2015a). The literature has seldom addressed social externalities, albeit some studies have pointed out problems such as vandalism (Lee et al., 2019) and green gentrification (Sbicca, 2019).

These undesired effects anticipate trade-offs at various levels, including those between policy goals and sustainability spheres. Zhou et al. (2019) documented trade-offs between economic and social functions and ecological services in the Xi'an metropolitan zone in China. Other studies have proven that the ecological services provided by cultivated land can compensate for the ecological deficit caused by agricultural production (Guo et al., 2019). Of course, it is important to acknowledge that UA is highly contextual and will respond to different social, cultural, geographical and environmental concerns. As such, the trade-offs required may look different in different contexts. One common theme, regardless of context, is the need for reliable and comprehensive evidence on which to base decision making.

Despite growing research attention towards UA, systematic approaches to measuring impacts across different cultural contexts are lacking (Kingsley et al., 2019). Similarly, a structured conceptual analyses of urban sustainability benefits, including its operationalisation, are still scarce (Zasada et al., 2020). The transition toward sustainable urban horticulture practices requires the simultaneous preparation of supportive and compatible spatial development, agricultural and sustainable development policies, and adequate policy implementation and also evaluation tools (Hosseinifarhangi et al., 2019). In particular, there is a need for an integrated evaluation of urban agricultural practices (Perrin et al., 2014).

This report addresses this shortcoming by assessing the impact of UA on urban sustainability using an innovative and interactive assessment approach. The approach is based on key economic, social and environmental indicators that have been developed based on the literature and in dialogue with relevant stakeholders. The assessment tool is multidimensional, including four "pillars" of urban sustainability: 1) Environmental resilience and resource efficiency; 2) Inclusive society; 3) Food security and income generation and; 4) Sustainable urban development. It is designed to accommodate perspectives from different groups, communities and cities and can be fed by multiple data strategies, including interviews, storytelling, focus groups, documents, participant observation, surveys, statistical databases. It enables comparability between gardens according to a set of central dimensions but can also be adapted to a specific local or national context.

The framework has been validated by the partners and stakeholders participating in the SiEUGreen project and tested in two gardens in Aarhus and in Turunçlu greenhouse in Hatay. Following submission of this deliverable, the framework will be made available to other practitioners outside the project through appropriate dissemination activities (e.g., task report and scientific publication).

1.1) The report in the context of the SiEUGreen project

This delivery proposes a means through which to measure the impact of UA on urban sustainability and as such, is an essential outcome of WP1. It builds on the knowledge of the other WP1 deliverables in a range of ways and contributes to the understanding of UA at a project level. The structure for the assessment tool is based on the four pillars used to map the showcases in *D1.1 Maps of quantitative and qualitative data* (land use, food security, resource efficiency and societal inclusion). The extensive literature review on how UA can contribute (or not) to social, economic, environmental and urban sustainability takes as its starting point the comprehensive conceptual framework presented in *D1.2 Baseline study, including key indicators and development of a typology*. The current report is, in many ways, the culmination of the discussion about data that featured in both D1.1 and D1.2. It addresses the need to identify more fine-grained indicators to support the monitoring and evaluation of UA at city level.

D1.5 Engagement Strategies has also made an important contribution to this deliverable. It has inspired critical reflection on how the assessment of costs and benefits of UA may differ between groups, communities and cities depending on their stakes, power, and interests. The participatory process through which the engagement strategies were designed led to the development of relationships that were invaluable when it came to testing the assessment tool in a practical context.

At the SiEUGreen project level, the systematic evaluation of the environmental, societal and economic impact of UA presented in this report contributes to WP3 precisely to *Task 3.3. Benchmarking and impact assessment* and to WP5, *Task 5.2. Development of exploitation and scaling plans for each of the SiEUGreen showcases*. The SiEUGreen monitoring framework for UA introduced in this report has been designed according to the specific objectives and requirements of this task, namely:

- focus on the social and economic effects that are relevant in each area;
- make use of key economic and social indicators;
- engage stakeholders at local and regional levels in the development of evaluation methods (choice of criteria, processes and monitoring methods);
- accommodate perspectives from different groups, communities and cities;
- incorporate multidimensional perspective regarding criteria and scope;
- work incrementally based on existing monitoring and evaluation methods;
- consider aspects related to territorial governance;
- be fed by multiple data strategies, including interviews, storytelling, focus groups, documents, participant observation, surveys, statistical databases, etc.;
- enable comparability according to a set of central dimensions.

The original idea was to apply the framework to different SiEUGreen showcases. Unfortunately, this was not possible due to the delay in implementing technologies in Hatay and Campus Ås, the Covid-19 restrictions that inhibited the activities in Sanyuan Farm in Beijing, and the absence of residents in the Futiancangjun community in Changsha. Given these constraints, the tool was tested on two gardens from the Taste Aarhus program, Fællesgartneriet Brabrand (hereafter referred to as Brabrand) and Pier 2 in 2020. Further testing took place in 2021. This included the complete assessment process in the case of

Turunçlu greenhouse in Hatay Municipality and a comprehensive and interactive process leading up to the application of the tool in a private company (Company X).

1.2) How to read this report

This report is presented in four sections. The first section, **introduction**, has provided a short introduction to the task, contextualising it within the SiEUGreen project. The second section, **framework design**, details the stepwise process through which the analytical tool was developed. This process is depicted in the upper part of Figure 1 and included: 1) deciding on the type of monitoring framework to use; 2) identifying the relevant aspects to monitor; 3) Designing the performance matrix and developing indicators, and 4) defining a scoring system based on the definition of utility functions. Each step is described in detail in a dedicated sub-section. A fifth and final section describes additional adjustments that were made to the tool based on additional testing.

The third section, **framework implementation**, details the steps involved in the practical application of the tool, as depicted in the lower part of Figure 1. The first three sub-sections are based on the application of the tool to the selected cases and include: 1) collecting data based on published references, interviews, questionnaires and GIS analysis; 2) definition of scoring criteria and calculation of scores for individual indicators; 3) visual representation and interpretation of scoring results and 4) guidelines for implementation in other contexts, in the form of step-by-step instructions designed to support others to apply the tool.

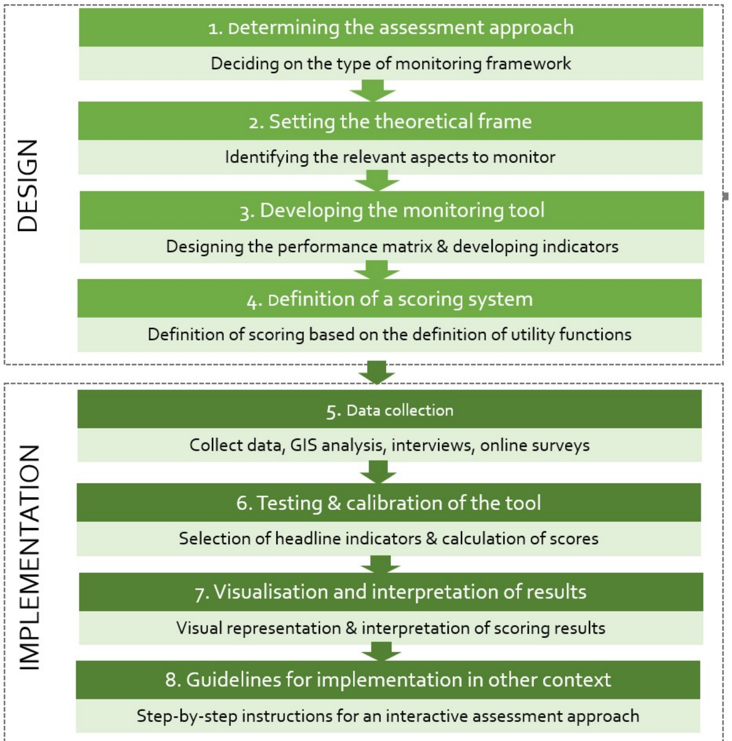


Figure 1: Analytical sequence followed for the development and application of the sustainability evaluation framework

The fourth section, **final considerations**, includes an assessment of the strengths and weaknesses of the tool, based on the implementation in the cases. It closes with some reflections on the implications of the process for future work. The bulk of the report follows the stepwise process of framework design and implementation depicted in Figure 1. This figure appears throughout the report as a guide for the reader.

2) Framework design

2.1) Design criteria

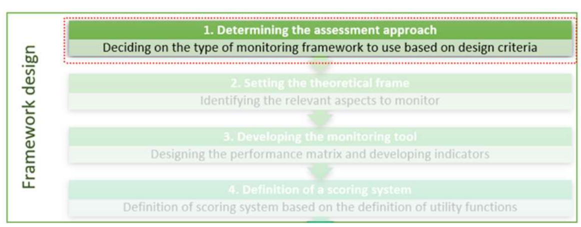
The SiEUGreen monitoring framework for UA is a highly flexible decision support tool for the planning, follow-up, and evaluation of UA and community gardening initiatives. In correspondence with the description of Task 1.3 in the Grant Agreement, the following design criteria were proposed and validated together with partners and stakeholders participating in the SiEUGreen project:

- **Incremental**: The framework is based on mature and established tools defined in the literature to capture, quantify and value the impacts caused by UA. This includes accepted valuation approaches, such as the ecosystem services framework.
- **Systematic**: The SiEUGreen framework enables a systematic assessment of the implications of UA initiatives for sustainable urban development and planning. This essentially implies adopting a comprehensive, consistent and robust evaluation procedure.
- **Multidimensional**: Rather than focusing on one specific aspect or impact domain, our approach provides a comprehensive overview of the most relevant components of sustainable development. We focus on all the sustainability dimensions that, according to the insights gained in other tasks of the SiEUGreen project and previous studies, can be affected by UA initiatives in multiple ways.
- **Multi-directional**: The approach considers not only beneficial impacts but also potentially detrimental or negative consequences of community gardening initiatives on urban sustainability priorities.
- **Multi-scale**: Though it has been primarily designed with the individual garden level in mind, it is possible to apply the framework at various scales, ranging from a single plot to the whole city.
- **Indicator-based**: The framework consists of a comprehensive and well-documented set of indicators that measure the various implications of UA initiatives on urban sustainability. The indicators have been proposed by adopting a flexible practice-oriented perspective. This implies that they can be adapted to the local setting and reflect the different interests or perspectives of the end-users.
- **Data-driven**: The data framework takes into consideration data requirements in terms of availability, complexity and accuracy. This ensures the overall comparability

of the evaluations while at the same time providing enough flexibility to accommodate various perspectives, interests and skill levels among potential users.

- **Multi-purpose**: The framework aims to support local governance processes for increased sustainable urban development. It has been primarily conceived and designed for monitoring and evaluation purposes. However, the approach can also be used to support decision making processes at other stages of the policy cycle, such as problem identification, agenda-setting or iterative planning revision. Thus, the tool may have manifold applications, ranging for strategic urban planning and urban design, to optimisation and improvement of community gardening initiatives by the communities participating in the schemes.
- **Multi-user**: The target groups for this tool are academics, city planners (or other relevant local government actors) and those who run community gardens. All the design elements mentioned above have been carefully considered with the aim of increasing the attractiveness and usability of the tool among a wide variety of stakeholders, ranging from researchers and urban planners to the managers of community gardens. Usability is enabled through detailed documentation and an incremental design that accounts for the various degrees of expertise among participants.
- **Aligned:** The framework is anchored in existing sustainability appraisals. In particular, it is aligned to the Sustainable Development Goals (SDGs).

2.2) Determining the assessment approach



Prevalent production and consumption patterns in cities and urban systems are paired with a wide range of environmental, social and health externalities, such as pollution, traffic congestion, as well as social, cultural, political, spatial and environmental forms of inequality and segregation (UN General Assembly, 2016). Against this framework, urban sustainability quickly made it through the policy agendas and is today promoted as one of the key areas for action towards the accomplishment of the sustainability agenda worldwide. The SDGs address urban sustainability challenges through Goal 11 – Sustainable cities and communities.

Significant efforts have also been invested in the adaptation of the entire SDG framework beyond Goal 11 to the local level (Klopp & Petretta, 2017, 2017; OECD, 2020; Zinkernagel et al., 2018).

Urban sustainability measurement attracted significant research attention following the introduction of the concept of sustainable development in the 1980s (Alberti & others, 1996). A vast range of metrics and indicators have been used in an attempt to evaluate the sustainability of urban systems (see, e.g. Verma & Raghubanshi, 2018, for a relatively recent review). In terms of approaches, researchers, planners and sustainability experts have advocated the adoption of systemic (Frank et al., 2017), nested (Mori & Christodoulou, 2012) and multidimensional perspectives for the evaluation of the sustainability performance of urban development processes (Klopp & Petretta, 2017). However, urban sustainability frameworks have also attracted criticism for legitimising green fixes that contribute to the externalisation of impacts rather than to their reduction in absolute terms (Borges et al., 2020; Krähmer, 2020)

From a methodological standpoint, most of these assessments stem from two broad families of performance evaluation methods. The first one includes sustainability indicators, and derived products such as multidimensional indices, dashboards, scoring systems and benchmarks which evaluate cities and urban solutions against an array of sustainability criteria (Huang et al., 2015). The second category builds on metrics adapted from environmental sciences like urban metabolism (Kennedy et al., 2011). Whereas the first approach places emphasis on the multidimensional nature of decision-making processes, often involving trade-offs between spheres or priorities, the second strand emphasises comprehensiveness and precision by looking at cities as complex systems. Notably, both approaches can be used to analyse a set of possible options such as investment or design alternatives (i.e. supporting ex-ante decision-making processes) or to focus on the evaluation of already implemented solutions.

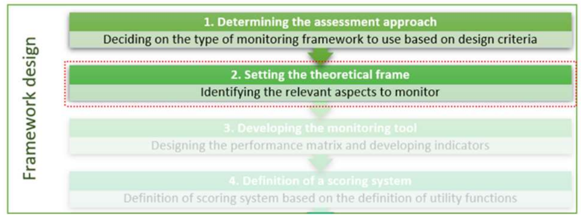
The advantage of indicator-based approaches to urban sustainability analysis is their ability to simplify otherwise complex information. Scoreboards, rankings and similar tools visualise evaluation results in a manner that can be understood, even by those lacking specialised knowledge. Indicator-based approaches may facilitate public participation in sustainable urban design while at the same time providing a solid foundation for decision-making at all governance levels (Hiremath et al., 2013). Used alone or in combination with 'harder' metrics pertaining to sustainability science, indicators and frameworks for sustainable development contribute to the design of sustainable systems that integrate urban development and environment protection (Singh et al., 2009).

The contribution of UA and community gardening to urban sustainability has also been assessed through a range of other methods and tools. These include in-depth interviews, participant observation (Taylor & Lovell, 2015a), surveys (Lee et al., 2019; Menconi et al., 2020; Mourão et al., 2019a; Zasada et al., 2019), landscape metrics (Anderson et al., 2019; Zhao & Zhang, 2019), life cycle assessment (Fisher & Karunanithi, 2014; He et al., 2016; Pérez-Neira & Grollmus-Venegas, 2018), footprint metrics (Guo et al., 2019; Martinez et al., 2018), and agricultural monitoring (Perrin et al., 2014), among others. Despite growing research attention towards UA, systematic frameworks and approaches to the measurement of impacts across different cultural contexts are lacking (Kingsley et al., 2019). Similarly, a structured conceptual analyses of urban sustainability benefits, including its operationalisation, are still scarce (Zasada et al., 2020).

In this report, we present a novel indicator-based sustainability assessment framework for UA that builds on agreed frameworks at global level. In particular, our approach is consistent with relevant sustainability appraisals produced through consensus-generation processes, remarkably with the SDG framework (Hák et al., 2016). Our evaluation scheme is also rooted in scientifically-sound concepts like the notion of ecosystem services (Costanza et al., 1997). With this, we aim at an evaluation framework that is scientifically robust while at the same time being relevant for urban management and accessible to a broad range of potential users. Simplicity and transparency are further assured through the utilisation of straightforward reporting tools that elicit the relations between the various dimensions considered in the analysis.

Based on these features, the SiEUGreen monitoring framework for UA is intended to support city planners, managers of community garden initiatives and other decision-makers in the process of understanding and communicating the value-added of community gardening as a tool for sustainable urban development. The framework is also expected to contribute to on-going academic debates about, among other things, the role of community gardening for increased environmental and community resilience, the significance of the various expressions of urban innovation for 'sustainable city making', as well as the challenges surrounding the monitoring and evaluation of sustainability goals by means of indicator-based evaluations.

2.3) Setting the theoretical frame



This section sets the theoretical frame for the tool based on a systematic review of the relevant literature on the key aspects to be monitored. As noted in the introduction, the tool is structured around the four pillars of UA identified in previous deliverables (Borges et al., 2018; Borges et al., 2019). As such, the literature review is also structured according to these themes. Relevant sources were identified from within the researchers' existing UA library (over 700 sources), as well as though literature searches conducted using Scopus, ScienceDirect and Google Scholar. The main aim was to identify the most relevant benefits and costs related to each pillar, to consider how these aspects are currently understood within the scientific community, and to explore potential methods through which they could be measured.

2.3.1) Environmental resilience and resource efficiency

Cities face many environmental challenges, including, but not limited to, air and water quality issues, lack of sufficient green space, excess heat capture, polluted stormwater runoff and lack of ecological biodiversity. UA presents a range of environmental benefits and risks. On the positive side, sustainable agricultural practices in urban and peri-urban settings may significantly reduce environmental impacts in relation to traditional agriculture. Previous studies have shown that organic farming may halve energy consumption (55%) and global warming potential (65%) in relation to conventional agricultural practices (Caputo et al., 2020; Kulak et al., 2013). Other environmental benefits of UA include biodiversity conservation, water infiltration, supporting healthy soils, waste recycling, contributions toward air and water quality, and amelioration of heat island effects (Hallett et al., 2016; Nicholls et al., 2020; Nowak et al., 2006). On the negative side, potentially contaminated soil and water, as well as chemical fertiliser and animal manure, can negatively impact the environment and pose health problems to the human being. The environmental impacts of UA which have been identified to date centre on the following aspects:

UA can contribute to **climate regulation** by reducing the net discharge of CO_2, one of the greenhouse gases contributing to global warming, through plants and trees capture of CO_2. The captive capacity is at its highest in the growth phase of vegetation. Through agricultural activities in cities, urban ecosystems are kept continuously in their "primary production phase". This means that much more CO_2 per surface area is captured than in natural systems like tropical forests. UA reduces greenhouse gasses by shortening the distance between production and consumption (so-called "food miles") (Hallett et al., 2016) and helps to purify and improve air quality as the vegetation uptake gaseous air pollutants and facilitate deposition of particles. UA can also help ameliorate the urban heat island effect by modifying the land surface at the local level, i.e., rooftop gardens.

UA's impact on **energy consumption** is multifaceted. On the one hand, integrating agriculture into existing buildings as zero-acreage farming, including rooftop gardens and greenhouses, edible green walls, and indoor farming operations, can provide significant energy savings for buildings and increase the energy efficiency of buildings. For example, it is estimated that installing a rooftop garden could reduce the annual energy consumption of buildings by 1-15% (Wong et al., 2003). On the other hand, high-intensity greenhouse growing may result in additional energy consumption. Energy is used primarily for electricity (for artificial lighting, irrigation pumps and other equipment) and as heat for greenhouse climate control (Weidner & Yang, 2020).

UA can have a positive effect on **biodiversity conservation**. UA presents a unique opportunity to utilise vacant or idle land throughout the city, providing habitats for wildlife. With variation in vegetation cover, diversity, and structure, UA can exhibit high levels of biodiversity that often exceed the contribution made by other green areas in the city (Lin et al., 2015). Empirical studies also suggest that UA contributes to the diversity of animal species, with the diversity of the spider and beetle populations found to be greater in UA plots than in remnant forests or traditional flower beds (Clucas et al., 2018).

Sustainable urban farming contributes to **sustainable soil management** by protecting the soil and increasing its productivity. Soil should be enriched with natural fertilisers such as organic waste and green manure rather than chemical fertilisers. Amendments made from organic materials can reduce soil compaction and enhance stormwater infiltration (Taylor & Lovell, 2014). They can also improve soil quality in previously degraded vacant lots, provide nutrients, and increase crop yield in urban gardens (Beniston et al., 2016). Rotating the type of crop grown every 3-6 years or cultivating multiple agricultural products in the land can also help to keep nutrients in the soil and improve the soil quality (Tuğrul, 2019).

Agricultural activities in cities can indirectly improve **urban water management** because green spaces with permeable land surfaces allow rainwater and runoff to drain through the soil. This mitigates against the growing risk of floods and landslides caused by the increased volumes of runoff from non-permeable surfaces in cities (e.g., streets, roofs, and car parks). The need for costly stormwater sewers and drainage can be minimised when enough permeable surfaces are available. To invest in UA, therefore, can be just as effective as developing a network of channels and drains. The direct use of recovered wastewater for food production in cities can also improve the efficiency of water use – especially important in countries with limited water resources (Dalla Marta et al., 2019b; Pollard et al., 2018). Green infrastructure can decrease the volumes of pollutants and runoff entering the waterways and relieve the strain on wastewater infrastructure.

Recycling urban waste, in particular organic waste, is commonly cited as one of the greatest environmental benefits of UA. The waste generated from crop farming (dried vegetables) is recycled and used as mulch and compost to enrich the soil. Waste generated from livestock farming, such as cow and chicken manure, is the main source of fertiliser for vegetable farming. There is, however, the **potential for contamination** as repeated applications of an excessive amount of compost can result in soil phosphorus accumulation and negatively impact water quality (Rudisill et al., 2015). Moreover, if organic fertilisers, especially those contain animal manures, are not composted properly before application, fruits and vegetables can be contaminated with pathogens that may cause gastrointestinal illness in humans (Beuchat, 2006). UA can also play an important role in reducing the amount of waste as it can help to reduce the need for food packaging (Hallett et al., 2016).

Existing and emerging **technological innovations** have the potential to solve many of the global challenges connected to the development of sustainable urban food, water, waste, and energy systems. The technologies to be used under the SiEUGreen project cover a wide range of water management, energy-saving, and planting techniques. These technologies can be categorised into three groups: *green technologies*, *blue technologies*, and *yellow technologies* (European Commission, 2017). Green technologies concern soil-based traditional plant growing, water-based hydroponic culture (soilless) and aquaponics (fish and plant), paper-based plant-growing technology, greenhouse technology. Blue technologies include water and waste management, production of fertiliser and soil amendment from waste, resource recycling. Yellow technologies encompass biogas production from waste resources, seasonal solar storage, combined heat and power, and photovoltaic generation of electricity.

2.3.2) Food security and income generation

According to the definition agreed at the 1996 World Food Summit, food security refers to a situation "when all people at all times have physical, economic and social access to a sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO, 1996). Even if some works have questioned the role of UA as a successful food security strategy (Badami & Ramankutty, 2015; Crush et al., 2017; J. Davies et al., 2020; Zezza & Tasciotti, 2010a), most studies have emphasised its contribution to ensuring food security at the local level. In particular, UA can contribute to securing sufficient caloric intake, dietary diversity, and improving nutritional outcomes in the Global South (Chiappe Hernández, 2019a; Khumalo & Sibanda, 2019a; Poulsen et al., 2015a; Moucheraud et al., 2019a; Tasciotti & Wagner, 2015a). Several studies have also documented the important contribution made by food allotments to the fruit and vegetable diet of participants in community gardening initiatives in cities located in the Global North, particularly in low-income neighbourhoods (Edmondson et al., 2020a; Gregory et al., 2016a).

Food production in urban and peri-urban areas has significant potential to satisfy local food demand as well as having considerable growth potential worldwide (Nicholls et al., 2020). In a case study in Leicester (UK), Edmonson et al. (2020a) estimated an annual city-wide allotment production equivalent to feeding >8500 people. In Northern Italy, Sanyé-Mengual et al. (2018a) determined that an average family garden of 30.6 m^2 and 21 crop cycles could satisfy the food requirements of between 1 and 2 members of the household. Hara et al. (2018) estimated that communal gardens could feed between 50 thousand and 3.4 million people per year in Osaka, and between 1.7 thousand and 0.55 million people per year in New York City, depending on the share of vacant space allocated to community gardening initiatives. In the city of Havana, Cuba, Säumel et al. (2019) have documented yields of up to 20 kg of fresh vegetables per square meter. This is ten times the size of the average harvest of small-scale mixed-stands agriculture in the country (Säumel et al., 2019). This implies that more than half of the food consumed in the city is grown organically on-site. However, such promising outlooks for UA are not unanimous. In areas such as Southern Africa, urban food production is not particularly significant in most communities, few of which manage to capitalise on these activities to increase food security nor generate income (Crush et al., 2017).

However, the contribution that UA can make to food security goes beyond the quantification of per-unit area yields and production potentials. There are measurement challenges related to the characterisation of **food security** and related concepts, such as the establishment of standard caloric intake and nutrient thresholds, as well as to the definition of famine and undernourishment risks. Aspects such as the stability food prices are relevant determinants of food security. For instance, at the global level, Ma et al. show that the countries with the most changeable levels of food production are those showing greater levels of food insecurity (Ma et al., 2020). FAO's Committee on World Food Security Round Table on hunger measurement, developed a methodology to assess food security. The methodology is based on a set of indicators capturing various aspects of food insecurity, namely *availability*, *access*, *stability* and *utilisation* (FAO, 2020). The FAO methodology has been regularly updated since it was initially launched under the Millennium Development Goals framework (MDG indicator 1.9). The last modification was introduced in 2014 (Wanner et al., 2014).

For the sake of consistency and alignment to on-going consensus-building processes, the indicators used in this research are aligned to this framework wherever possible. The proposed indicators on the food production and income generation category hence focus on *availability*, *access* and *stability* of the food, as well as on income streams generated by UA. **Food availability** is captured through the overall production of food and the variety of crops. **Stability of food supply**, income and dietary diversity refer to the reliability of food production systems, in terms of seasonal or annual variability of yields. **Access to food** is interpreted as the capacity to satisfy one's own food requirements at the household level. The utilisation dimension has been excluded from this classification as indicators in this category mostly cover background information collected at population level, like the prevalence of nutrition-related diseases, or the use patterns of various services, such as treated drinking water, sanitation, etc. which have only indirect relationship to community gardening.

Together with the satisfaction of nutritional needs, UA can also make a relevant contribution to household finances. A number of previous works have emphasised the role of UA as an **income generation** strategy, particularly for low-income households (Batitucci et al., 2019). Although the literature provides little guidance on the financial dimension of UA, a few studies document the input flows of community gardening initiatives and place them in a broader financial perspective. Victor et al. (2018a) showed that, on average, UA initiatives in Kinondoni Municipality (Tanzania) generated sufficient revenue to keep a household of six members above the monetary food poverty line. CoDyre et al. (2015) estimated that the commercial value of the products from a commercial garden in a mid-sized Canadian city would be worth \$6.56 USD/m^2 per year.

Regardless of their profitability, community gardening initiatives typically involve a range of complementary activities that can generate substantial income streams for some or all participants. Examples include crop diversification beyond food production, in particular floriculture (Manikas et al., 2020; Recasens & Alfranca, 2018), as well as other types of income generation activities related to, among others, the exploitation of amenities and the provision of training and other services (Gregory et al., 2016a; Holland, 2004a). These often attract other economic activities, creating synergies that can boost local economies, particularly in low-income or degraded areas (Hatchett et al., 2015). Even if direct impacts are highly localised, spillovers spread to the economy as a whole. In sum, community gardening may contribute to satisfying dietary requirements and may also induce economic activity in sectors that supply urban farmers with the necessary production means. This effect generates *new direct* and *indirect jobs* in community gardens and ancillary activities down the value chain.

2.3.3) Inclusive society

This dimension of the framework is interested in the degree to which UA contributes to an inclusive society. Three broad aspects of societal inclusion have been identified as relevant based on the literature on UA and community gardening in the Global North and in line with the goals of the SiEUGreen project:

- **Community engagement** – In what ways do people participate in UA initiatives?
- **Social capital** - How does participation in UA initiatives contributes to the development and maintenance of different types of social connections?
- **Wellbeing** – How does UA support connections to culture and place?

The **community engagement** aspect is concerned with establishing the ways in which people participate in UA initiatives. At the most basic level, this aspect seeks to understand overall *participation* in UA activities (e.g., number of participants; the amount of time spent in the gardens). This relates to the gardeners themselves, but it may also be relevant to consider the way that outsiders are encouraged (or not) to participate through, for example, the location of the garden, specific events designed to encourage community participation (Kingsley and Townsend, 2006).

The framework is also interested in the depth of engagement and seeks to understand the different ways in which participants are engaged in the *governance* of UA initiatives. In a study comparing the democratic values of community garden leaders and non-leaders, Glover et al. (2005), found that, while all participants reported a similar degree of social motivation for getting involved, those responsible for the leadership of the garden were more social in practice (Glover, Shinew, et al., 2005). Collective decision making has also been found to be an important predictor of viability and sustainability of UA initiatives, particularly when a team of dedicated people get involved (Kingsley & Townsend, 2006; Teig et al., 2009).

The **social capital** aspect is concerned with how involvement in UA initiatives contributes to the development and maintenance of social connections within and between different groups. UA is often considered as an enabler of new forms of social engagement, providing an arena for challenging stereotypes, exchanging knowledge and dismantling social barriers (Corcoran & Kettle, 2015; Davidson, 2017). Despite this, numerous studies have found that the make-up of participant groups in UA initiatives often fails to mirror the diversity of the neighbourhoods in which these initiatives occur (Christensen et al., 2019; Kingsley & Townsend, 2006). This is perhaps a reflection of the fact that community gardens are both a consequence and a source of social capital (Firth et al., 2011). In other words, the social capital required to get involved in the first place may put participation out of reach for some groups.

As such, an important first step in understanding the development of social capital through UA will be to establish the *diversity* that exists within the UA initiative. Indicators related to cultural background, age, gender and socio-economic background will be included by comparing data collected through questionnaires (to determine the diversity of the gardeners) with data on the demographic make-up of the city as a whole (as a benchmark for the level of diversity that might be expected among gardeners) (Christensen et al., 2019).

Following on from this, we seek to understand the different types of connections that are made within and between groups through participation in UA. Much of the literature on this aspect of community gardening depart from the work of Putnam (2000), which makes a clear distinction between *bonding* social capital and *bridging* social capital. Bonding social capital refers to ties between individuals from similar socio-demographic backgrounds who may already share a common sense of identity while bridging social capital is developed between those from diverse socio-demographic backgrounds (Firth et al., 2011). It is important to recognise that these are not either-or categories, and they may be difficult to differentiate between in practice (Kingsley and Townsend, 2006).

Previous research has found evidence for the development of both bonding and bridging social capital through UA activities (Audate et al., 2019; Christensen et al., 2019; Firth et al., 2011; Kingsley & Townsend, 2006; Shostak & Guscott, 2017). Though these connections generally begin through a shared enjoyment of gardening, they have also been found to deepen over time, with fellow gardeners becoming a source of social support (e.g. living with

Alzheimer's disease; dealing with the death of a partner) Kingsley & Townsend, 2006; Teig et al., 2009; Veen et al., 2016). The development of networks the extend beyond the gardens themselves has received less attention. Studies which have explored this aspect found it to be less common (Kingsley and Townsend, 2006), except in circumstances where strong relationships already exist between participants (Veen et al., 2016). Svendsen (2009) found that, while gardens often started out as a small group of friends or neighbours, they often expanded to include rich social networks both within neighbourhoods and beyond.

In the literature, the **wellbeing** benefits associated with UA have been found to include improved physical health, decreased risk factors for poor health (e.g. obesity), improved mental health, increased life-satisfaction, reduced loneliness, increased happiness, decreased stress, connection to culture, and healthy ageing (Audate et al., 2019; Genter et al., 2015; Mourão et al., 2019; Taylor & Lovell, 2015; A.E. Van Den Berg et al., 2010). It is beyond the scope of this research to investigate all these factors in-depth. As such, the research chooses to focus on the aspects of wellbeing that are of most relevance in the context of the SiEUGreen project, which is primarily concerned with the societal level and has a strong focus on the integration of those from different cultural backgrounds.

The first aspect of wellbeing that will be addressed is the *connection to culture.* This aspect is largely concerned with the degree to which UA supports people to maintain their cultural identity and share aspects of their culture with others. For immigrant populations, gardening, culture-specific food plant assemblages, and the foodways they support frequently represent a continuation of cultural practices and traditional agroecological knowledge associated with their home country (Taylor & Lovell, 2015). In the U.S. context, Shostak and Guscott (2017) found that growing vegetables and herbs from their country of origin provided newly arrived immigrants with an important connection to life in their home country. It was also seen by many as a means through which to pass on cultural values around health and healing to their children (Shostak & Guscott, 2017).

The second aspect of wellbeing that is of interest here is *environmental stewardship.* Environmental stewardship in an urban context is somewhat under-explored, largely due to the perceived disconnect between nature and the built environment (Romolini et al., 2012). It is of particular interest here as it provides the potential to explore the wellbeing benefits of UA that are derived specifically from engagement with and feelings of ownership over urban space. There is some evidence that participation in UA has benefits that go beyond simply being outside or being physically active. Hawkins et al. (2011) found participation in allotment gardening to be more effective than other forms of exercise in reducing stress, even when the exercise was conducted outdoors. Similarly, Vanden Berg et al. (2010) found that subjective wellbeing was higher for those who spent more time actively engaged in their garden than for those who used it for passive relaxation.

Svendsen (2009) assessed over 300 community garden groups in New York City and found a clear connection between individual wellbeing, stewardship and the built environment. Restorative aspects varied between individuals, and included pride in the space, contributing something positive to the neighbourhood, satisfaction with the ability to grow one's own food, and a place to relax and centre oneself (Svendsen, 2009). Many of the participants in the research were immigrants, who described the gardens as providing both a link back to their country of origin and a connection to their new home (Svendsen, 2009). Interestingly, Svendsen's research found that, while the original motivation to join the garden group was generally personal, the outcome almost always included individual and collective benefits. This is consistent with the work of Romolini et al. (2012), who found that a common expectation of environmental stewardship, regardless of the organisational form it took, was that benefits would extend beyond the bounds of a particular site or project.

2.3.4) Sustainable urban development

This pillar deals with the impacts UA can have on sustainable urban development. It complements the other components of the tool by approaching the garden as an element of the urban structure and considering its spatial and functional relations with other urban elements (e.g., roads, buildings, green areas). This perspective also considers top-down policies and mechanisms (e.g., strategic plans, programs, thematic plans) and bottom-up efforts that incentivise the practice of UA in cities.

This pillar borrows perspectives from urban morphology research (Hillier, 1996; Krafta, 1994; Næss & Saglie, 2000). These studies argue that, despite the common understanding that physical space mediates social relationships, the materiality of the space is often overlooked when analysing social interactions. In urban morphology, the physical structure of the city is a result of the articulation between different elements, such as public and private spaces and built forms, open spaces, and roads (Krafta, 1994). The way these elements interact with each other results in different spatial configurations that can enforce barriers and/or create accessibilities (Weibul, 1976). Both barriers and accessibilities influence social behaviour and can, for example, enhance social integration or segregation (Vaughan, 2007), make urban spaces safer (Çamur et al., 2017) or encourage anti-social behaviour (Armitage, 2011; Friedrich et al., 2009).

In fact, the physical structure of cities enables or inhibits growing food within urban boundaries. For example, compact urban development, often regarded as sustainable as it limits the environmental burden of cities (BRE Global, 2017; USGBC, 2018), may discourage the practice of traditional UA due to scarcity of land. On the contrary, sprawled urban structures, frequently seen as less sustainable, are likely to offer more opportunities for traditional urban farming. Here, we argue that depending on the characteristics of the plot/garden, and the spatial and functional relations it has with the existing urban environment, UA may support or inhibit the sustainability of the urban environment. Given these arguments, this pillar includes three dimensions:

- *The garden as an element of the urban structure:* describes the characteristics of the plot/garden.
- *The garden in relation to other elements of the urban structure* acknowledges spatial and functional interactions (e.g. connectivity) the plot/garden has with other urban elements (e.g. roads, buildings).
- *The garden from an institutional perspective*: refers to top-down policies and incentives and bottom-up efforts that regulates and/or influences the implementation of agriculture in urban spaces.

Conceiving **the garden as an element of the urban structure** implies acknowledging its spatial and functional characteristics (e.g., size, topography, main purpose). Here, an important first step was identifying if the UA initiative demands land (traditional gardening) or if it is zero-acreage farming (Z-Farming) which includes all types of building-related food production, (e.g. rooftop gardens, rooftop greenhouses, balconies, edible walls or indoor farming) (Piorr, 2018; Thomaier et al., 2014). Each type impacts the urban structure in different ways. For example, as food is grown inside buildings, the greatest advantage of Z-Farming is that it does not pressure the use of land in cities, which is often a matter of competition. On the other hand, the impact Z-Farming has on open public spaces is limited if compared with traditional gardening. Growing food inside buildings constrain the number of people that can be involved and consequently lessen social interaction and affects negatively the dynamics (movement) in public spaces (Hillier et al., 1993; Krafta, 1994).

The shape and topography of the plot refer to the geometry of the garden that can have an influence on the area available for cultivation, choice of growing techniques and types of crops. These aspects influence the environmental qualities of the urban spaces (R. G. Davies et al., 2008; Eizenberg et al., 2019). As Davies et al. (2008) claim, the topography is an important driver of the availability and quality of urban green spaces. The size and the subdivision of the plot into beds indicate how many people can grow food and thus the potential of the garden to promote social interaction not only within its limits but also in the surrounding environment (Bokalders & Block, 2014; Mougeot, 2000; Piorr, 2018). For example, gardens that are larger in size and/or number of members will generate more movement, thus improving the dynamic of the public spaces (Hillier et al., 1993; Krafta, 1994). Likewise, the availability of facilities such as toilets and storage rooms add qualities that can make the garden more attractive to people (Krafta, 1996). The transition between the plot/garden to the public space - called permeability - is also relevant, as the presence of barriers (e.g. fences, gates, walls) may constrain the accessibility of visitors to the garden (Andrade et al., 2018).

The main purpose of the garden is also an important aspect as it may inform our understanding of the types of mobilities that may be generated and the subsequent impact on public spaces. For example, a garden with economic purposes is likely to generate more movement and traffic in public spaces than a garden that has a recreational function (Krafta, 1994). Despite focusing solely on the characteristics of the plot/ garden, these properties help to estimate the 'potential' the UA initiative has to influence the dynamics of the public spaces (e.g., social interaction, mobilities in public areas, urban economies).

When it comes to the garden in relation to other aspects of the urban structure, several aspects come into play. The location in intra-urban or peri-urban spaces has profound implications on the type of UA (EPRS, 2017; Mougeot, 2000; Opitz et al., 2016; Piorr, 2018). The main differences between the two types relate to the scale of activities undertaken, the legal status, contractual arrangements, land use and cultivation practices. Differences in the socio-economic status and backgrounds of UA practitioners and their motivation may also be associated with the location of the garden (Opitz et al.,2016). Another important aspect regards the 'public utility of the land', which is a proxy for the competing uses for land in cities. Specifically relevant is to understand if the garden takes place in a land that can be used for other purposes (marketable) or in leftover spaces of the city (non-marketable) (Borges et al., 2019; Fernandez Andres, 2017; Heather, 2012; Horst et al., 2017; La Rosa et al., 2014).

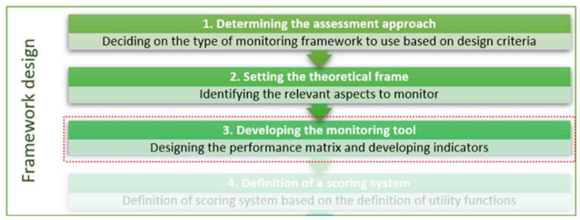
The way the garden is connected to the urban surroundings is also relevant. The distance/proximity to roads, open spaces, buildings and urban services and amenities (e.g., public transportation, green areas) portray, to some extent, the function UA performs within the city. For example, the distance from public green areas may indicate that UA plays a vital role in the city as it provides opportunities for recreation and social interaction to people who could not easily access green areas otherwise (Bowman et al., 2009; Eggermont et al., 2015; Lin et al., 2017; Peschardt, 2014; WHO, 2017). Distance to public transportation is also a proxy for the physical accessibility of the UA initiatives (Olofsson et al., 2011). The location of the garden close to busy roads (e.g. highways) may be harmful as the quality of the food produced in these areas may be compromised due to pollution (e.g. stormwater runoff, soil contamination, air pollution) (Hallett et al., 2016). On the other hand, it can also be positive, as the garden may contribute to the reduction of pollution and noise (Lopez & Souza, 2018; Van Renterghem et al., 2012).

The way in which the garden alleviates urban density by reducing urban heat islands is also relevant (Arama et al., 2019; DeKay, 1997a; Eizenberg et al., 2019). Another important aspect regards how the garden contributes to delivering mixed uses to the neighbourhood (Deelstra et al., 2001; Krafta, 1996; Poulsen et al., 2017). This depends on the purpose of UA (e.g. commercial, leisure, educational) and how this purpose 'consents' or 'conflicts' with the other activities in the surrounding area.

The garden from an institutional perspective includes aspects related to land security and ownership, top-down policies and mechanisms that safeguard or incentivise the implementation of gardens in the city and bottom-up initiatives that promote UA practices. Limited access to land for those who would like to practice UA, along with lack of secure tenure on that land (especially if there are competing uses of land) are among the key constraints to the widespread of UA (Taylor and Lovell, 2015; Viljoen et al., 2015). This aspect is closely interlinked with ownership and is closely related to market forces, including the real estate markets of cities, with UA being displaced as investment interest increases (Opitz et al., 2015). This perspective is shared by Wekerle and Classens (2015), who argue that property rights and security of tenure continue to be the key policy and political issue for UA.

The literature pinpoints weaknesses concerning the governance and policy context of UA in the EU (Lohrberg et al., 2016). National governments play no major role in promoting UA, and there is a lack of strategic engagement from the municipalities. Despite this criticism, UA appears to be gaining more attention in local agendas, particularly if compared to the EU and the national level. In the SiEUGreen framework, top-down incentives include formal (sanctioned by law) and informal frameworks (e.g. policies, strategies, programs) adopted by public authorities to support UA. For example, the acknowledgement of urban agriculture in strategic documents such as land use plans reflects the authorities' understanding of UA's potential to deliver sustainability (Casazza & Pianigiani, 2016; Lohrberg et al., 2016; Martin & Wagner, 2018; Teitel-Payne et al., 2016). Despite not sanctioned by law, top-down informal frameworks such as thematic plans and programs also play an important role in incentivising UA. Bottom-up initiatives acknowledge the private sector and civil society's efforts to implement UA initiatives (Casazza & Pianigiani, 2016; Lohrberg et al., 2016). In fact, UA in Europe is characterised by bottom-up initiatives, most of them informal, fragmented and voluntary (Lohrberg et al., 2016). As Teitel-Payne et al., (2016) pinpoint, networks, associations and other types of private and civil society actors are increasingly involved in supporting UA initiatives.

2.4) Developing the monitoring tool



This subsection presents an operationalisation of the monitoring framework for UA. This operationalisation is responsive to the goals introduced in Section 2.1) and is also grounded on the theoretical developments described in Section 2.2).

In practical terms, the SiEUGreen monitoring framework for UA initiatives is operationalised by means of a performance matrix that groups all the domains, sub-domains and criteria contained in the framework. The performance matrix provides an overview of the relevant analytical dimensions included in the framework and classifies and organises the information required to perform the assessment. The information is organised in three main components: the impact chains conceptualise the indicator within the theoretical framework of the model, indicator descriptions provide information (metadata) about each individual indicator, and reference frameworks place each indicator in its broader sustainability research and practice context, including reference to ecosystem services and the SDGs, as well as the scientific literature. Figure 2 provides an overview of these components. The remainder of this sub-section further elaborates the specific aspects of each of the three areas of the performance matrix.

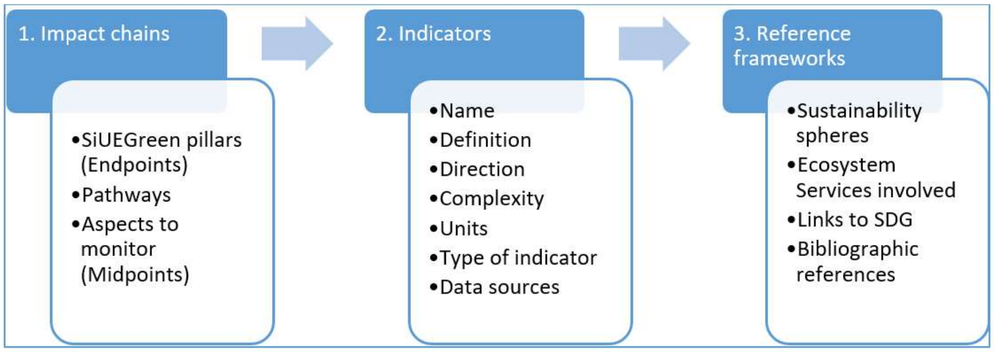


Figure 2: Analytical sequence followed for the development and application of the sustainability evaluation framework
Source: own elaboration

2.4.1) Identification of impact chains

The first step for the development of the performance matrix focused on the definition of the *impact chains*. These describe plausible cause-effect relations linking the effects of UA initiatives to the strategic priorities of urban sustainable development processes. Impacts can reflect either positive or beneficial contributions (e.g. food provisioning), and/or undesired effects (e.g. water contamination).

The impact chains are defined as a combination of three elements: (1) The SiEUGreen *Pillars* conceptualised as the key dimensions or enablers for sustainable urban development (e.g. environmental resilience and resource efficiency, social inclusion, etc.); (2) the *pathways* through which progress towards the pillars may be verified (e.g. climate regulation, community engagement, etc.), and; (3) the specific *aspects to monitor* in order to generate evidence that the garden effectively contributes to the pillar through the defined pathway (e.g. GHG captured by UA, evidence of social interactions between gardeners, etc.).

For the characterisation of impact chains, we adopt the *midpoint* and *endpoint* terminology used in life cycle assessment (LCA), although with a slightly different meaning. Here, we use the term endpoint to refer to multidimensional constructs (e.g. example, food security and income generation) that can be defined as a combination of single elements or midpoints (e.g. caloric intake and dietary diversity in the case of food security). In other words, the endpoints reflect the SiEUGreen pillars, and the midpoints illustrate the specific aspects to monitor that contribute to enabling or undermining the urban sustainability priorities.

2.4.2) Indicator selection and characterisation

In the second (and final) step, relevant and ad-hoc indicators are proposed within each of the impact chains. The indicators are chosen in a way that ensures a flexible application of the framework. The goal is to produce sustainability evaluations that are scientifically robust, but that can still be adapted to situations with relatively severe data constraints. Hence, virtually all the indicators selected for the performance matrix can be replaced by proxies or alternative measures. In particular, more complex indicators have been complemented by at least one alternative option with a lower level of technical complexity. This ensures the transferability of the framework to settings with limited data availability and/or limitations in terms of technical capacity.

The following basic descriptors are provided for each indicator:

- **Name**: If the indicator is retrieved from a public source, the full name is reported. Codes and similar labels have been avoided. In the case of new or self-defined indicators, the name has been defined in a way that the indicator becomes clearly identified and its relevance can be grasped by its name.
- **Definition**: Indicators are clearly described by means of textual descriptions, formulae, etc. All forms of ambiguity have been avoided as far as possible. The definitions ensure that anyone with the required skills and access to the background data may calculate the indicator. If relevant for the definition, details on possible sources of information and data collection strategies are also provided.
- **Units**: Refers to the way the indicator will be measured (e.g., CO_2 in kgs per year; kg of vegetable produced per hectare and year; the total number of hours spent by participants in a community gardening initiative in a given time period, etc.).
- **Data type and origin**: This may include numerical records (e.g., environmental measurements, socio-economic statistics, etc., written records in all possible forms (e.g., research papers, reports, minutes, etc.), observational data, and records of interviews, etc.
- **Reference frameworks:** To contextualise the tool in a broader policy and academic perspective, we have elicited the links between each of the dimensions, topics and indicators addressed in our framework to previous academic works and existing sustainability appraisals. This is intended to assure the relevance, transparency and robustness of the proposed framework. We have placed a particular emphasis on the following aspects:

- SDGs: we have pinpointed the SDGs that are more closely related or directly affected by the specific processes that are being monitored by each impact chain.
- Ecosystem Services: we have formalised connections between the impacts that are being monitored and the ecosystem services valuation framework. In some cases, the ecosystem services identified in the literature are the areas of interest for us (e.g. food provisioning services). Other ecosystem services, in particular cultural services, are more difficult to characterise and/or connect to our framework.

- **Scientific relevance** is demonstrated by peer-reviewed publications, including academic papers that have explored the topics considered in our framework and/or have proposed methods or indicators focusing on those aspects.

Additionally, all indicators have been classified based on the following categories:

- **Type (relevance)**: Not all the indicators in the performance matrix have the same relevance. *Headline* indicators are those that bear critical information for the application of the monitoring framework in a case study. *Standard* indicators provide complementary information on UA initiatives but do not bear essential information for the understanding of the critical impacts of community gardening on urban sustainability. *Background* indicators provide information on the conditions surrounding the implementation of UA initiatives but do not directly affect the impact chains. As it is already implicit in these definitions, headline, standard and background qualifiers are specific to each evaluation. In other words, the choice of headline indicators is context and application specific. In particular, the promotion of an indicator as a headline or standard depends on the capacity of that specific indicator to address the sustainability challenge in a specific way. For instance, in the implementation examples presented in Section 3) below, we placed emphasis on food production stability and accessibility more than on absolute availability or total production capacity. In a different context, however, the latter option may have been more relevant.
- **Direction**: As a rule of thumb, when an increase in the magnitude of the indicator leads to a positive impact on the endpoint, we classify this indicator as *beneficial* (e.g., carbon captured by vegetation has a beneficial effect on climate change). When the opposite is true, we classify the indicator as *detrimental* (e.g., direct CO_2 emissions by UA practice has a detrimental effect on climate change). Since these two categories may vary depending on specific conditions of UA practices, we have created another category named

contextual. This label reflects the fact that certain indicators may bear implementation-specific implications for sustainability performance. For example, the location of the UA initiative within the urban fabric is a relevant aspect that cannot be qualified as beneficial or detrimental in abstract terms. On the contrary, this specific aspect needs to be evaluated against specific planning criteria (DeKay, 1997b; Wentz et al., 2018).

- **Complexity**: In general, our framework uses indicators that are simple to collect and understand, as both qualities ensure transparency of the assessment and potentially also increase its accuracy and comparability. Whenever selecting simple and accessible indicators is incompatible with the relevance or expected accuracy of the evaluation, more complex or sophisticated indicators have been proposed. In these situations, less-skilled users should still be able to apply the framework by using simpler indicators or proxies to measure the impact of UA on the specific sustainability dimensions. Complexity is defined by considering the instrumental capacities and/or skills needed to respectively collect and interpret the indicator and its associated values. Three complexity levels have been defined (see Table 1).

Table 1: Criteria used to assess the degree of complexity of the indicators

Instruments required / Technical skills*	Complex, sophisticated or expensive equipment is needed to calculate the indicator (e.g. professional software, electronic sensors, etc.)	No equipment or simple devices are needed to calculate the indicator, and/or the data come from an external provider (e.g. census data)
Specialised knowledge/skills required	High	High
Basic knowledge/skills required	High	Average
No knowledge/skills needed	Average	Low

* Technical skills refer to pre-existing knowledge and/or training required to collect the data and/or properly interpret the indicator

The above criteria imply that the classification of indicators in these categories, particularly the ones dealing with relevance and direction, need to be reassessed at each evaluation.

This scoping and classification process allowed us to propose **83 indicators**. These are introduced and described in the performance matrix presented in the following section. Of these, we chose **24 headline indicators** which were included in the testing and calibration step described in Section 3.2).

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2.4.3) Overview of the performance matrix

Table 2 provides an overview of the performance matrix. The full version of the matrix is available in Annex 6.6).[1]

Table 2: Structure of the indicator panel

SiUEGreen Pillars (Endpoints)	Pathway	Specific aspect to monitor (Midpoints)	Type of indicator	Link to SDGs	Relevance
Environmental resilience and resource efficiency	**Climate regulation: GWP savings**	**GHG captured by UA**	**Headline**	**13**	**(Caputo et al., 2020; Kulak et al., 2013)**
Environmental resilience and resource efficiency	Climate regulation: air purification	Estimated air purification capacity by UA	Standard	13	(Cortinovis & Geneletti, 2019; Nowak et al., 2006)
Environmental resilience and resource efficiency	Climate regulation: climate comfort	Urban temperature regulation by UA	Standard	13	(Habeeb, 2017; Hallett et al., 2016)
Environmental resilience and resource efficiency	Energy balance	Heating intensity and energy balance	Standard	12	(Weidner & Yang, 2020)
Environmental resilience and resource efficiency	Energy balance	Electricity intensity and energy balance	Standard	12	(Weidner & Yang, 2020)
Environmental resilience and resource efficiency	Energy balance	UA's contribution to the energy efficiency of buildings	Background	12	(Hallett et al., 2016)
Environmental resilience and resource efficiency	**Land reclamation**	**Repurposing vacant or idle land for UA**	**Headline**	**15**	(Carlet et al., 2017; Lin et al., 2015; Schwarz et al., 2016)

[1] It should be noted that the version of the matrix shown here and in the Annex is the original iteration. As this version is now referred to in a scientific publication (see: Tapia et. al., 2021) it was deemed important to keep it intact. The revised version of the matrix is shown in Section 2.6) Revision of the framework (2021).

Environmental resilience and resource efficiency	**Soil conservation**	**Adoption of organic farming practices aimed at soil conservation**	**Headline**	**11.12**	**(Tuğrul, 2019)**
Environmental resilience and resource efficiency	Reduction of food packaging	UA's contribution to the reduction of food packaging	Standard	11.12	(Hallett et al., 2016)
Environmental resilience and resource efficiency	Water management	Water consumed in UA	Standard	6	(Dalla Marta et al., 2019b)
Environmental resilience and resource efficiency	Water management	Irrigation method used in UA	Standard	6	(Dalla Marta et al., 2019b)
Environmental resilience and resource efficiency	**Water management**	**Water sources in UA**	**Headline**	**6**	(Dalla Marta et al., 2019b)
Environmental resilience and resource efficiency	Water management	Wastewater reused in UA	Standard	6	(Pollard et al., 2018)
Environmental resilience and resource efficiency	**Soil sealing**	**Stormwater infiltration enhanced by UA practice**	**Headline**	**6**	**(Hallett et al., 2016)**
Environmental resilience and resource efficiency	**Soil amendment**	**Prevalence of using fertilizers in UA**	**Headline**	**3**	**(Van der Wiel et al., 2019; Wielemaker et al., 2019)**
Environmental resilience and resource efficiency	Potential contamination	Prevalence of using pesticides and herbicides in UA	Standard	3	(Aboagye et al., 2018)
Environmental resilience and resource efficiency	Potential contamination	Concentration of heavy metals	Standard	3	(Aboagye et al., 2018)
Environmental resilience and resource efficiency	Technology innovation: green technology deployment	Planting techniques' environmental impact	Background	9	(European Commission, 2017)
Environmental resilience and resource efficiency	Technology innovation: blue technology deployment	Waste and water management techniques' environmental impact	Background	9	(European Commission, 2017)
Environmental resilience and resource efficiency	Technology innovation: yellow technology deployment	Renewable energy techniques' environmental impact	Background	9	(European Commission, 2017)

Inclusive society	Community engagement: Participation	Number of members	Standard	11	(Davidson, 2017)
Inclusive society	Community engagement: Participation	Frequency of visits by members	Standard	11 & 3	(Davidson, 2017; Glover, Parry, et al., 2005)
Inclusive society	Community engagement: Participation	Average length of a visit by garden members	Standard	11 & 3	(Davidson, 2017; Glover, Parry, et al., 2005)
Inclusive society	**Community engagement: Participation**	**Time spent in the garden**	**Headline**	**11 & 3**	(Davidson, 2017; Glover, Parry, et al., 2005)
Inclusive society	Community engagement: Participation	Broader community participation	Standard	11	(J. Y. Kingsley & Townsend, 2006)
Inclusive society	Community engagement: Participation	Longevity of UA initiative	Background	11	(ioby, 2018)
Inclusive society	Community engagement: Participation	Main motivation(s) of participants	Background	12	(Christensen et al., 2019)
Inclusive society	Community engagement: governance	Self-management	Standard	16	(Glover, Shinew, et al., 2005; J. Y. Kingsley & Townsend, 2006; Teig et al., 2009)
Inclusive society	Community engagement: governance	Inclusive self-management	Standard	16	(Glover, Shinew, et al., 2005; J. Y. Kingsley & Townsend, 2006; Teig et al., 2009)
Inclusive society	Social capital: diversity	Cultural background of participants	Standard	10	(Christensen et al., 2019; Corcoran & Kettle, 2015; Davidson, 2017; J. Y. Kingsley & Townsend, 2006)
Inclusive society	Social capital: diversity	Socioeconomic background of participants	Standard	10	(Christensen et al., 2019; Corcoran & Kettle, 2015; Davidson, 2017; J. Y. Kingsley & Townsend, 2006)
Inclusive society	Social capital: diversity	Gender of participants	Standard	5	(Christensen et al., 2019; Corcoran & Kettle, 2015; Davidson, 2017; J. Y. Kingsley & Townsend, 2006)
Inclusive society	Social capital: diversity	Age of participants	Standard	10	(Christensen et al., 2019; Corcoran & Kettle, 2015; Davidson, 2017; J. Y. Kingsley & Townsend, 2006)
Inclusive society	**Social capital: Diversity**	**Demographic diversity of participants**	**Headline**	**10 & 5**	(Christensen et al., 2019; Corcoran & Kettle, 2015; Davidson, 2017; J. Y. Kingsley & Townsend, 2006)

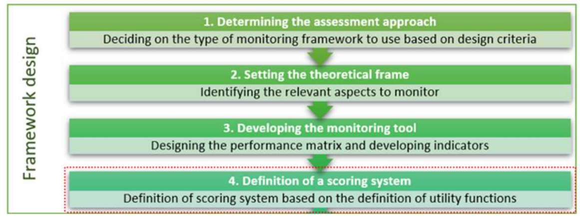
Inclusive society	**Social capital: Interactions**	**Evidence of social interactions between gardeners**	**Headline**	**11**	(Audate et al., 2019; Christensen et al., 2019; Firth et al., 2011; J. Y. Kingsley & Townsend, 2006; Shostak & Guscott, 2017)
Inclusive society	Social capital: Interactions	Evidence of social interactions between gardeners in the garden setting	Standard	11	(Audate et al., 2019; Christensen et al., 2019; Firth et al., 2011; J. Y. Kingsley & Townsend, 2006; Shostak & Guscott, 2017)
Inclusive society	Social capital: Relationships	Evidence of social interactions between gardeners beyond the garden	Standard	11	(J. Y. Kingsley & Townsend, 2006; Teig et al., 2009; Veen et al., 2016)
Inclusive society	**Social capital: Relationships**	**New social relationships**	**Headline**	**11**	(J. Y. Kingsley & Townsend, 2006; Teig et al., 2009; Veen et al., 2016)
Inclusive society	**Wellbeing: connection to culture**	**Cultural and religious expression**	**Headline**	**11**	(Shostak & Guscott, 2017; Taylor & Lovell, 2015b)
Inclusive society	Wellbeing: connection to culture	Cultural significance of gardening	Standard	3	(Shostak & Guscott, 2017; Taylor & Lovell, 2015b)
Inclusive society	Wellbeing: environmental stewardship	Environmental motivations	Standard	11	(Romolini et al., 2012)
Inclusive society	Wellbeing: environmental stewardship	Ownership of space	Standard	3 & 11	(Hawkins et al., 2011; Romolini et al., 2012; Svendsen, 2009; Van Den Berg et al., 2010)
Inclusive society	Wellbeing: environmental stewardship	Community pride	Standard	11	(Hawkins et al., 2011; Romolini et al., 2012; Svendsen, 2009; Van Den Berg et al., 2010)
Inclusive society	**Wellbeing: environmental stewardship**	**Environmental stewardship**	**Headline**	**11 & 13 & 3**	**(Hawkins et al., 2011; Romolini et al., 2012; Svendsen, 2009; Van Den Berg et al., 2010)**
Food security and income generation	Food availability	Production of food: totals	Standard	2	(Edmondson et al., 2020b; Gregory et al., 2016b; Lynch et al., 2013; Sanyé-Mengual et al., 2018b; Tasciotti & Wagner, 2015b)
Food security and income generation	**Food stability**	**Production of food: stability**	**Headline**	**2**	(Dixon et al., 2007; Poulsen et al., 2015b)
Food security and income generation	**Food accessibility**	**Production of food: self-sufficiency**	**Headline**	**2**	(Chiappe Hernández, 2019b; Furness & Gallaher, 2018; Khumalo & Sibanda, 2019b; Moucheraud et al., 2019b)
Food security and income generation	**Food waste generation**	**Total food lost or wasted**	**Headline**	**2, 12**	(S. Brown & Goldstein, 2016; Zorpas et al., 2018)

Food security and income generation	Food safety	Potential contamination of food due to growing practices	Standard	3, 14, 15	(Audate et al., 2019; Igalavithana et al., 2017; Prudic et al., 2019)
Food security and income generation	Food safety	Potential contamination of food due to lack of safety protocols and measures	Standard	3	(Audate et al., 2019; Gallaher et al., 2013)
Food security and income generation	**Preparedness for food sovereignty**	**Training for food sovereignty**	**Headline**	**2**	(Gregory et al., 2016b)
Food security and income generation	Preparedness for food sovereignty	Training for food sovereignty	Standard	2	(Gregory et al., 2016b)
Food security and income generation	Financial resilience of households	Potential income generated by food production activities: total	Standard	1, 10	(Holland, 2004b; Manikas et al., 2020; Moustier, 2014; Victor et al., 2018b; Zezza & Tasciotti, 2010b)
Food security and income generation	Financial resilience of households	Stability of revenue generation potential	Standard	1, 10	(Holland, 2004b; Manikas et al., 2020; Moustier, 2014; Victor et al., 2018b; Zezza & Tasciotti, 2010b)
Food security and income generation	Financial resilience of households	Contribution of UA to household finances	Standard	1, 10	(Holland, 2004b; Manikas et al., 2020; Moustier, 2014; Victor et al., 2018b; Zezza & Tasciotti, 2010b)
Food security and income generation	Financial resilience of households	Relative contribution of food production to household finances	Standard	1, 10	(Holland, 2004b; Manikas et al., 2020; Moustier, 2014; Victor et al., 2018b; Zezza & Tasciotti, 2010b)
Food security and income generation	**Financial resilience of the UA initiative**	**Financial sustainability**	**Headline**	**1, 10**	(Haberman et al., 2014; Hashimoto et al., 2019)
Food security and income generation	Financial resilience of the UA initiative	Financial stability	Standard	11	(Haberman et al., 2014; Hashimoto et al., 2019)
Food security and income generation	Financial resilience of the UA initiative	Revenue: External financial support: self-sufficiency	Standard	11	(Haberman et al., 2014; Hashimoto et al., 2019)
Food security and income generation	Financial resilience of the UA initiative	Design costs & installation costs	Standard	11	(Haberman et al., 2014; Hashimoto et al., 2019)
Food security and income generation	Financial resilience of the UA initiative	Operation costs: garden	Standard	11	(Haberman et al., 2014; Hashimoto et al., 2019)
Food security and income generation	**Financial resilience of the UA initiative**	**Operation costs: participants**	**Headline**	**11**	**(Haberman et al., 2014; Hashimoto et al., 2019)**

Food security and income generation	Job creation	Direct jobs created	Standard	1, 8	(Bohm, 2017)
Food security and income generation	Job creation	Indirect job effects	Standard	1, 8	(Bohm, 2017)
Sustainable urban development	The garden as an element of the urban structure	Characteristics of the garden	Background	11	(Piorr, 2018; Thomaier et al., 2014)
Sustainable urban development	The garden as an element of the urban structure	Characteristics of the plot/garden	Background	11	(Bokalders & Block, 2014; Piorr, 2018)
Sustainable urban development	The garden as an element of the urban structure	Characteristics of the plot/garden	Background	11	(Krafta, 1994; Mougeot, 2000)
Sustainable urban development	The garden as an element of the urban structure	Characteristics of the plot/garden	Background	11	(R. G. Davies et al., 2008; Eizenberg et al., 2019)
Sustainable urban development	The garden as an element of the urban structure	Characteristics of the plot/garden	Standard	11	(Krafta, 1996)
Sustainable urban development	The garden as an element of the urban structure	Characteristics of the plot/garden	Standard	11	(Andrade et al., 2018)
Sustainable urban development	The garden as an element of the urban structure	Characteristics of the plot/garden	Background	11	(Krafta, 1994)
Sustainable urban development	The garden in relation to other elements of the urban structure	Garden proximity of the city centre	Background	11	(EPRS, 2017; Mougeot, 2000; Opitz et al., 2016; Piorr, 2018)
Sustainable urban development	**The garden in relation to other elements of the urban structure**	**Perceived public utility of the land**	**Headline**	**11**	(Borges et al., 2019; Fernandez Andres, 2017; Heather, 2012; Horst et al., 2017; La Rosa et al., 2014)
Sustainable urban development	The garden in relation to other elements of the urban structure	Garden proximity of other green areas	Standard	11	(Bowman et al., 2009; Eggermont et al., 2015; Lin et al., 2017; Peschardt, 2014; WHO, 2017)
Sustainable urban development	The garden in relation to other elements of the urban structure	Garden proximity of busy roads	Standard	11	(Hallett et al., 2016; Lopez & Souza, 2018; Van Renterghem et al., 2012)
Sustainable urban development	**The garden in relation to other elements of the urban structure**	**Accessibility to the garden**	**Headline**	**11**	(Olofsson et al., 2011)

Sustainable urban development	**The garden in relation to other elements of the urban structure**	**Garden contribution to relief urban of density**	**Headline**	**11**	(Arama et al., 2019; DeKay, 1997a; Eizenberg et al., 2019)
Sustainable urban development	The garden in relation to other elements of the urban structure	Garden contribution to a mixed neighbourhood	Standard	11	(Deelstra et al., 2001; Krafta, 1996; Poulsen et al., 2017)
Sustainable urban development	**The garden from an institutional perspective**	**Land security and tenure**	**Headline**	**11**	(J. Davies et al., 2020; Opitz et al., 2016; Taylor & Lovell, 2015b; Viljoen et al., 2015; Wekerle & Classens, 2015)
Sustainable urban development	The garden from an institutional perspective	Land value	Standard	11	(Taylor & Lovell, 2015b; Viljoen et al., 2015; Voicu & Been, 2008; Wekerle & Classens, 2015)
Sustainable urban development	**The garden from an institutional perspective**	**Top-down initiatives to support urban gardening**	**Headline**	**11**	(Casazza & Pianigiani, 2016; Lohrberg et al., 2016; Martin & Wagner, 2018; Teitel-Payne et al., 2016)
Sustainable urban development	The garden from an institutional perspective	Public budget	Standard	11	(Casazza & Pianigiani, 2016; Lohrberg et al., 2016; Teitel-Payne et al., 2016)
Sustainable urban development	**The garden from an institutional perspective**	**Bottom-up initiatives to support urban gardening**	**Headline**	**11**	**(Casazza & Pianigiani, 2016; Lohrberg et al., 2016; Teitel-Payne et al., 2016)**

2.5) Defining a scoring system



Consistent with the goals defined in Section 2.1), the main principle guiding the definition of a scoring system was overall consistency and ease of interpretation. As such, the scoring methodology is very straightforward.

Since the indicators considered in our data model are measured in very different units, it was necessary to transform them in such a way that side-by-side reporting and comparison become feasible and intuitive. This was done by applying a simple linear transformation that adjusts indicator values basing on reference minimum and maximum values.

$$v_i' = \frac{x_i - \min x_i}{\max x_i - \min x_i} \cdot 100 \qquad (1)$$

where the transformed indicator score v_i' gets a value ranging from 0 to 1 based on a minimum ($\min x_i$) and maximum ($\max x_i$). In this setting, a higher score represents higher performance (increasing utility; beneficial direction in our performance matrix).

To account for decreasing utility situations (detrimental direction in our performance matrix), the normalisation formula (1) was reversed as follows:

$$v_i' = \frac{\max x_i - x_i}{\max x_i - \min x_i} \cdot 100 \qquad (2)$$

where a lower score represents higher performance (declining utility).

By applying these transformations, all indicators become a-dimensional, ranging from 0 to 100, where higher scores are preferable to smaller ones. Once the indicators are transformed, a range of simple plots is produced for each indicator, UA initiative and sustainability pillar. This ensures transparency and robustness of the evaluation. A similar approach is used in the last editions of the Sustainable Development Report that combines the production of index scores (based on a simple and hence fully compensable arithmetic mean that we avoid here) with a range of visuals, including dashboards, dispersion indices, radial plots, as well as background indicators (Sachs et al., 2020).

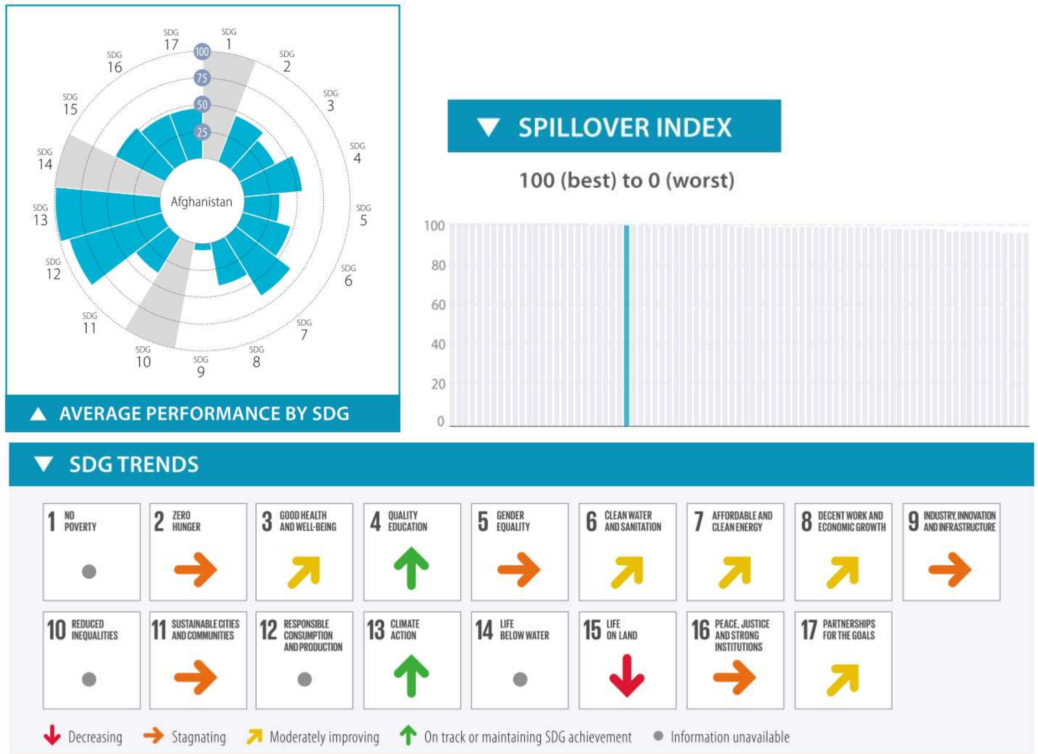


Figure 3. Example of visualisations summarising progress in multiple directions in the last edition of the Sustainable Development Report

Source: The Sustainable Development Goals and Covid-19. Sustainable Development Report 2020 (Sachs et al., 2020)

It is worth noting that we deliberately avoided the production of some sort of *synthetic score or composite indicator* to summarise evaluation results in one single number, as is typical of multi-domain evaluations in multi-criteria decision analysis (Munda, 2004). Synthetic scores summarise complex or multidimensional information, facilitating communication by allowing easier benchmarking and trend analysis (Nardo & Saisana, 2009). As such, composite indicators are increasingly used in policy decision making processes with different purposes (see, e.g. Diaz-Balteiro et al., 2017 for a recent review focusing on sustainability indices). Composite indices have also become extremely popular in various fields of research, including urban sustainability (Huang et al., 2015; Mori & Christodoulou, 2012; Verma & Raghubanshi, 2018) and urban and peri UA evaluation (Vanni & Henke, 2017; Zasada et al., 2020).

The production of composite indicators requires formal aggregation procedures that, by design, simplify data structures in a way that greatly reduces the internal variability and complexity in the data model. These procedures have well-known methodological limitations that stem from two critical steps in the production of the indices, namely weighting and data aggregation.

- **Weighting** is implicit to all types of multi-domain evaluations (when weighting schemes are not formally applied, aggregation models simply imply the use of equal weights). Composite indicators use weights to determine the relative importance of the elements under consideration or reduce the redundancy of the data model (EC & OECD, 2008). Depending on the aggregation procedure used, weights may define the 'relative importance' of the considered criteria or resolve 'trade-offs' among the attributes (Greco et al., 2019). In either case, the selection of weights may have a significant effect on the units ranked (Saisana et al., 2005). Inevitability, mutable value choices linked to the selection and application of weighting schemes lead to unstable results or even questionable indices (Greco et al., 2019).
- **Data aggregation** involves combining a range of indicators into a reduced number of composite indices. These are often re-combined down to a single global sustainability score. Aggregation methods can be divided into two broad categories, namely, compensatory and non-compensatory approaches (EC & OECD, 2008). Compensatory methods are those where the decline in one criterion or component of the construct can be offset by the progress in another one. Traditional multi-criteria analyses based on additive (e.g. weighted arithmetic mean) or geometric (e.g. weighted geometric mean) methods fall in this category. In this case, weights take the meaning of substitution rates (trade-offs) and do not indicate the importance of the associated criterion. In contrast, non-compensatory methods allow the establishment of a preference relation between the evaluation criteria. Multi-criteria decision analyses based on ordinal criterion scores like Borda and Condorcet compliant methods enable this setting. Unfortunately, however, non-compensatory approaches face a different set of methodological limitations that undermine the interpretability of results (Greco et al., 2019).

To summarise, whenever multi-dimensional data is aggregated in the form of synthetic indices or scores, there seems to be a trade-off between the interpretability of the results and the statistical robustness of the scoring system. In general, more robust aggregation approaches (like pairwise and outranking methods) tend to be less intuitive and hence difficult for the average person to interpret. Conversely, simpler methods based on linear aggregation models often lead to compensability issues. These problems may be worsened using weighting schemes that, by definition, tend to be unstable and change with value choices and/or data samples. Based on these arguments, and in line with our main objectives around transparency

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and accessibility, we decided to avoid aggregating the indicators into synthetic scores or multidimensional indices.

2.6) Revision of the framework (2021)

The framework was further refined based on tests undertaken in two additional gardens from different geographical contexts and using different UA approaches (e.g., higher technology, commercial). As with the original tool development, the revision was undertaken using an interactive approach. Representatives of the initiatives were invited to meetings and a workshop to provide feedback on how the tool and its various indicators could be applied (or not) to their specific initiative. This process is further described in section 3.1) Data collection methods.

Prior to presenting it to the stakeholders, the research team conducted its own internal review of the framework. This review involved assessing the framework according to two parameters:

1) **Simplicity:** Was it possible to present the framework to stakeholders in a clear, relatable, and transparent way?
2) **Responsiveness:** Was it possible to identify relevant mid-points (specific aspects to monitor) and indicators for the new cases in response to the pillars and pathways, as previously defined?

Table 3 highlights the limitations of the tool that were identified in the review, including the steps that should be taken to address these.

Table 3. Limitations of SiEUGreen monitoring framework

	FINDING	ACTION
Simplicity	The first iteration of the tool identifies a large number of pathways under the four pillars. This makes it difficult to present the tool in a straightforward manner. It also limits the comparability of cases that achieve similar outcomes through different means.	Simplify the framework to include a smaller number of (broader) pathways per pillar.
Responsiveness	The framework makes a fundamental (but incorrect) assumption that the producer of the food and the consumer of the food will be the same person. This is particularly relevant to the social and food security pillars. This means that, in a commercial setting, the benefits that can be derived under the societal inclusion pillar (as previously defined) are fairly limited.	Ensure that at least some of the pathways are responsive to a situation where the producer and the consumer are not the same.
		Develop additional midpoints (specific aspects to monitor) that incorporate a customer perspective.
		Remove income generation from the food security pillar, thus allowing economic opportunity and economic access to become a pathway under societal inclusion.

With respect to simplicity, the main challenge was the large number of pathways, many of which were unlikely to be applicable in all cases. The solution was to reduce the number of pathways, while at the same time broadening their scope slightly. For example, one of the pathway in the previous iteration of the framework was "Climate regulation". While climate regulation is obviously an important contribution of UA, it is only applicable to UA practised outdoors, and thus it excludes vertical farming, an important application of UA. Therefore, the framework has been adjusted so that "Energy and Climate" is the pathway and climate regulation is a midpoint, a specific aspect that may be monitored in some types of UA practice. In examples of UA practice where climate regulation is not a relevant aspect to monitor, a different midpoint may be selected to monitor the contribution to energy and climate.

With regards to responsiveness, the research team identified a fundamental (but incorrect) assumption within the tool: that the producer and consumer of the food will be the same person. This assumption meant that the societal inclusion pillar was skewed towards the societal benefits of being involved in the food production process. While this works well in a community garden setting, it makes it very difficult to assess the societal benefits of an initiative in which community members are simply consumers of UA produce (e.g., in the case of a commercial enterprise). As such, the research team adjusted the framework so that economic aspects of UA, for example, job creation and household access to food, would be grouped under the societal inclusion pillar. This meant that the pillar previously known as "food security and income generation" was retitled simply "food security". We also worked with the stakeholders to develop additional midpoints that incorporate a customer perspective.

The changes to the framework also included adjusting the selection of midpoints and indicators. In some cases, this was as simple as slight changes in wording to make a midpoint or indicator more inclusive. In other cases, this included generating whole new indicators that could allow a particular pathway to be assessed in a context not considered in the first iteration. These changes were largely informed by the workshops, though it was necessary to go back to the literature in some cases to clarify the particularities of existing indicators and check the validity of new indicators proposed by the stakeholders. The outcome was an improved framework that can easily and transparently be applied to different types of UA applications, including commercial enterprise and UA practice using more advanced technology.

The revised matrix, including suggested indicators, is shown in Table 4.

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Table 4. Complete performance matrix including suggested indicators

PILLAR	PATHWAY	MIDPOINT	INDICATOR
Environmental resilience and resource efficiency	Energy & Climate	GHG Capture	Estimated global warming potential (GWP) savings, according to the products cultivated in the garden
		Climate regulation	Air purification capacity as measured by the vegetation index (NDVI)
			Temperature reduction in UA area: temperature differential observed in the area in relation to city average, city centre or confining areas
			The prevalence of rooftop and vertical gardens in the community
		Energy efficiency	Renewable energy as a proportion of total energy use
			How much energy is consumed per unit of product produced? (in KW hours)
		Reduction of food miles	Units of product sold
			Estimated food-mile savings by product
	Waste generation & reuse	Waste avoidance	Type of packaging used
		Waste utilisation	Organic matter as a proportion of total fertiliser use
			Use of waste steams as an energy source
			Recycled / wastewater as a proportion of total water use
			Infrastructure constructed from recycled / repurposed materials
	Water management	Water consumption	Water use compared to traditional agriculture
			Proportion of primary-sourced water consumed in UA per unit area per year
			Irrigation methods used
			Water sources utilised
		Stormwater infiltration	Share of land covered by permeable material
Societal inclusion	Participation	Engagement in activities	Number of members / participants
			Number of participation opportunities offered (e.g., training etc.)
			Possibilities for general public to participate
			Size of customer base
			Overall time spent in the garden (during growing season) including number and duration of visits
		Engagement in decision making	Existence of a board or steering committee which meets at least once per quarter
			Diverse representation on the board / steering committee
			Mechanisms for interaction with customers
			Existence of participation mechanisms for all members in the initiative
	Social capital development	Demographic diversity	Demographic makeup of garden participants compared to that of the neighbourhood/city
			Demographic makeup of the client base compared to that of the neighbourhood/city
		Social interaction	Extent to which garden participants report interactions of any kind with other gardeners.
			Extent to which garden participants report interactions with other gardeners in the context of the garden
			Extent to which garden participants report interactions with other gardeners outside of the context of the garden

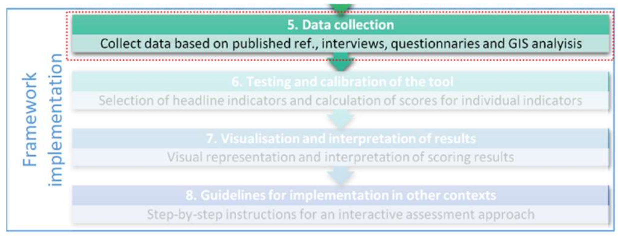
			Number of new relationships develop through participation in the garden
		Cultural expression	Extent to which the garden supports cultural and/or religious expression
			Extent to which urban agriculture provides a connection to the place of origin
	Environmental stewardship	Community pride & ownership of space	Extent to which participants feel proud of what they have achieved with the garden
			Extent to which participants believe that the neighbourhood as a whole is improved by the presence of the garden
		Global responsibility	Extent to which participants/consumers have environmental motivations and attitudes
			Extent to which the initiative promotes environmental stewardship
	Economic opportunity	Job Creation	Direct jobs created through the initiative
			Indirect jobs created through the initiative
			Diversity of jobs created through the initiative (education level)
			Diversity of jobs created through the initiative (gender)
			Diversity of jobs created through the initiative (ethnicity)
		Household finances	Donation of food
			Estimated income generated by activities performed in UA, including agriculture and other practices
			Percentage of annual household income obtained from UA initiatives (considering food production and other activities)
Food security	Food accessibility	Self-sufficiency	Share of total annual household consumption satisfied through the initiative: (1) Energetic crops: cereals, roots and tubers; (2) Vegetables, all kinds; (3) Fruits, all kinds; (4) Products of animal origin: milk, eggs, meat, fish
		Cost	Cost compared to a comparable product produced through traditional agriculture
			Cost of participation in the initiative
	Food Availability	Food sovereignty	Proportion of annual income reinvested in R&D
			Number of aspects covered by existing training programmes: food production (gardening methods) and/or food sharing and/or food preparation and/or financial management
			Amount of food produced in relation to the population
			Total amount of food produced, considering diversity of products: (1) Energetic crops: cereals, roots and tubers; (2) Vegetables, all kinds; (3) Fruits, all kinds; (4) Products of animal origin: milk, eggs, meat, fish
			Share of participants in initiative trained to grow healthy food
	Food Quality	Food safety	Prevalence of herbicide and pesticide use
			Monitoring of contamination and pathogens
			Existence of general food safety assurance mechanisms including: (1) formalised food safety managing protocols and programs, AND/OR; (2) food traceability systems, AND/OR; (3) compulsory food safety training programs addressed at participants
			Number of professional laboratory or on-site tests tracking potential: (1) chemical and (2) microbial contamination on soils (last 5 years)
		Customer satisfaction	Average number of customer complaints over a one-month period
			Average number of customers praising the product over a one-month period

		Freshness	Average time from harvest to purchase
	Stability	Longevity of initiative	Time since the garden was first established
		Harvest predictability	Predictability in the annual/seasonal production of food
		Financial stability of the initiative	Fraction of operation costs covered with external sources (e.g., public grants, venture capital)
Sustainable urban planning	Characteristics of the initiative	Type of UA	Type of UA (e.g., raised beds, vertical farm)
			Size of the plot/garden
			Number of beds in the garden
			Primary purpose of the initiative (e.g., gardening, recreational, educational, mental health, social integration, food production for commercial sale).
		Accessibility / openness	Extent to which the initiative connects urban dwellers with the food production process
			Presence of physical elements (e.g. fences, walls, gates) defining the limits of the garden.
			The UA initiative is open to the public
		Facilities and infrastructure	Existence of facilities/infrastructures in the UA (e.g., toilets, storage room, kitchen)
	Relationship to other aspects of the city	Contribution to mixed use neighbourhoods	Population density in the area where the garden is based (1sq km grid)
			Positive or negative contribution of the garden to the mixed-use of the neighbourhood.
		Accessibility / mobility	Distance from the city centre
			Distance from green areas. Indicates the potential of the garden to deliver access to recreational facilities
			Distance from main roads (in the case where food is distributed)
			Means of transport vs travel time to reach the garden
	Institutional context	Land security and tenure	Type of land (e.g., marketable, or non-marketable) in which the garden is located.
			Access to land via formal documents (e.g., lease or property contracts)
			Comparative evolution of land prices in the area in relation to the city as a whole
		Supportive policy context	Official (sanctioned by law) and non-official policies and strategies adopted to support urban gardening (e.g., strategic planning, physical planning, design regulations, thematic strategies and plans, thematic problems)
		Supportive funding context	Receives municipal funding
			Receives government funding at the national or sub-national level
			Receives EU funding
			Receives funding through venture capital
		Partnership approach	Involvement of actors from different spheres (e.g., private, public, community)

3) Framework implementation

This section describes the implementation of the SiEUGreen monitoring framework for UA, that was tested in two community gardens in Aarhus Municipality, DK (Brabrand and Pier 2 gardens) and in Turunclu Greenhouse in Hatay, TK. It also includes a section which provides guidelines for implementation in other contexts.

3.1) Data collection



3.1.1) Data collection methods

The first version of the tool was tested in two community gardens of Aarhus: Brabrang Fallesgartneriet and Pier 2 in 2020. The choice of these cases, as opposed to other SiEUGreen showcases, was due to circumstances beyond the control of the research team. These circumstances included the delay in the implementation of technologies in both Hatay and Fredrikstad, Covid-19 restrictions that made it impossible to reach out to gardeners in Sanyuan Farm in Beijing, and the absence of residents in the Futiancangjun community in Changsha. As a result, two gardens from the Taste Aarhus program were chosen, Brabrand and Pier 2.

The selection of Brabrand was based on the fact that the research team has both substantial knowledge of the garden and a good relationship with the garden manager. This garden is testing one of the SiEUGreen technologies (solar-driven toilet). Pier 2 was deemed a good candidate for comparison to Brabrand based on two key characteristics, size and location. With regards to size, the similarities between the gardens were considered helpful for the comparison. Both are large gardens in the context of the Taste Aarhus program, with a significant number of highly engaged members. Regarding location, Brabrand is located in a peri-urban area, whereas Pier 2 is located in the inner-city. Here, the difference between the gardens provides a rich opportunity for comparison. The different location influences a range of other aspects, including the purpose of the garden and the profile of the members.

Data was collected about the two gardens using a combination of methods, including:

- Online one-on-one semi-structured interviews with the garden leaders

- Online semi-structured interview distributed to planners of Aarhus Municipality via the Taste Aarhus manager
- Online surveys distributed via the contact person from the interview
- GIS analysis using QGIS and ArcGIS
- Previous reports from the project.

Interviews were conducted with the garden leaders from each of the selected gardens with the aim of eliciting general information about the garden as a whole. In the case of Brabrand, the research team was already acquainted with the garden leader and was able to reach out directly. In the case of Pier 2, an introduction was provided by the Taste Aarhus program manager via email. The interviews were based on an interview guide which was circulated to interviewees in advance (see Annex 6.2) for a copy of the interview guide). Interviews ranged in length from 40 minutes with the manager of Brabrand to 75 minutes with the manager of Pier 2. The extra time required for the interview with the manager of Pier 2 is explained by the need to introduce the SiEUGreen project, as well as the fact that the research team had minimal knowledge of this garden prior to the interview.

A short follow-up interview with the manager of Taste Aarhus was necessary to complement the information provided by the garden leader about Pier 2. This information included a few questions related to the establishment of the garden and a question about the duration of the financial support provided by Taste Aarhus. An interview targeting planners from Aarhus Municipality was designed to understand how local planning documents address (or not) UA (see Annex 6.3) for a copy of the interview guide). The survey was sent to the manager of Taste Aarhus program, who forwarded it to the relevant planning department of the municipality.

Online surveys were conducted with the aim of eliciting information directly from garden participants about a range of issues relating to their participation in the garden. The survey included questions around themes including: demographic background, participation in the garden (e.g. motivations, travel to the garden, interactions with other gardeners), information about their specific plot (e.g. type of garden, fertilisers used, watering methods), details of the food they grow, economic inputs and outputs, and opinions about the specific benefits of the garden.

The survey was set up using the online survey platform Survey Monkey. A link to the survey was distributed to all garden participants by the garden leader via email and posted on the Facebook page of each garden. The survey was open for three weeks, with a reminder email sent by the garden leaders one week prior to the closing date. A disqualification question was included at the beginning of the survey to ensure responses were only received from gardeners in these specific gardens. Separate links and collectors were used for the two gardens to avoid any confusion with the data. Both the survey itself and all related communication was undertaken in Danish. The full survey can be found in Annex 6.1).

The GIS analysis was conducted to supplement the quantitative data collection process. Satellite images of Brabrand and Pier 2 were imported and analysed in QGIS. Photo interpretation was employed to calculate the area of the gardens and to check the land cover (e.g. sealed soil with greenhouses, pavement), enabling the estimation of permeable land. Data on 1km grid-level was overlaid with the satellite image to estimate the population density in the surroundings of the garden. The population of the 1km grid where the garden is located was taken as the population density for the garden and its surrounding area. The Network Analyst tool in ArcGIS was applied to conduct accessibility analysis, calculating the distance from the gardens to the city centre, public green areas, busy roads, and public transport, respectively.

To test the tool in other UA initiatives that employ different technologies, the research team reached out to stakeholders within the SiEUGreen project in 2021. This resulted in the following outcomes:

- **Turunçlu Greenhouse, Hatay**: Implementation of the showcase had advanced significantly since our previous discussions regarding Deliverable 1.4. As a result, it was now possible to test to tool in the greenhouse.
- **Chinese showcases**: A dialogue with CASS began in May 2021 to explore the possibility to test the tool in Sanyuan Farm. After several exchanges, the team found out that researchers outside China are not allowed to collect data about UA activities conducted within China. Further, the Chinese partners could not collect data on behalf of actors outside of China. Therefore it was impossible to coordinate data collection activities beyond the sharing of ideas that had already occurred when preparing the original deliverable.
- **Campus Ås**: Discussions with NMBU revealed that it was not possible to test the framework in Campus Ås due to delays in the implementation of SiEUGreen technologies.

Given the challenges associated with testing the tool in the Chinese and Norwegian showcases, the research team explored opportunities outside the SiEUGreen project. To provide the requisite contrast between the gardens already assessed, the team prioritised finding a garden with a commercial focus and high technology use. Two options presented themselves:

- **Company A**: Established in 2011, Company A uses waste heat to produce food in a large greenhouse. It is a reference project for the energy-efficient use of waste heat and operate completely without any bought-in energy.
- **Company X:** A privately driven for-profit business focused on reducing food miles using cutting-edge vertical farming technology that is used to grow food in supermarkets in inner urban areas and vertical farms in the peri urban area.

Company A was rejected as an example in which to test the tool on two grounds. First, it was quite similar to the Hatay showcase in terms of the technology used (greenhouse, aquaponics and hydroponics) and therefore did not present substantial additional learning opportunities. Second, the greenhouse was located on the outskirts of a small village, thus calling into question a classification as "urban" agriculture. In contrast, Company X was deemed to be an excellent opportunity to test the framework for several reasons. First, Company X is a commercial enterprise employing a complex array of technologies in their growing practices, providing a very different context in which to test the tool. Second, Company X is located in a large European city outside of the Nordic Region, thus providing some geographical and cultural contrast.

Discussions with representatives of both Turunçlu Greenhouse and Company X began via email in mid-June. Initial meetings were held with representatives of both initiatives, which included:

- A presentation of the SiEUGreen project (only in the case of Company X) and the assessment framework.
- A presentation of the results of the implementation of the framework in the two Taste Aarhus gardens, and explaining the potential benefits of the process.
- A description of what would be required from them should they choose to take part.

Shortly after these initial meetings, both Turunçlu Greenhouse and Company X agreed to participate in a workshop designed to test the responsiveness of the tool to their initiative. The main aims of the workshop were to:

- Present the SiEUGreen monitoring framework for urban agriculture in detail.
- Consider how the tool responded to the particularities of the initiative in question, with respect to its contribution to urban sustainability.
- Gather suggestions on how to improve the framework (in general) and for new indicators that could be introduced in the assessment.

The workshops were facilitated using the online whiteboard tool, Miro, and included discussing the relevance of each aspect of the tool in the context of the UA initiative in question as well as brainstorming ideas for new indicators. Figure 4 and Figure 5 provide a snapshot of the interactive workshop documentation process.[2]

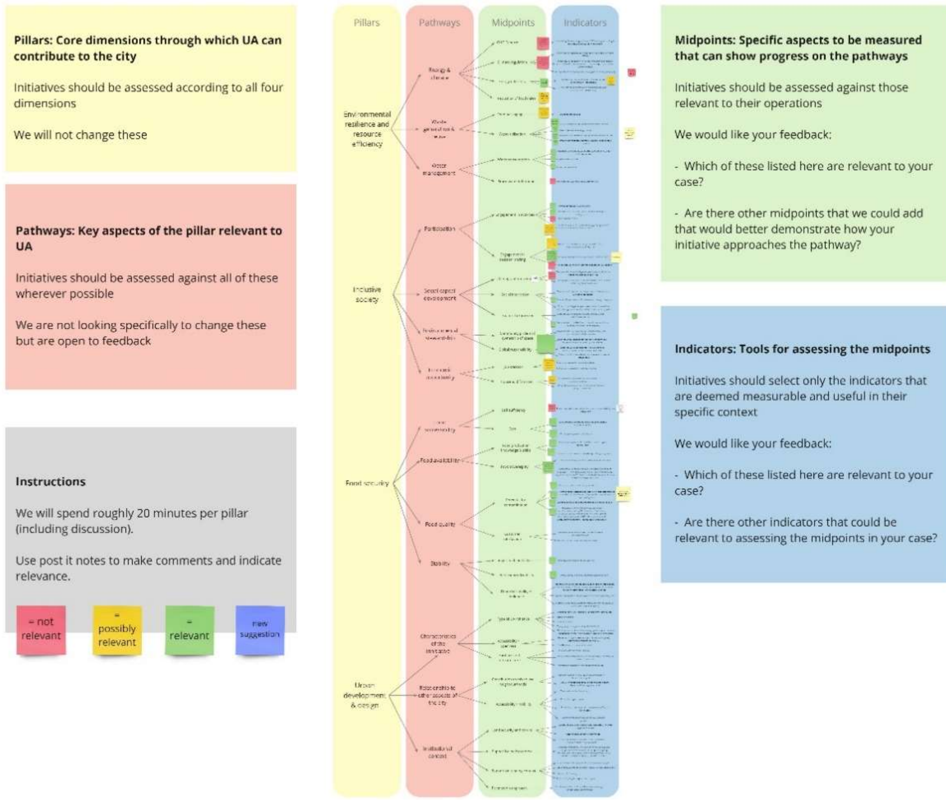


Figure 4: Snapshot of the workshop with the leaders of the Turunçlu Greenhouse

[2] Note: Examples of workshop documentation are given only for the workshop with leaders of the Turunçlu Greenhouse UA initiative due to data sensitivity concerns from Company X.

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Co-funded by the Chinese Ministry of Science and Technology

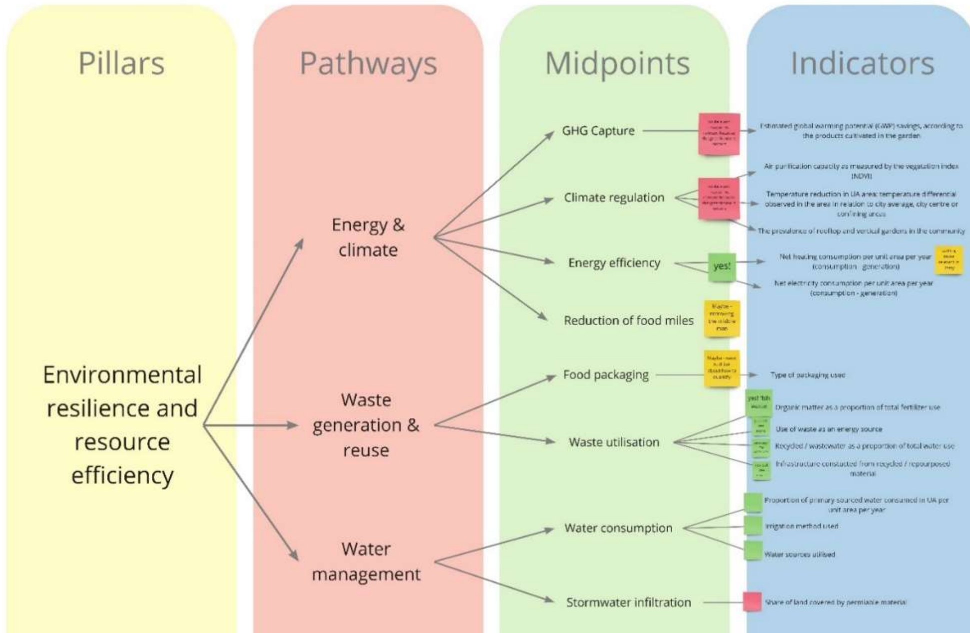

Figure 5: Example of workshop documentation: Turunclu Greenhouse

Following the workshops, data collection tools were developed for each case. For Company X, this included a single questionnaire which clearly outlined the indicators selected and requested the data required to calculate each indicator. For Turunçlu Greenhouse, two questionnaires were developed. The first, aimed at the organisers of the initiative, clearly outlined the indicators selected and requested the data required to calculate each indicator. The second was designed to collect data from participants in the initiative. The first questionnaire was delivered and filled out in English. The second questionnaire was delivered in English and translated to Turkish by the organizers of the initiative. The data collection tools can be found in Annex 6.4 and 6.5).

Data were delivered by Turunçlu Greenhouse, allowing the framework to be applied in full for this case. The results are shown in the next section of this report. Unfortunately, concerns about the collection and sharing of data prevented the full application of the framework in the case of Company X. Despite this disappointing outcome, the insights from Company X were useful in further developing the framework to respond to a commercial enterprise.

3.1.2) Case: Brabrand

About the garden

Brabrand is one of the oldest gardens of the Taste Aarhus Program. It was established in 2014 by an architect, who, together with 20 others interested in growing food, rented out an area in the peri-urban area of Aarhus Municipality, approximately 8 km from the city centre. Currently, 100 members cultivate vegetables in an open-air area and in two large greenhouses that were previously used for commercial growing of herbs and ornamental flowers. The total size of the plot is 11 000 m^2 (see Figure 6). It includes 6 000 m^2 of open cultivation land, 3 000 m^2 of greenhouses, and 2 000 m^2 of other built facilities. The garden includes amenities such as a shared kitchen, toilets, and a storage room for tools.

In September 2019, a solar-driven toilet was implemented in the site as part of the SiEUGreen project. This toilet does not use water to flush the waste and, powered by the sun, transforms the waste into biochar, which is charcoal that can be used for soil additive and, as a fertiliser for growing food. This technology aims to demonstrate alternative ways of dealing with human waste (faeces and urine) while addressing the scarcity of phosphorous, a non-renewable resource fundamental for growing food. This toilet is currently in use, and the human waste (faeces and urine) after treatment will be used in a testbed that will be implemented in summer 2021.

The greenhouses allow for growing food over an extended period of the year and, as a result, this garden attracts a diverse range of participants from across the city. The garden has 85 beds in the open area and 80 in the greenhouses. All 165 beds are the same size, 50m^2. The total number of beds does not correspond to the number of members as many of them rent out two beds: one in the greenhouse and another in the open field.

Figure 6: Satellite Image – Brabrand

Source: Aarhus Municipality

The garden is situated between two farms and is fenced to protect the growing area from animals (e.g., deer, hare). The entrance gate is always open, but the greenhouses are locked during the night.

Grid electricity is available in the garden and is included in the rent. Consumption is low as electricity is used only sporadically to open the windows of the greenhouses, to charge batteries of the tools, and in the communal kitchen. The greenhouses are not heated. Groundwater is the main water source for cultivation, though rainwater is also collected. The most common irrigation method reported by survey respondents was manual watering (94%), and approximately half of the respondents also reported using the drip method.

Vegetables, herbs and flowers are cultivated in pallets outdoors and in the greenhouses, but some members also grow food directly in the soil. The use of pesticides and fertilisers is forbidden, and animal manure was the most common fertiliser use reported by respondents (92%).

Tenure is determined based on a formal agreement that is renewed on an annual basis. The private ownership of the land is perceived with concern, mainly because the land is currently for sale and the surrounded areas have been developed for residential purposes. According to the garden manager:

> *Maybe we can use this land for only two more years or maybe ten years. We do not know. But if we get displaced, we will just find some other area in the periphery of the city which has inactive greenhouses, and we will move in.*
>
> *Manager of Brabrand*, interview *in June 2018.*

In December 2020, the manager has been informed that the garden is under threat of eviction. In her words:

> *We are in Fællesgartneriet fighting right now against the municipality and the new plans for our land. We see a complete lack of understanding and nearly no interest in the value of our project. We produce food and make people happier; we have created something with great value for the city, but we have no documentation. The possibilities in large-scale urban farming and peri-urban farming are sadly unknown for the planners in Aarhus; they want us to move out soon and stop what we are doing.*
>
> *Manager of Brabrand,* e-mail communication in December 2020.

With regards to the economy, the initial set-up cost of 20 000 DKK (approximately 2 700 Euros) was backed by the 20 members who established the garden. This capital was used to rent out one of the greenhouses of the site. Currently, the annual cost is around 100 000 DKK (approximately 13 400 Euros) 40 000 of which is dedicated to operational costs (e.g., supplies, maintenance) and 60 000 of which covers the lease of two greenhouses and the open field. These costs are covered with the membership fees that vary between 450 and 1 850 DKK per year, depending on the conditions of the plots. This results in annual revenue of 110 000 DKK per year, leaving the association with a surplus of 10 000 DKK which is used to deal with unforeseen issues, if necessary. The garden has no employees, and the management is based on voluntary work. Still, currently, there is a part-time worker, who is sponsored by SiEUGreen project to maintain the solar-driven toilet and for implementing the test-bed.

The board of the garden has six members who are elected by the garden membership. The board takes the major decisions in six yearly meetings. The Facebook page is the main channel for communication between the members and is also the main platform to share achievements, disseminate information and report problems.

About the gardeners

Forty-eight of the 100 members of Brabrand participated in the online survey. Their demographic makeup is shown in Figure 7.

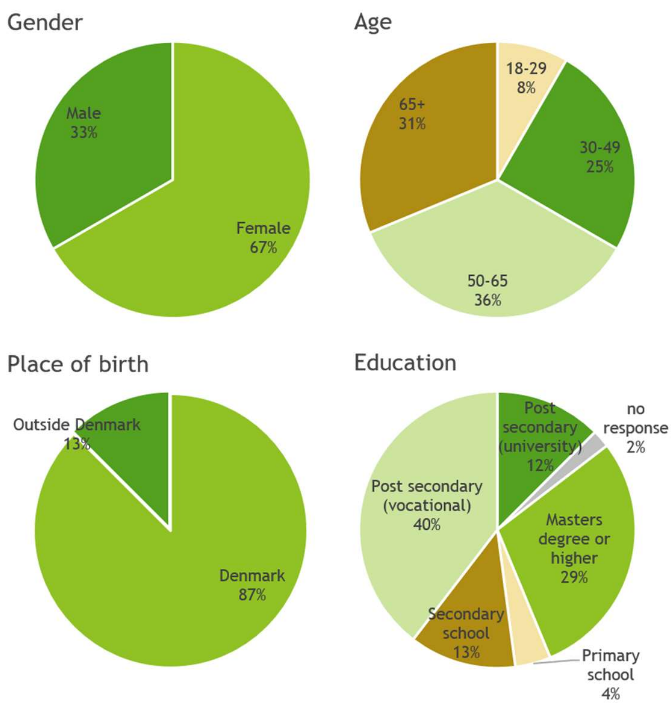

Figure 7: Demographic background of the respondents - Brabrand

The most common motivations for involvement in the garden were relaxation/stress relief, to get access to fresh organic food and to reduce the environmental impact of the food consumed (see Figure 8). Over 80% of participants reported these aspects as being either important or very important motivators. In contrast, few respondents reported financial or cultural/religious motivations.

Figure 8: Motivations to gardening - Brabrand

Most respondents visited the garden once a week (44%) or more (50%). The duration of visits ranged from less than 1 hour (6%) to over 4 hours (10%), with the majority of respondents reporting visits of 1-2 hours (44%) or 2-4 hours (38%). The most common way to travel to the garden was to cycle (54%) or drive alone in a car (31%). Just over half of respondents could reach the garden in under 20 minutes, and a further 25% could reach the garden in under 30 minutes.

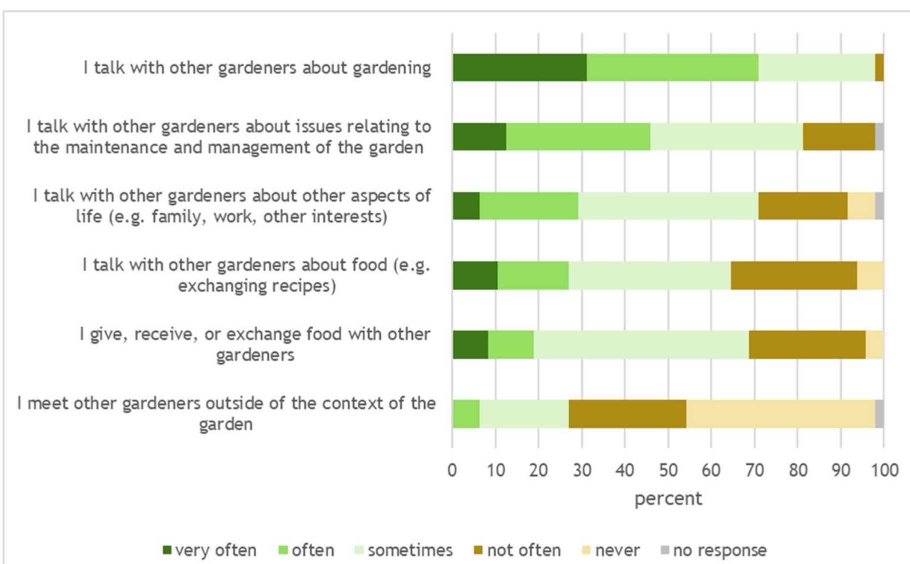

Figure 9: Social interaction promoted by the garden - Brabrand

With regards to social interactions, the most common uniting factor was, perhaps unsurprisingly, gardening, both in a general sense and with respect to the maintenance and management of the site (see Figure 9). In a general sense, other garden members were seen as an important source of knowledge, with most respondents (93%) reporting that they learned about growing through their interactions with other gardeners. Workshops about how to grow, cook and conserve food are frequently held onsite, and, according to the garden manager, these workshops are not just attractive to garden members. Visitors to the garden made up approximately half of the participants in the workshops held during last year. Other common methods for learning about how to grow healthy food included learning by doing (93%) and accessing information online (93%).

Almost all respondents reported growing vegetables in their garden, and almost 60% reported growing fruit. Only 15% reported growing or producing other products in their garden. A more detailed picture of respondents' fruit and vegetable growing is shown in Figure 10 and Figure 11.[3]

[3] The percentages shown in Figure 10 and Figure **11** are based on the total number of respondents who reported growing vegetables (n = 47) and fruits (n = 28) respectively.

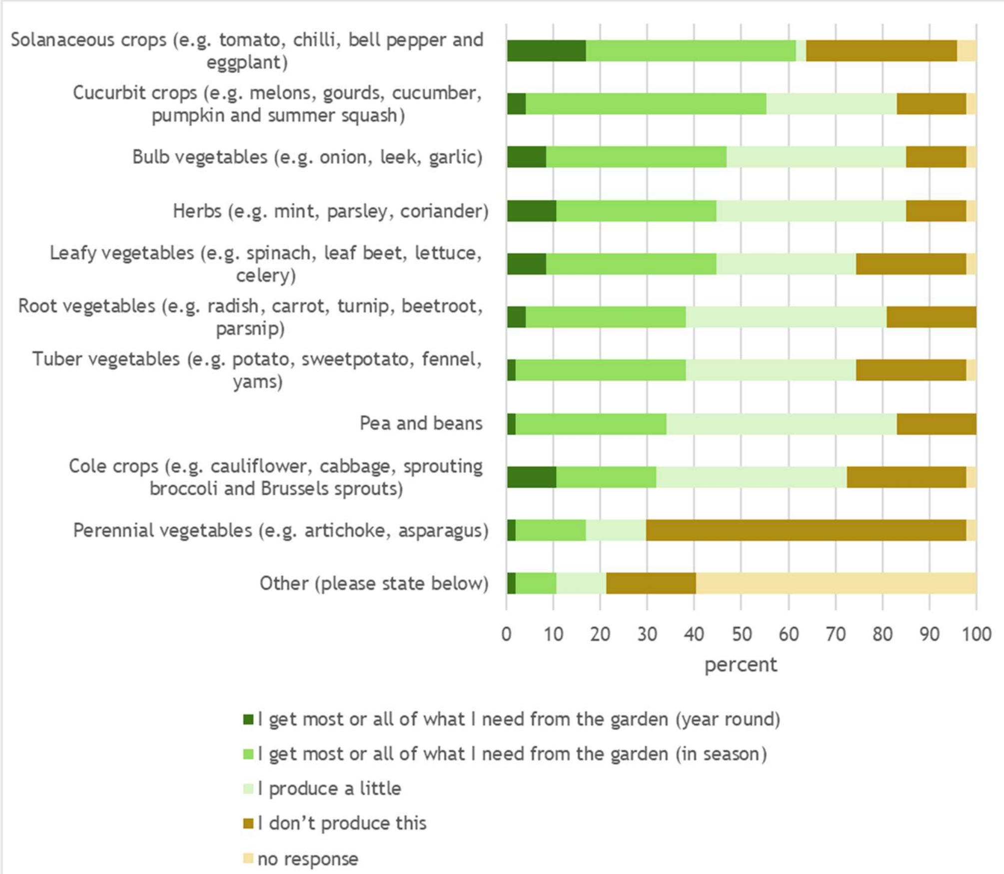

Figure 10: Types of crops produced in the garden vs needs of gardeners - Brabrand

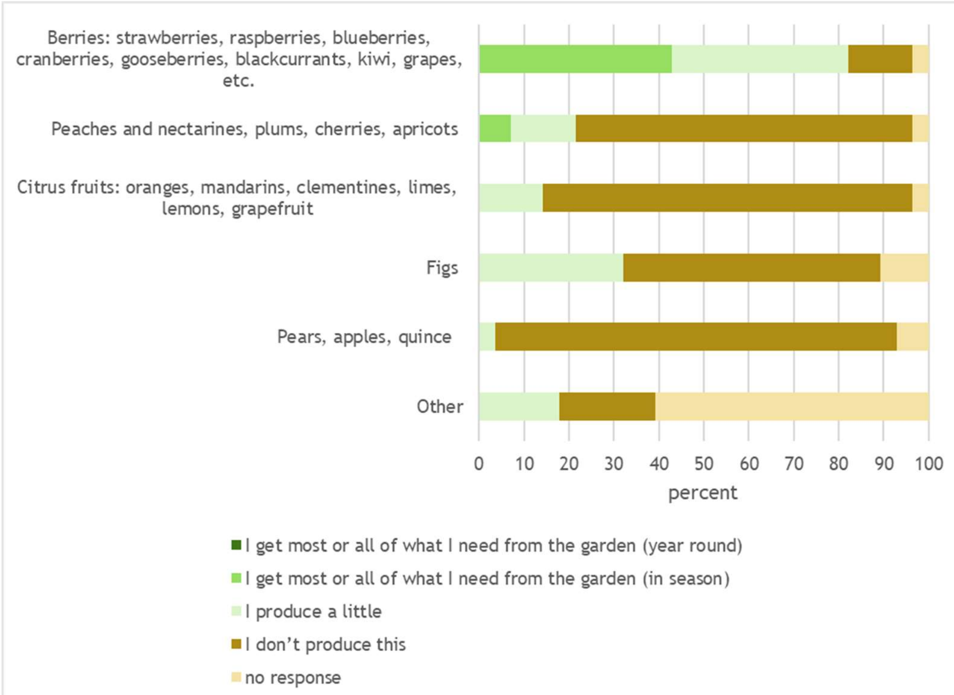

Figure 11: Types of fruits produced in the garden vs needs of gardeners – Brabrand

As can be seen from Figure 10 and Figure 11, respondents were much more likely to meet most or all of their vegetable needs through their garden than their fruit needs. The most commonly grown vegetables were solanaceous crops (e.g., tomato, chilli, bell pepper and eggplant), bulb vegetables (e.g., onion, leek, garlic), and cucurbit crops (e.g., melons, gourds, cucumber, pumpkin and summer squash). The most grown fruit was berries. Vegetable production was also described as being more predictable than fruit production (see Figure 12).

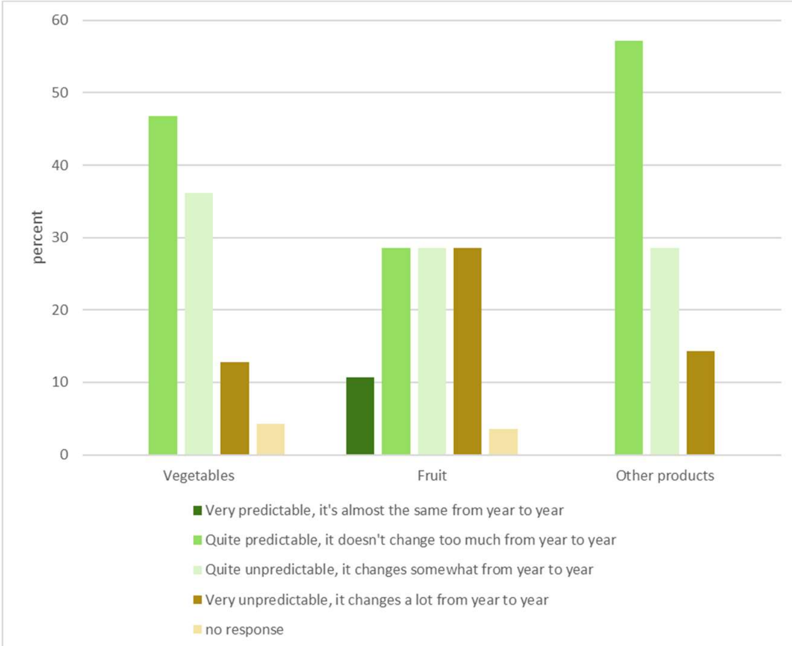

Figure 12: Predictability of the harvest - Brabrand

As noted above, economic motivations were not common among the garden participants. Only one respondent reported receiving income by selling products grown or produced in the garden. Five respondents reported a proportion of their annual income coming from activities related to the garden, though the proportion of annual income related to garden-based activities did not exceed 5%. The main expense for gardeners was the annual fees (see Figure 13)

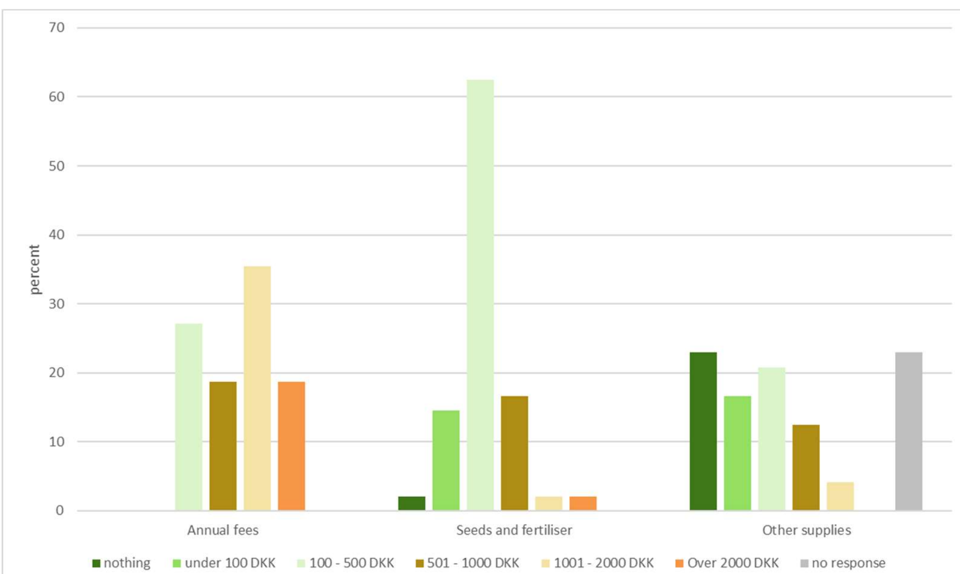

Figure 13: Main expenses for the gardeners – Brabrand

The main benefits of the garden reported by respondents were stress relief, improvements to their overall health and fitness and a sense of individual and community pride (see Figure 14). A substantial number of gardeners also reported reducing their carbon footprint through their involvement in the garden, making new friends and improving their diet.

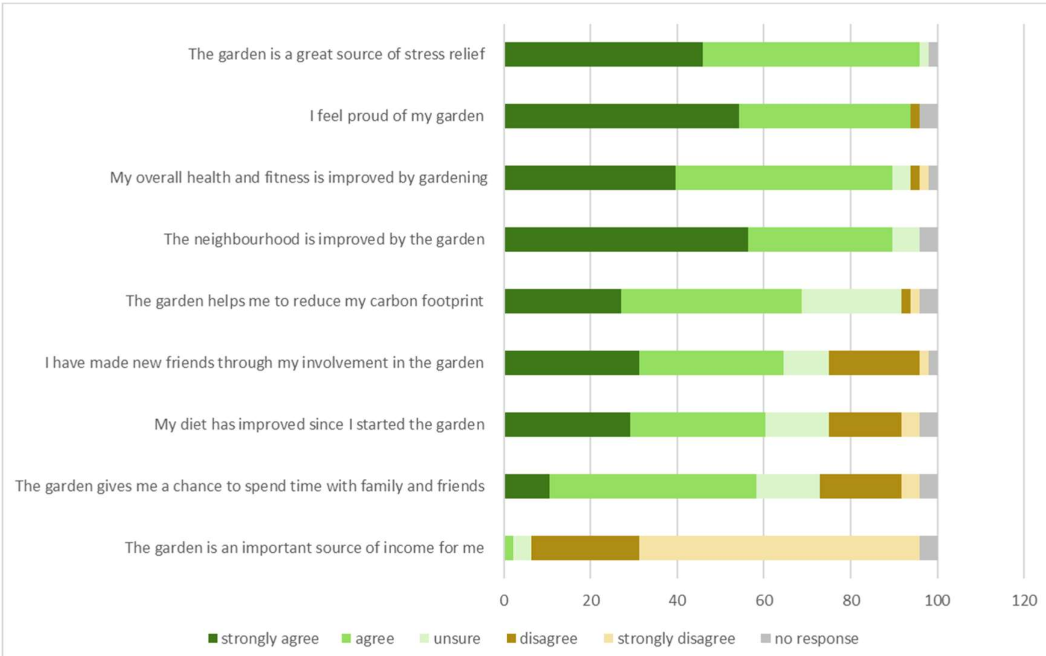

Figure 14: Benefits of the garden – Brabrand

The true value of the garden is perhaps best elicited through the qualitative responses given at the close of the survey in response to the question *"Tell us in your own words what you see as the greatest benefits of the garden for yourself and for the city".* Twenty-nine of the 49 survey respondents answered this question, with responses ranging from short statements to whole paragraphs. Responses were coded using an open coding technique that responded to all aspects of each response (i.e. a single response often received several codes, according to the themes raised). The most common aspect raised was the wellbeing benefits associated with participation in the garden. These responses often referred to stress relief, positioning the garden as a kind of antidote to city living.

The next most common responses all related to a connectedness of some kind. The most common was social connectedness. This, at times referred to the garden as an avenue for increased connectedness between existing social contacts (e.g., grandparents and their grandchildren). More often, however, it referred to a connectedness between strangers, united by a common love of gardening. The second type of connectedness that was commonly reported was connectedness to nature. The ability to follow the seasons through the growing process was a particular source of joy for many. Finally, garden members reported connectedness to the food they consume. Importantly, these responses were distinct from those which reported the food itself as a benefit and related specifically to an increased understanding or consciousness of the food-production process.

Other aspects that were raised by several respondents included: environmental and conservation benefits, increased access to organic food, the garden's contribution to improving the city, and the development and exchange of knowledge. The following quote from one survey respondent encapsulates nicely several of the themes raised:

> *The garden is a huge asset. If you are depressed and go out into the garden, it is certain that the mental clouds will disappear even if the weather is bad. It is also incredibly nice and life-giving to see all the different birds (now also rare) that use Årslev Engsø and the surrounding areas. It is really worth its weight in gold for the city to have this enclave, the city's breathing hole/lung. Where even the receding insects can thrive. The community is also a very important thing – the linking of new friendships across social strata, where the importance of healthy lifestyles and helpfulness, care and interest can unfold and bind people together with a better quality of life. Not least in these corona-times when one can meet in the open air and be together with distance. I've been part of the community since it started and am incredibly happy that it exists. I can't imagine not having this lovely plot anymore.*
>
> *Garden participant* Brabrand, survey conducted in September 2020 (translated from Danish to English by the authors).

3.1.3) Case: Pier 2

About the garden

Pier 2 was established in 2017 by a group of enthusiastic citizens. The garden came about following a workshop carried out by Taste Aarhus Program to promote the use of underutilised spaces and meet the growing demand for gardens in the harbour area. As shown in Figure 15, the total surface area of the garden is 500 $m^{2,}$ and it includes 45 plots made of pallet frames of $4m^2$ each. The garden neighbours two other Taste Aarhus gardens: Dome of

Visions and Coffee grounds to Gourmet. The Dome of Visions aims to showcase new ideas in construction and urban thinking and planning and inspire solutions for climate change. This initiative is currently under the responsibility of Aarhus Municipality. 'From Coffee grounds to Gourmet' is a group which collect coffee grounds from local restaurants and cafes. They use these grounds to grows mushrooms which are then sold back to the restaurants and cafes for use in their cuisine.

Pier 2 offers an opportunity for people who live in the city centre to grow food and reconnect with nature, and it is also a mean of transforming an unattractive, unused space into a site of social interaction. The number of members (60) exceeds the number of beds (45). This reflects the popularity of the garden, which has had a significant waiting list since its inception. Nevertheless, as the garden manager explained, only ten members have been involved since the garden was established. The main reason for this is that many members have moved away from the city centre to the suburbs.

The garden is not fenced, but the limits of the plot are defined by pallets where the members grow flowers and herbs. A sign with the name, history and rules of the garden was recently installed. This intervention aims to create a sense of privacy, organisation and also spark the interest of the general public. Facilities are limited to one shelter where the members store a few tools. There is no toilets and no kitchen or place to prepare food. When necessary, the members make use of public restrooms located in the Dome of Visions. Neither electricity nor heating is available at Pier 2. Currently, grid water is the main water source for cultivation, though there are plans to install a rain-water tank in 2021.

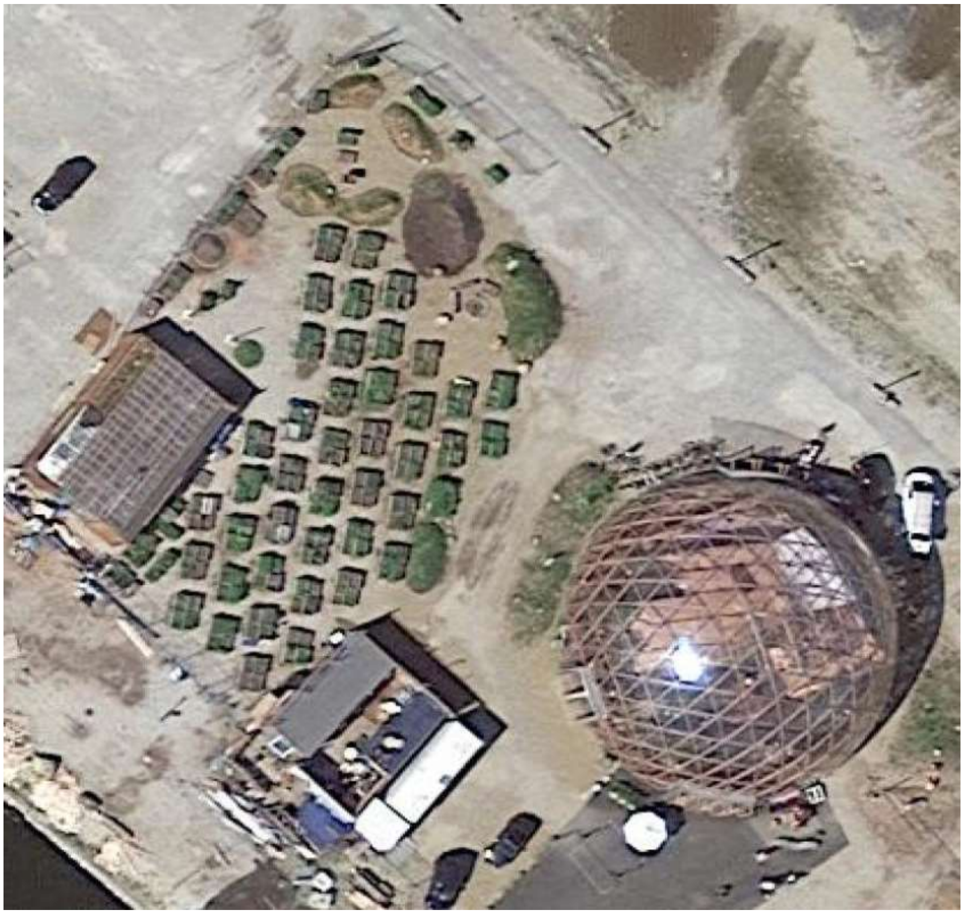

Figure 15: Satellite image – Pier 2
Source: Google

The garden is located on public land, and tenure is based on an agreement that is updated every two years. Despite this, the garden manager expressed concerns about the lack of long-term security. She explained that this issue influences budget allocations and calls into question the wisdom of spending resources in a garden that is temporary.

Pier 2 has a robust economic situation. The start-up funding of 40 000 DKK in 2017 has undoubtedly contributed to financial stability. In the first year, this resource was dedicated entirely to an investment in the 45 pallets. This enabled the quick engagement of members who paid a membership fee of 250 DKK per year. Subsequently, a turnover of 51 250 DKK (start-up funding plus membership) was reported in the first year, providing a solid economic basis for future activities. Currently, the garden has an annual turnover of around 16 000 DKK and members pay 350 DKK annually to be part of the Pier 2 community.

According to the manager, the financial surplus has allowed for some interventions aimed at improving the site (e.g., install pallets that delimitate the area of the garden, information signs that mark the entrances, purchase a table, grass, solar bulb lights, beach umbrellas, hammock). It also incentivises the establishment of groups, who can enjoy financial support to realize activities in the garden (e.g. compost, social events).

The garden does not have many expenses as machinery and tools, are borrowed from different members who partake other UA initiatives in the city. The maintenance of the common areas (e.g., pallets that define the limits of the garden) is shared among the members, and the garden has no employees.

The garden is run by a board that consists of seven members that meet around five times per year. One of these meetings is the general election, where the new management group is chosen to operate in a yearly mandate. This meeting is also the one where new members sign up to the garden. During the interview, the garden manager described the management of the garden as being quite open, as any member can propose activities and interventions. There are 'task forces' that engage different members who take responsibility for dealing with different issues such as the organisation of social events, composting techniques, spreading information on methods to grow, and ordering material for the maintenance of the garden. The Facebook page is the main channel to exchange information, share pictures, raise issues, and solve problems.

About the gardeners

The survey was distributed to all members of Pier 2, and a total of 11 responded. Unfortunately, this small sample raises some questions about the representativeness of the data. These concerns are addressed as relevant the sections dealing with the interpretation of the results and in section 4). The demographic makeup of the 11 respondents is shown in Figure 16.

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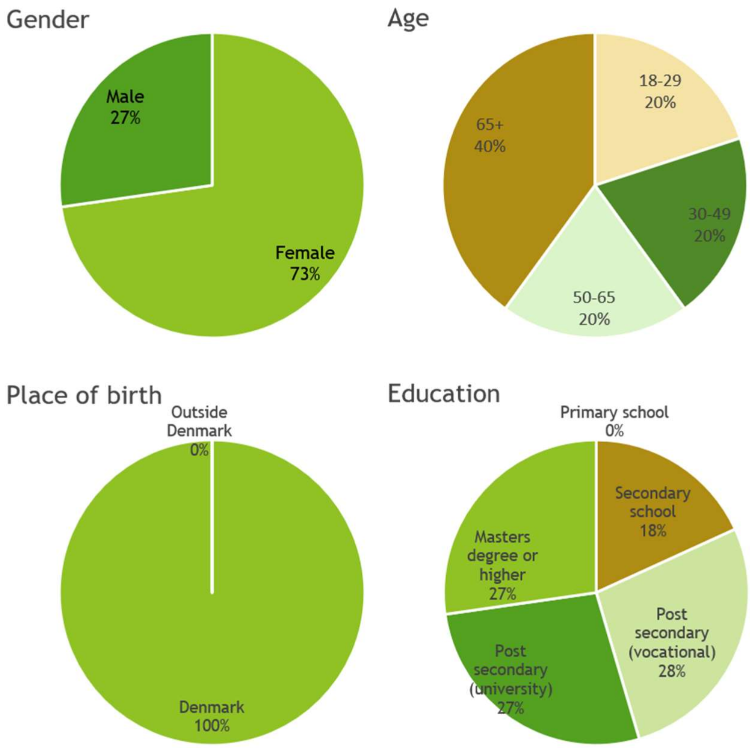

Figure 16 – Demographic makeup of survey respondents for Pier 2

As can be seen in Figure 17, the most common motivations for involvement in the garden were relaxation/stress relief, improving my neighbourhood/city, and meeting new people. Over 70% of participants reported these aspects as being either important or very important motivators. According to the garden manager, having a place to grow food is often important as an initial motivator, but once people get involved in the garden community, social motivations become equally important. Few respondents reported financial or cultural/religious motivations. Consistent with this, no participants reported selling anything that they had produced in their garden nor having any share of their income coming from garden activity. This is also in line with the regulations of Taste Aarhus that does not allow the commercialisation of products from gardens located on public land. The main expense for gardeners was the annual fees (see Figure 18).

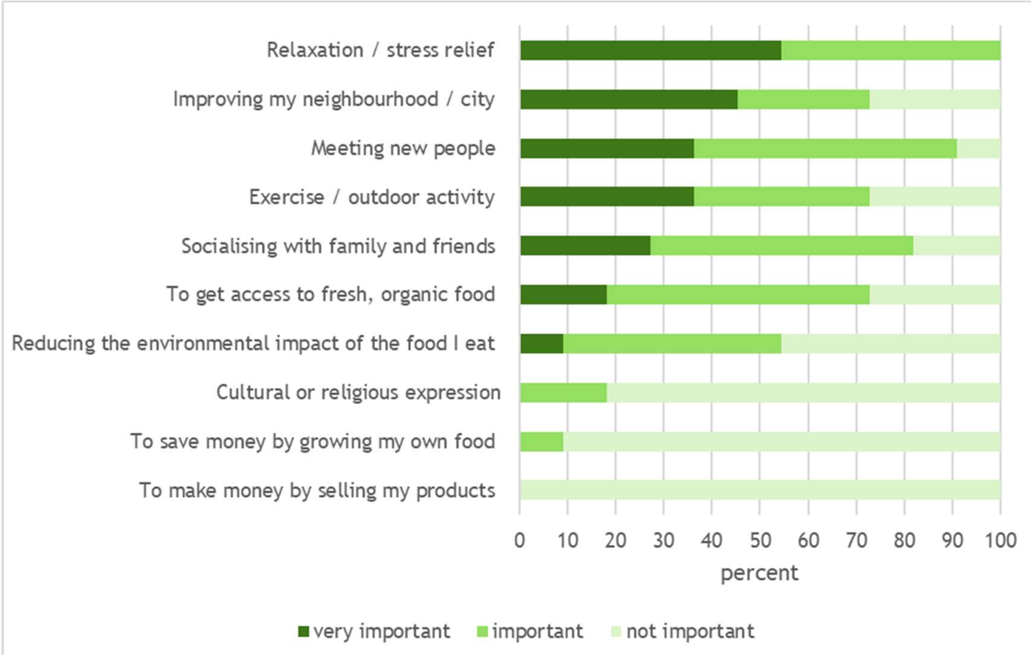

Figure 17: Motivations for gardening – Pier 2

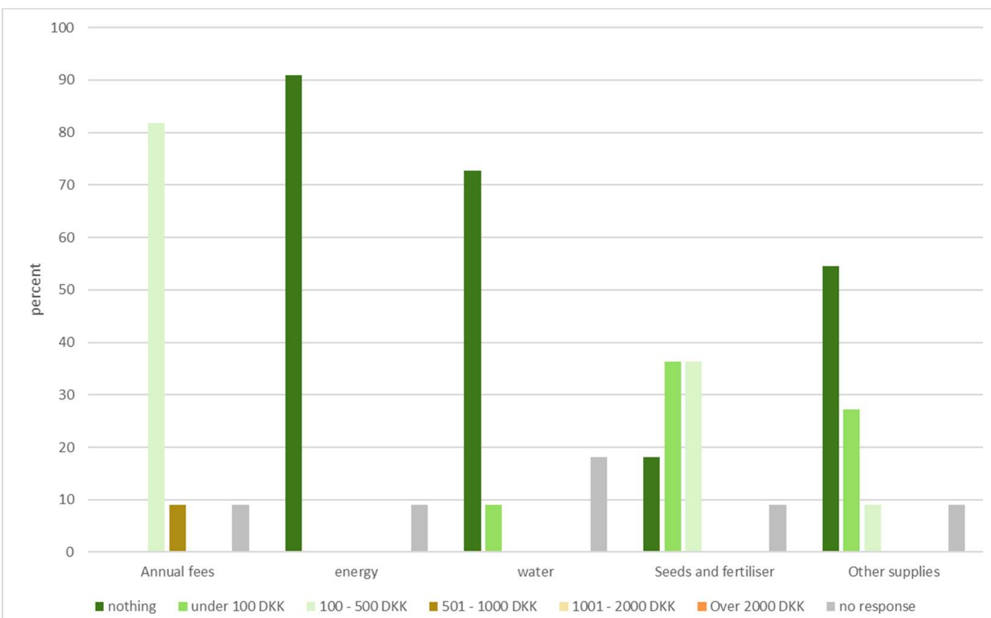

Figure 18: Main expenses for the gardeners – Pier 2

Most respondents visited the garden once a week (27%) or more (54%). The duration of the visits was reported as being either less than 1 hour (45%) or 1-2 hours (55%). All respondents reported either cycling (64%) or walking (36%) to the garden, and almost all respondents could reach the garden in under 20 minutes (91%).

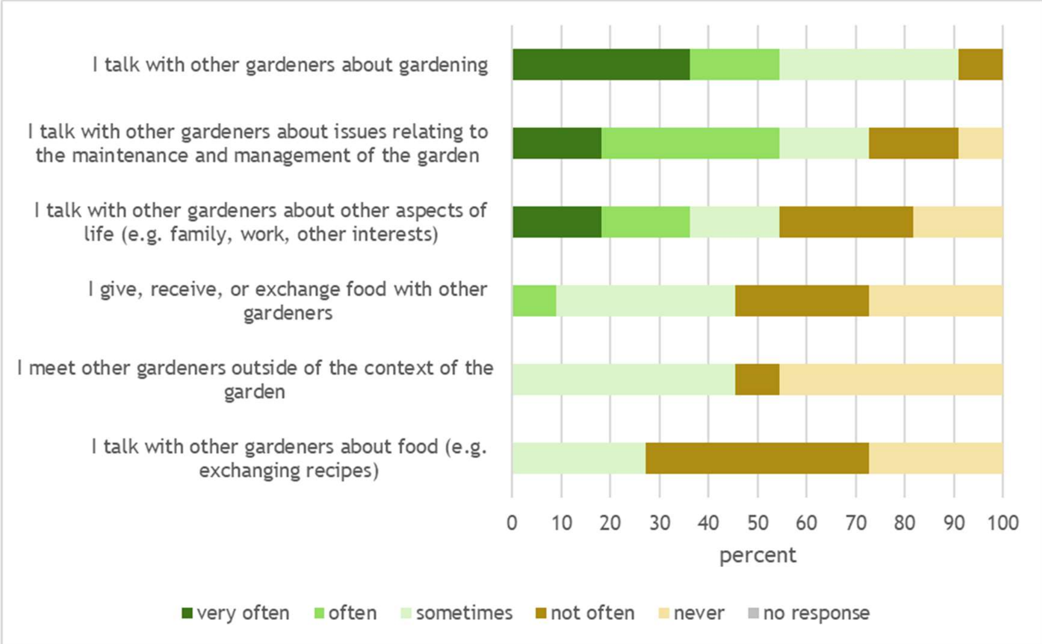

Figure 19: Social interaction promoted by the garden – Pier 2

With regards to social interactions, the most common uniting factor was, perhaps unsurprisingly, gardening, both in a general sense and with respect to the maintenance and management of the site (see Figure 19). There was also some evidence of deeper interactions such as discussions about other aspects of life and sharing food. Meeting other gardeners outside of the context of the garden appears to be less common.

Other gardeners were also a common source of new knowledge about gardening for most respondents (82%). Other common methods for learning about how to grow healthy food included learning by doing (64%) and accessing information online (64%). There are plans for a more structured approach to knowledge development in collaboration with the neighbouring Dome of Visions and from coffee grounds to gourmet in future, but, as yet, no formal knowledge-sharing events have been held at the garden.

All respondents reported growing vegetables in their garden, and one reported growing fruit. None reported growing or producing other products in their garden nor producing products of animal origin. A more detailed picture of respondents' vegetable growing is shown in Figure 20.

Figure 20: Types of crops produced in the garden vs needs of gardeners – Pier 2

As can be seen in Figure 21, only a very small portion of respondents fulfil their vegetable needs through their garden, with most producing only a little of each commodity. The most grown vegetables were herbs and tuber vegetables (e.g., potato, sweet potato, fennel, yams). Vegetable production was reported as being relatively predictable while fruit production was viewed as very unpredictable by the one participant who reported growing fruit.

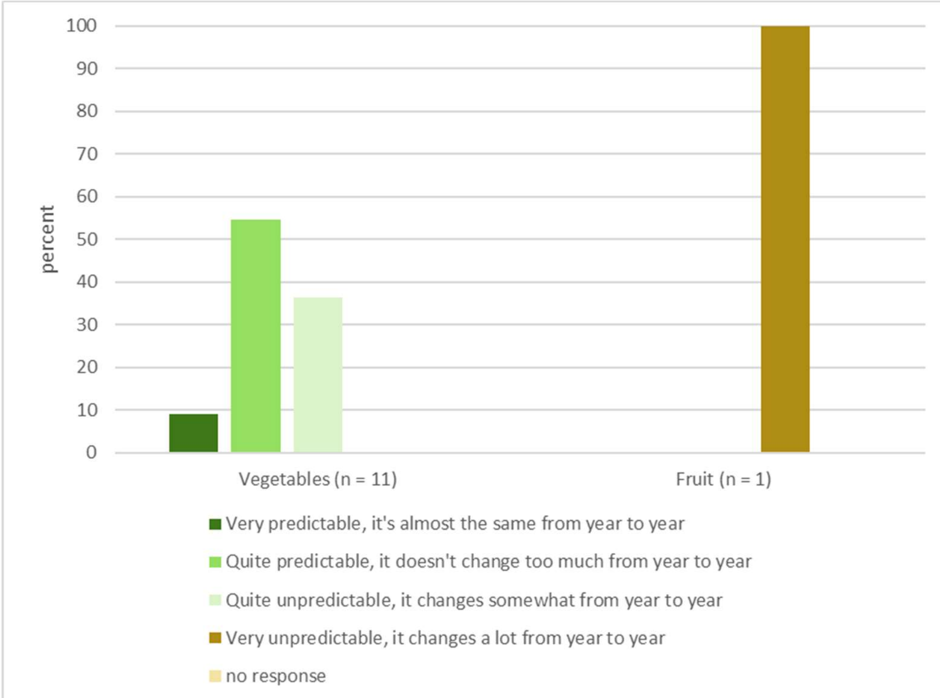

Figure 21: Commonly grown crops – Pier 2

None of the survey respondents reported using pesticides in their gardens, and those who used fertilizer used organic materials such as animal manure (18%), household waste (9%) or other organic fertilizer (55%). According to the manager, there are plans to implement a common compost system in the coming months. All survey respondents reported watering their garden manually with a watering can.

When it comes to the main benefits of the garden, all participants reported that their garden contributed to a sense of individual and community pride (see Figure 22). Many participants also agreed that the garden provided a great sense of stress relief as well as a chance to spend time with family and friends. These ideas are further elicited in the free-text responses to the final question of the survey *"Tell us in your own words what you see as the greatest benefits of the garden for yourself and for the city".*

Here, several participants emphasised the social connections that were made through the garden. For example:

> *Everyone speaks to everyone because of a small piece of land and plants. That's the unique thing. It requires that you talk to strangers you otherwise do not want to talk to - so the social aspect and the community are the most important – not so much the plants.*

Garden participant Pier 2, survey conducted in September 2020 (translated from Danish to English by the authors).

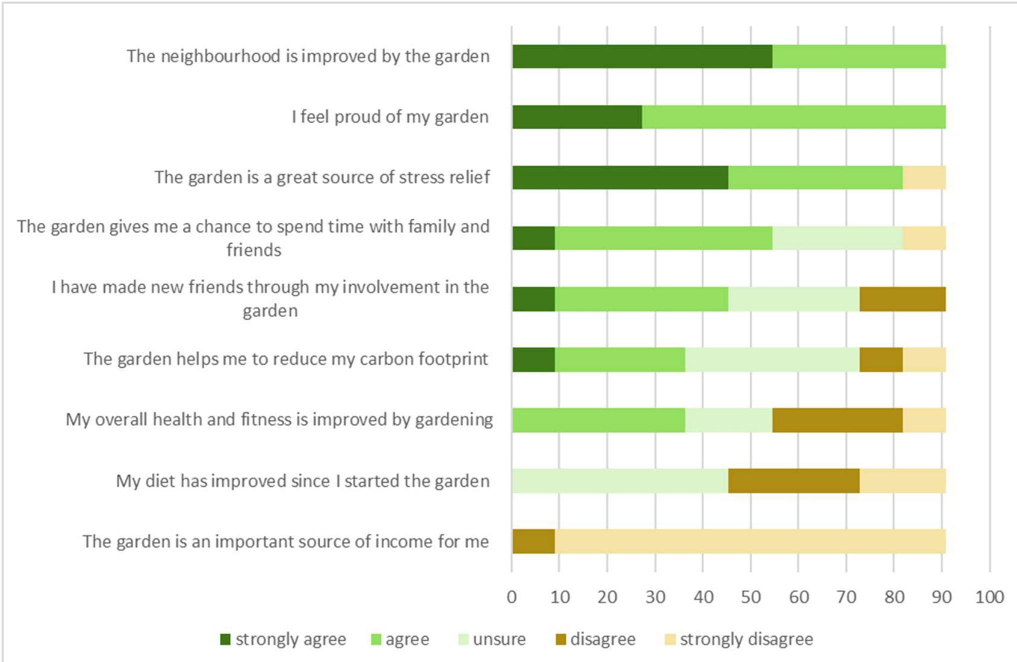

Figure 22: Benefits of the garden– Pier 2

3.1.4) Case: Turunçlu Greenhouse

About the greenhouse

Turunçlu greenhouse was built by Hatay Municipality, with the support of SiEUGreen European funding, and has been in operation since May 2021. The greenhouse is located in the southern part of Antakya, capital of Hatay. The plot is 45000 m^2 and belongs to the Department of Parks, Gardens and Green Areas of Hatay Municipality. Prior to becoming a greenhouse, the area was used as a nursery for the Department of parks, gardens and green areas. The greenhouse consists of three tunnels with dimensions of 30 meters width and 50 m in length equalling 1500 m^2 of built area. Besides the greenhouse there is also in the plot a hobby garden (5000m^2), an open area for growing flowers and seedling (29000m^2), a pet care and shelter (6000 m^2) and the office of the department and parking lot with 3500 m^2.

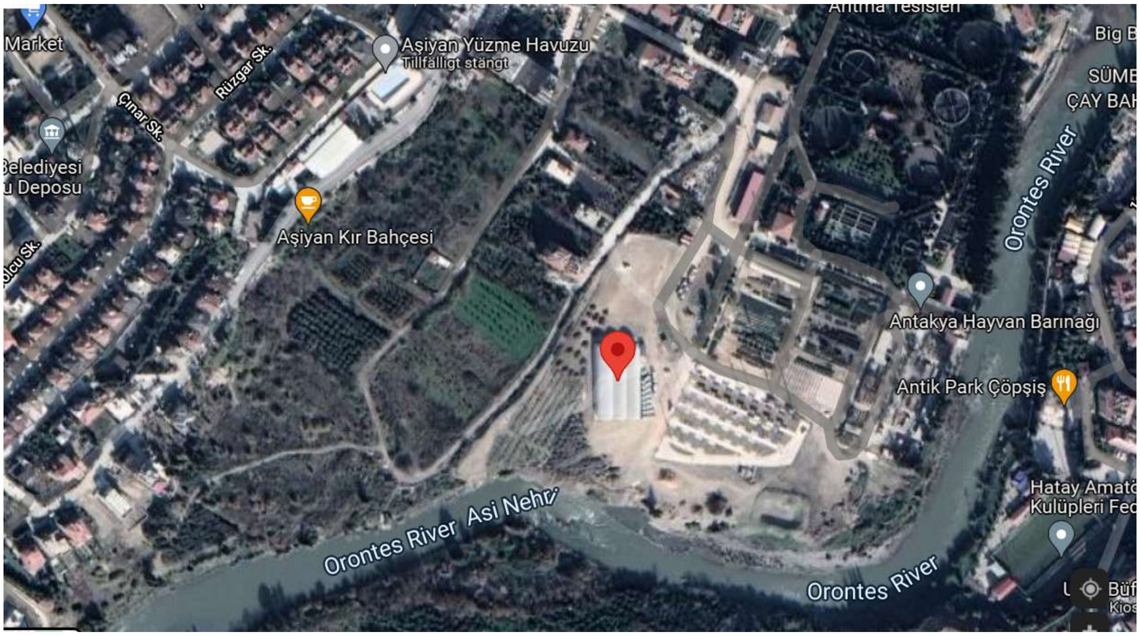

Figure 23: Location of the Turunçlu Greenhouse

Turunçlu Greenhouse showcases hydroponic and aquaponics technologies. Of the 1500 m^2, approximately 800 m^2 are occupied by 6540 holes in the grow channels where lettuce and basil are cultivated (see Figure 24). The aquaponics installation includes six fish tanks with a capacity of five tons each. These tanks are connected to a biofiltration pool, that collects the fish waste to produce a liquid fertiliser used in the hydroponic system. The installation of innovative features such as photovoltaic panels and sensors to control the quality of the environment (e.g., humidity) are planned for the coming months.

Co-funded by the Horizon 2020 programme of the European Union
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Figure 24. Aquaponic system

The land is owned by the municipality and tenure appears to be quite secure. Though there is no formal agreement in place stating that this land should be used as a garden, the substantial investment of the municipality in setting up the greenhouse makes a change of land use unlikely. The primary land use in the area is recreational (e.g., greenspace) but in the surroundings there is a water treatment plant and other municipal services. Some residential buildings with three or four stores high are also found in the neighborhood. Nevertheless, the population density in the area is not high as these buildings have between six to eight dwellings. Alongside financial support from the municipality, the initiative has also received considerable support from the EU Commission through the SiEUGreen project. The garden is run by the municipality and does not include any private or community partners.

The greenhouse uses natural heat and sources its other energy needs from the grid. All of the water used is recycled / wastewater and the hydroponic system uses 90% less water than traditional agriculture. All the fertiliser used in the initiative is organic and no chemicals are used on site. The main foods cultivated in the greenhouse include lettuce and basil. So far, two harvests have been made. Harvest 1 had a yield of 1 800 kg of lettuce and 1 250 kg of basil. Harvest 2 had a yield of 2 237 kg of lettuce and 1 529 kg of basil. Once harvested, the greens are generally consumed straight away. The yield is quite predictable. Nevertheless, part of the production was lost due to the warm weather in and lack of proper ventilation during the summer. There is however a degree of uncertainty when it comes to the financial stability of the initiative, as, currently, over 75% of the operational costs are covered by external grants.

The primary purpose of the greenhouse is social integration and to become an educational centre that will offer training on the new growing techniques (aquaponics, hydroponics and paper-based) to Syrian refugees and disadvantaged groups (e.g., members of Women's cooperative). To this end collaboration with the local universities is planned and the greenhouse will also function as a centre for disseminate the value of urban agriculture to younger students from primary and secondary schools. Up to December 2021, six workshops have been carried out engaging mostly women and volunteers that will work with the upcoming EXPO HATAY. These workshops engaged 148 people. Table 5 describes when these events took place, the target group and number of participants

Table 5. List of workshops carried out in Turunçlu greenhouse

Data (2021)	**Target group**	**Number of participants**
27th August	Students	33 students
3rd, September	Women	15 participants
17th September	Women	19 participants*
5th October	Women	26 participants*
22nd October	Volunteers for EXPO Hatay 2022	38 participants*
9th December	Women	17 participants

*Workshops that are part of the survey

The workshops run for a day. The program includes an introduction to the SiEUGreen project and technical specifications on aquaculture, aquaponics, and hydroponics. After this theoretical part, the participants are invited to the greenhouse where they see how these systems have been implemented. Figure 25 illustrates some moments of the workshops carried out in Turunçlu greenhouse.

Figure 25. Workshops held in Turunçlu

There is no cost to participate in the workshops and the food produced in the greenhouse is regularly donated through an initiative called the social market (see Figure 26). The greenhouse employs seven people fulltime; however, it should be noted that these people were already employed by the municipality before the UA initiative began. Participants in the initiative do not play any formal role in garden operations and the initiative does not have a board or a steering committee.

Figure 26. Social market in Hatay

About the gardeners

Participants of three workshops carried out in Turunçlu greenhouse participated in the short survey (see Annex 6.4) that informs the assessment. Of the 60 people who have participated in these workshops 51 provided responses to the questions. Surveys were translated into Turkish by the SiEUGreen partners and distributed in paper form at the conclusion of the workshop. Answers were then translated back into English and analysed by the research team. The demographic makeup of respondents is shown in Figure 2727. As the figure demonstrates, almost all respondents were women born in Hatay and over half had not taken their education beyond the primary level. Regarding age, approximately one third of respondents were aged over 65, approximately one third 50-65 years and approximately one third were aged between 18-50.

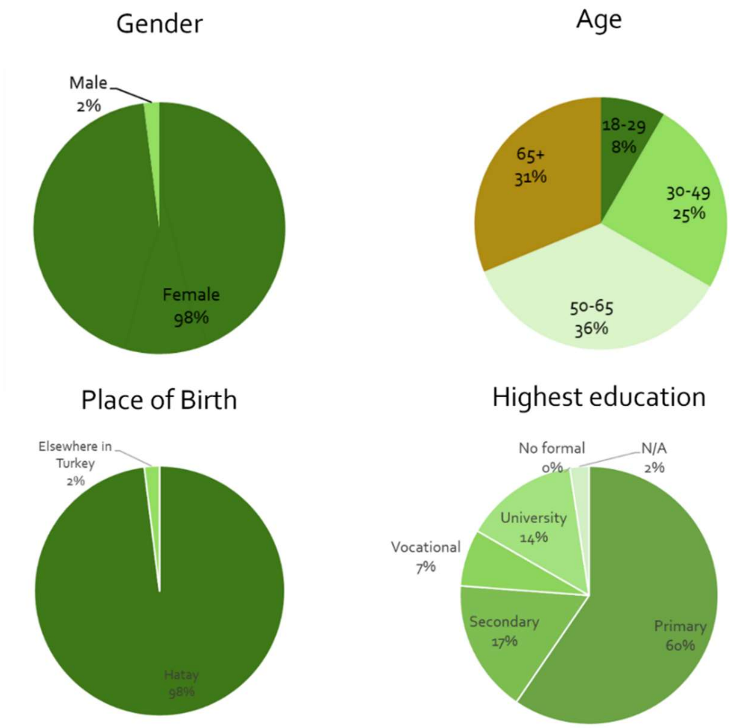


Figure 27. Demographic background of the respondents - Turunçlu Greenhouse

The most common motivations for involvement were learning how to reduce the environmental impact of food, to get access to fresh and organic food and exercise/outdoor activity (see 28). Over 80% of participants reported these aspects as being either important or very important motivators. In contrast, less respondents reported financial motivations.

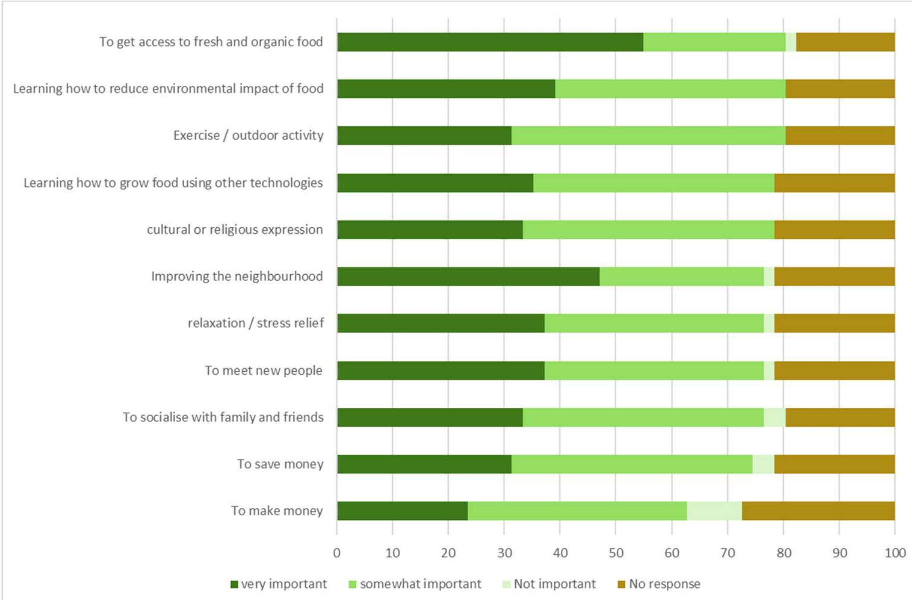


Figure 28: Motivations for taking part in the program

Although not one of the top motivators, 75% of respondents reported meeting new people as an important reason for participating in the course. A similar proportion reported that it was likely or very likely that they would see other course participants again in the future (see Figure 29).

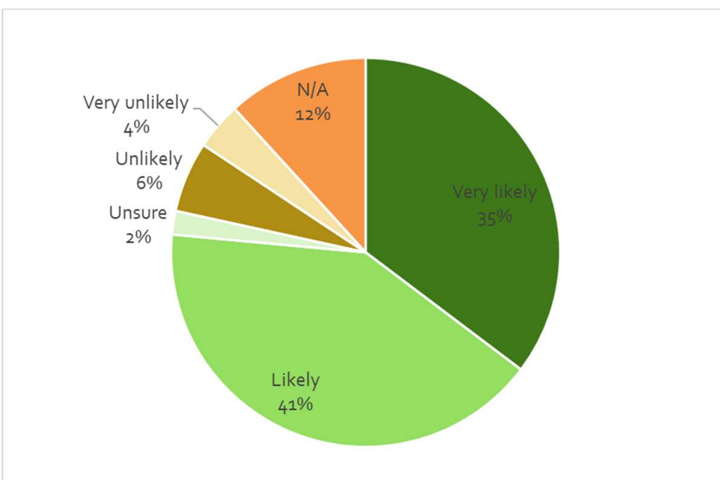


Figure 29. Likelihood of meeting other course participants again in the future

The main benefits of the course reported by respondents were stress relief, and social benefits (see Figure 30). In the free text responses, the participants expressed positive opinions about the training:

'I have obtained ideas that can contribute to the family economy. It was effective and useful'

'I was very surprised to hear plants can grow with fish manure. I got a lot of different information'

'By participating in this program, I both socialized and learned good practices. It was a nice event. Thank you to the organizers'

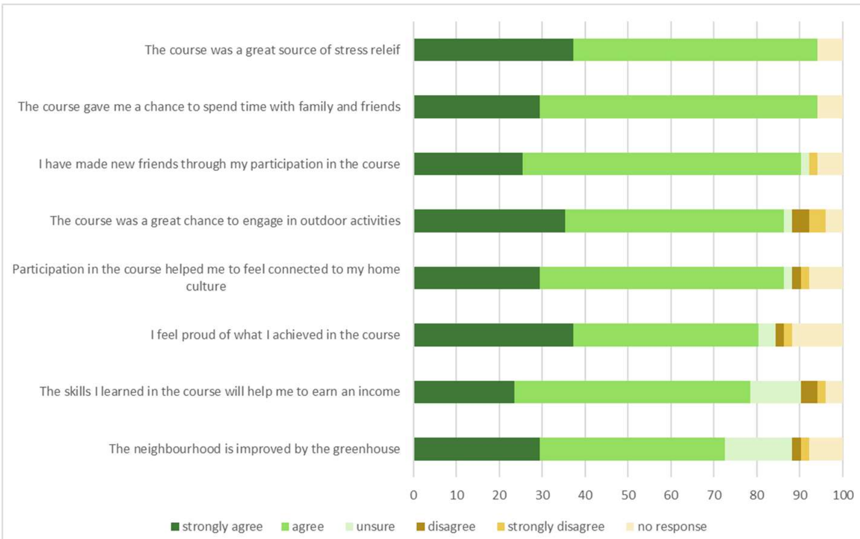
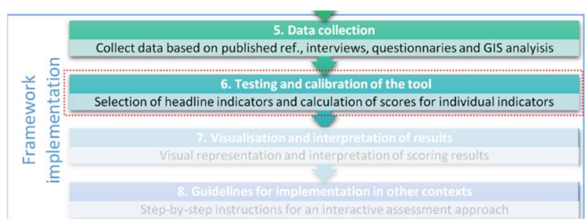


Figure 30. Benefits of participation in the course

3.2) Testing and calibration of the tool in the case studies



3.2.1) Selection of headline performance indicators

Headline performance indicators have been selected considering:

1) coverage of all sustainability pillars and relevant impact chains, consistent with the framework described in the previous section and with the UA practices observed in the case studies;
2) significance of the indicators, in terms of their capacity to illustrate the potential contribution to the sustainability pillars and domains to be profiled;
3) the characteristics of the gardens under analysis;

4) their interpretability and simplicity for communication purposes, and;
5) data availability at the garden level.

Table 6 provides a list of headline indicators selected for the evaluation of Brabrand and Pier 2 gardens, alongside complementary information regarding definitions and relevance. Table 7 provides the same information for the evaluation of Turunçlu Greenhouse.

Table 6. List of headline indicators included in the SIEUGreen monitoring framework for UA for Brabrand and Pier 2

Pillar	Indicator	Definition
Environmental resilience and resource efficiency	**GWP savings**	Estimated global warming potential (GWP) savings, according to the products cultivated in the garden
Environmental resilience and resource efficiency	**Land reclamation**	Area of previously vacant or idle land utilised for UA (e.g., abandoned lands, brownfields, etc.)
Environmental resilience and resource efficiency	**Soil conservation**	Share of plots that adopt organic farming method - crop rotation aimed at soil conservation
Environmental resilience and resource efficiency	**Water management**	Water sources used in UA, if wastewater is recycled and reused in UA
Environmental resilience and resource efficiency	**Soil sealing**	Share of land covered by permeable material or bare soil
Environmental resilience and resource efficiency	**Soil amendment**	Type of fertilizers used by garden participants in UA
Inclusive society	**Time spent in the garden**	Total time that participants spend in the garden
Inclusive society	**Demographic makeup**	Extent to which the socioeconomic composition of the garden is similar to that of the neighbourhood/city
Inclusive society	**Social interactions**	Evidence of social interactions between gardeners
Inclusive society	**New social relationships**	Evidence of new relationships developed through participation in the garden
Inclusive society	**Cultural dimension**	Extent to which the garden supports cultural and/or religious expression
Inclusive society	**Environmental stewardship**	Extent to which the garden promotes environmental stewardship
Food security and income generation	**Food production stability**	Stability (predictability) in the production of vegetables (excluding energetic crops) from UA
Food security and income generation	**Food self-sufficiency**	Share of total annual household consumption of vegetables (excluding energetic crops) from UA
Food security and income generation	**Food waste generation**	Share of participants in community garden initiatives that declare to throw food produced in the UA, at production, transport, storage or consumption stages
Food security and income generation	**Active learning**	Participation in formal and informal UA education schemes targeting food production practices

Food security and income generation	**Fees and costs**	Total amount spent by participants on garden-related activities per year, including fees, services, supplies, etc.
Food security and income generation	**Financial stability of the garden**	Income balance last year: garden's capacity to generate enough income to cover ordinary costs and generate a surplus to cope with future investments or unexpected expenses
Sustainable urban development	**Perceived public utility**	Perceived public utility. Type of land (e.g., marketable or non-marketable) in which the garden is located.
Sustainable urban development	**Accessibility**	Means of transport vs travel time to reach the garden
Sustainable urban development	**Relief of urban density**	Population density in the area where the garden is based (1sq km grid)
Sustainable urban development	**Land access & tenure**	Secure access to land in the UA granted via formal documents released by authorities
Sustainable urban development	**Policy formalization**	Official and non-official policies and strategies adopted to support urban gardening
Sustainable urban development	**Civil steering**	Private sector and civil society efforts to support/implement urban gardening

Table 7. List of headline indicators included in the SIEUGreen monitoring framework for UA for Turunçlu Greenhouse

Pillar	Indicator	Indicator definition
Environmental resilience and resource efficiency	**Renewable energy**	Renewable energy as a proportion of toal energy use
Environmental resilience and resource efficiency	**Organic fertilizer**	Organic matter as a proportion of total fertiliser use
Environmental resilience and resource efficiency	**Recycled water**	Recycled / wastewater as a proportion of total water use
Environmental resilience and resource efficiency	**Upcycling materials**	Infrastructure constructed from recycled/repurposed materials
Environmental resilience and resource efficiency	**Soil sealing**	Share of UA initiative space covered by permeable material or bare soil
Environmental resilience and resource efficiency	**Water reduction**	Water use compared to traditional agriculture
Societal inclusion	**Active engagement**	Existence of participation mechanisms for all members
Societal inclusion	**New relationships**	New relationships developed through the garden
Societal inclusion	**Community pride**	Extent to which participants feel proud of what they have achieved with the garden
Societal inclusion	**Environmental stewardship**	Extent to which participants have environmental motivations and attitudes

Societal inclusion	**Job creation**	Number of direct and indirect jobs created through the initiative
Societal inclusion	**Donating food**	Donation of food
Food security	**Participation cost**	Cost of participation in the initiative
Food security	**Active learning**	Number of aspects covered by existing training programmes: food production (gardening methods) and/or food sharing and/or food preparation and/or financial management
Food security	**Chemical use**	Prevalence of herbicide and pesticide use
Food security	**Food safety**	Existence of general food safety assurance mechanisms
Food security	**Harvest predictability**	Stability (predictability) in the production of vegetables (excluding energetic crops) from UA
Food security	**Financial stability**	Proportion of the garden's operational costs covered by external sources
Sustainable urban planning	**Accessibility / Openness**	Presence of physical elements (e.g., fences, walls, gates) defining the limits of the garden.
Sustainable urban planning	**Facilities & infrastructure**	Existence of facilities/infrastructures in the UA (e.g., toilets, storage room, kitchen)
Sustainable urban planning	**Accessibility / mobility**	Transport + travel time
Sustainable urban planning	**Land security & tenure**	Secure access to land in the UA granted to participants via formal documents released by authorities (e.g., lease or property contracts)
Sustainable urban planning	**supportive funding context**	Receives funding from external sources
Sustainable urban planning	**Partnership approach**	Involvement of actors from different spheres (e.g., private, public, community)

3.2.2) Scoring criteria

The scoring for the headline performance indicators used in Brabrand and Pier 2 was defined based on the criteria shown in Table 8. The scoring for the headline performance indicators used in Turunçlu Greenhouse was defined based on the criteria shown in Table 9.

Table 8. Scoring system for the different performance indicators in the monitoring system used to assess Brabrand and Pier 2

Indicator	Data origin	Scoring criteria
GWP savings	Literature and surveys	Potential GWP savings were estimated according to the figures provided by (Kulak et al., 2013) for the UK. The score was produced by weighing the GWP saving potential associated with each crop variety according to its diffusion in each garden. To account for differences in climate between the UK and Denmark, we used the estimates for autumn yields (instead of spring ones) and polytunnel (instead of outdoor crops).

Land reclamation	Interviews	Based on replies to question: "What was the area used for before it became a garden?"
Soil conservation	Surveys	Based on replies to question: "How often do you change what you grow in your garden?" Scores are defined as follows: 0: never; 1: every 3-6 years; 2: every two years; 3: every year
Water management	Interviews	Based on replies to questions: "From where do you get the water for the garden?" and "Do you use recycled/recovered wastewater for the garden?" Scores are defined as follows: 0: groundwater (wells); 1: grid water; 2: rainwater; 3: recycled water; 4: no water consumption. If multiple sources are used, the average of the scores is calculated.
Soil sealing	GIS analysis and interviews	Based on the photointerpretation method and replies to question: "What proportion of this area is occupied by greenhouses or other structures?"
Soil amendment	Surveys	Based on replies to questions: "What fertilizers do you use in your garden?" Scores are defined as follows: 0: chemical fertilizers; 1: other non-organic fertilizer; 2: urine water (e.g., urine mixed with water); 3: animal manure; 4: household waste (e.g., food waste); 5: other organic fertilizers (e.g., bokashi); 6: none
Time spent in the garden	Surveys	Calculated by combining weighted scores from two survey questions for a total maximum score of 8. The greater number of options in the first question means that it carries slightly more weight in the score. This is intentional. Questions and weight distribution: (In an average month (during the growing season), how often do you visit the garden? 0 = less than once per month; 1 = once per month; 2 = 2-3 times per month; 3 = Once per week 4 = 2-3 times per week; 5 = more than three times per week) + (How much time do you spend at the garden on an average visit? 0 = less than one hour; 1 = 1-2 hours; 2 = 2-4 hours; 3 = more than 4 hours)
Demographic makeup	Surveys and NSI based	The makeup of the garden population (based on the survey sample) is compared to the makeup of Aarhus Municipality for each of the demographic indicators, using the Chi-Squared test. Gardens receive one point for each instance of rejection of the null hypothesis, resulting in a potential maximum score of four if the garden is considered representative in all areas. • H_0: **There is NO relationship** between the makeup of the garden population and the makeup of Aarhus Municipality with respect to gender/age/place of birth/highest level of educational attainment. • H_1: **There IS a relationship** between the makeup of the garden population and the makeup of Aarhus Municipality with respect to gender/ age/place of birth/highest level of educational attainment. Survey questions: What is your gender? How old are you? Where were you born? What is your highest level of education?
Social interactions	Surveys	Calculated by combining weighted scores from six survey questions for a total maximum score of 24. Questions: I talk with other gardeners about issues relating to the maintenance and management of the garden; I talk with other gardeners about gardening; I talk with other gardeners about food (e.g., exchanging recipes); I give, receive, or exchange food with other gardeners; I talk with other gardeners about other aspects of life (e.g., family, work, other interests); I meet other gardeners outside of the context of the garden.

		Weight distribution: 0 = never; 1 = not often; 2 = sometimes; 3 = often; 4 = very often
New social relationships	Surveys	Calculated based on a weighted score for responses to the survey question: I have made new friends through my involvement in the garden. Weight distribution: -2 = strongly disagree; -1 = disagree; 0 = unsure; 1 = agree; 2 = strongly agree
Cultural dimension	Surveys	Calculated based on a weighted score for responses to the survey question: What is your main motivation for participating in the garden? Cultural or religious expression. Weight distribution: 0 = not important; 1 = important; 2 = important
Environmental stewardship	Surveys	Calculated by combining weighted scores from two survey questions and dividing the total by two for a total maximum score of 2. Questions: The neighbourhood is improved by the garden; I feel proud of my garden. Weight distribution: -2 = strongly disagree; -1 = disagree; 0 = unsure; 1 = agree; 2 = strongly agree
Food production stability	Surveys	Proportion of participants that selected any of the following options when asked: "How unpredictable is your vegetable harvest?": (1) "Quite predictable, it changes a little, but not very much from year to year" OR (2) "Very predictable, it's almost the same from year to year."
Food self-sufficiency	Surveys	Proportion of participants that subscribed any of the following statements: (1) "I get most or all of what I need from the garden (vegetables; in season)" OR (2) "I get most or all of what I need from the garden (vegetables; year-round)"
Food waste generation	Surveys	Proportion of participants that declared to (1) occasionally OR (2) systematically throw away food produced in the garden, at production, storage, transport and/or consumption stages.
Active learning	Surveys	Based on replies to the question: "How did/do you learn about gardening and food?" Scores are defined as follows: 0: no training (learn by doing); 1: self-training based on available sources; 2: informal, learning from other people; 3: formal training (online); 4: formal training (physical).
Fees and costs	Surveys	Based on replies to question: "Approximately how much do you spend on your garden each year?" Scores are defined as follows: 0: nothing; 1: under 100 DKK; 2: 101 - 500 DKK; 3: 501 - 1000 DKK; 4: 1001 - 2000 DKK; 5: Over 2000 DKK
Financial stability of the garden	Interviews	Based on replies to question: "What was the income balance last year in your garden? (considering all expenses and revenues)"
Perceived public utility	Interview	Interview-based (leaders), multiple-questions: *"What is the size/ area (m^2 or hectares) of your garden?"* AND *"Who owns the land where the garden is?"* and literature review (Borges et al., 2019). Scores are defined as follows: (0): marketable land that can be used for other purposes (the land is subject of competition for other functions); (1): in between buildings (public or private land of residential/institutional areas); (2): transitional spaces (public or private land, e.g., construction sites; alongside railways); (3): leftover spaces (public areas that cannot be used for other purposes)
Accessibility	Surveys	Calculated by combining weighted scores from two survey questions for a total maximum score of 11. Survey-based, question *"How do you usually travel to the garden?"* Weighted scores are defined as follows: (0): car; (4): public transportation and (8): cycle or walk. AND survey-based, question: "*How long*

		does it take you to get to the garden?" Scores are defined as follows: (0): over 30 minutes; (1): between 30 and 20 minutes; (2): between 20 and 10; (3): under 10 minutes
Relief of urban density	GIS-Analysis	Population on 1km grid level in Denmark is used to identify the thresholds.
Land access & tenure	Interview	Interview-based (leaders), multiple questions: *"Who owns the land where the garden is? "Is there a formal agreement in place that allows you to use this land as a garden?"* Scores are defined as follows: (0): the land is private with no formal agreement; (1): the land is public with no formal agreement, (2): the land is private with a formal agreement; (3): the land is public with a formal agreement
Policy formalization	Interview	Interview-based (planners), multiple questions (see Annex 6.3). Scores are defined as follows: (0): UA is not acknowledged in any official or non-official planning document; (1): UA is acknowledged in *no legally binding* specific instruments and supporting programs (e.g. city-wide food plans, public programs promoting UA); (2): UA is acknowledged in *legally binding* plans and instruments (land-use plans, physical plans, detailed development plans, design regulations, i.e. green are cover thresholds that incentivize allotment provision applied by the municipality); (3): UA is acknowledged in both *not* and *legally binding* plans and instruments
Civil steering	Interviews	Interview-based (leaders), "Does your garden partner with any private or public stakeholder?" Scores are defined as follows: (0): the garden does not partner with any private or public stakeholder; (1): the garden partners with private stakeholder; (2): the garden partners with public stakeholders; (3): the garden partners with both public and private stakeholders

Table 9. Scoring system for the different performance indicators in the monitoring system used to assess Turunçlu Greenhouse

Indicator	Data source	Scoring criteria
Renewable energy	Interview	Qualitative scale based on interview response about electricity consumption: 0: From the grid; 1: A mix of own production and grid (>50% grid); 2: A mix of own production and grid (approx. 50% grid, 50% own production); 3: A mix of own production and grid (>50% own production); 4: Own energy generation or no energy use
Organic fertilizer	Interview	Qualitative scale based on interview response about fertiliser use: 4: We do not use fertiliser; 4: All fertiliser used is organic; 3: Over 75% of fertiliser used is organic; 2: Over 50% of fertiliser used is organic; 1: Less than 50% of fertiliser used is organic; 0: We use only non-organic fertilisers
Recycled water	Interview	Qualitative scale based on interview response about water consumption: 4: All of our water use is recycled / wastewater; 3: Over 75% of our water use is recycled / waste water; 2: Over 50% of our water use is recycled / waste water; 1: Less than 50% of our water use is recycled / waste water; of our water use is recycled / waste water; 0: None of our water use is recycled / waste water

Upcycling materials	Interview	Qualitative scale based on interview response about material use: 4: All of our infrastructure has been developed using recycled/repurposed materials; 3: Over 75% of our infrastructure has been developed using recycled/repurposed materials; 2: Over 50% of our infrastructure has been developed using recycled/repurposed materials; 1: Less than 50% of our infrastructure has been developed using recycled/repurposed materials; 0: None of our infrastructure has been developed using recycled/repurposed materials.
Soil sealing	Interview	GIS analysis and interview response
Water reduction	Interview	Qualitative scale based on interview response about water consumption compared to traditional agriculture: 0: Similar; 1: Savings of up to 25%; 2: Savings of up to 50%; 3: Savings of up to 75%; 4: Savings of up to 90%
Active engagement	Interview	Qualitative scale based on interview response about gardeners participation in decision making: 2: They have the opportunity to participate on a board or steering committee; 1: They provide feedback through program evaluations or other single-point-in-time feedback mechanisms; 0: Participants do not have an opportunity to provide input into the running of the garden
New relationships	Survey	Proportion of participants who responded "likely" or "very likely" to the question: How likely is it that you will meet the other participants again now that the course is over?
Community pride	Survey	Proportion of participants who responded "agree" or "strongly agree" to the question: I feel proud of what I achieved in the course
Environmental stewardship	Survey	Proportion of participants who responded "very important" or "important" to the question: Learning how to reduce environmental impact of food
Job creation	Interview	0: none; 1: 1; 2: 2-4; 3: 5 or more
Donating food	Interview	Qualitative scale based on interview response about food donation: 0: No; 1: Sometimes; 2: Regularly
Participation cost	Interview	2: No cost; 1: Minimal cost (e.g., coving operational cost); 0: substantial cost (e.g., the initiative makes a profit)
Active learning	Interview	Qualitative scale based on interview response about food donation: One point per aspect covered up to a total score of 4: a) Growing techniques and methods (including planting, irrigation, recollection, fertilisers, etc.); b) Animal care and husbandry methods; c) Food manipulation and hygiene; d) Recipes and cooking; e) Food sharing and socialisation events; f) Other (please tell us about it)
Chemical use	Interview	Survey-based question on use of pesticides or herbicides 2: no use; 1: organic use; 0: use
Food safety	Interview	0: no; 1: yes, basic; 2: yes, comprehensive
Harvest predictability	Interview	Qualitative scale based on interview response about harvest predictability: 0: Very unpredictable; 1: Somewhat unpredictable; 2: Quite predictable; 3: Very predictable
Financial stability	Interview	Qualitative scale based on interview response about food donation: 5: None; 4: Less than 25%; 3: 25-50%; 2: 50-75% 1: Over 75% 0: All
Accessibility / Openness	Observation	0: closed; 1: semi-accessible; 2: fully accessible

Facilities & infrastructure	Interview	Qualitative scale based on interview response about facilities and infrastructure (initiative scores one point per element, up to 4 points): a) Drinking water; b) Toilets (public toilets nearby from the Dome); c) Storage rooms (for tools) – roof no walls; d) Storage rooms (for food); e) Kitchen; f) Other (Hooby garden, flower and seedling growing area, pet care house, car park, office)
Accessibility / mobility	Survey	Qualitative scale based on survey responses to questions about travel time and mode: 0 = The garden is not reachable by public transportation (PT); 1= the garden is a reachable PT over 30 minutes; 2: PT between 10-30 minutes; 3: PT under 10 minutes= the garden is a reachable walk or cycling (W or C) over 30 minutes; 5: W or C between 10-30 minutes; 6: W or C under 10 minutes
Land security & tenure	Interview	0: no agreement; 1: short term agreement (less than 12 months); 2: long-term agreement (12 months+); 3: initiative owns the land
supportive funding context	Interview	0: no funding from external sources; 1: Funding from one of the sources listed; 2: funding from two or more of the sources listed (Municipal Funding; National funding; EU Funding; Venture capital funding)
Partnership approach	Interview	0: Actors from only one sphere (public, private, community); 1: Actors from two spheres; 2: Actors from three speres

3.2.3) Calculating the scores

For consistency, the data retrieved from the surveys and other sources were transformed using a max/min linear adjustment approach using the two types of linear utility functions introduced in Section 2.5). The resulting scores for Brabrand and Pier 2, along with information regarding measurement units and data transformation approaches, are shown in Table 9. The resulting scores for Turunçlu Greenhouse, along with information regarding measurement units and data transformation approaches, are shown in Table 10.

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Table 9. Scores assigned on the different dimensions in Brabrand and Pier 2 gardens

Indicator	Definition	Units	Minimum	Maximum	Transformation method	Final score Brabrand	Final score Pier2
GWP savings	Estimated global warming potential (GWP) savings, according to the products cultivated in the garden	percentage (weighted share)	0	100	Increasing utility	65.3%	66.5%
Land reclamation	Area of previously vacant or idle land utilised for UA (e.g. abandoned lands, brownfields, etc.)	percentage	0	100	Increasing utility	0.0%	100.0%
Soil conservation	Share of plots that adopt organic farming method - crop rotation aimed at soil conservation	Weighted score	0	3	Increasing utility	80.0%	93.3%
Water management	Water sources used in UA, if wastewater is recycled and reused in UA	Weighted score	0	4	Increasing utility	25.0%	25.0%
Soil sealing	Share of land covered by permeable material or bare soil	Percentage	0	100	Increasing utility	45.5%	64.0%
Soil amendment	Type of fertilizers used by garden participants in UA	Weighted score	0	6	Increasing utility	57.2%	80.6%
Time spent in the garden	Total time that participants spend in the garden	Average hours per day	0	8	Increasing utility	63.8%	51.3%
Demographic makeup	Extent to which the socioeconomic composition of the garden is similar to that of the neighbourhood/city	Weighted score	1	4	Increasing utility	25.0%	100.0%
Social interactions	Evidence of social interactions between gardeners	Weighted score	0	24	Increasing utility	50.9%	43.2%
New social relationships	Evidence of new relationships developed through participation in the garden	Weighted score	-2	2	Increasing utility	68.1%	60.0%
Cultural dimension	Extent to which the garden supports cultural and/or religious expression	Weighted score	0	2	Increasing utility	12.2%	9.1%

Environmental stewardship	Extent to which the garden promotes environmental stewardship	Weighted score	-2	2	Increasing utility	88.0%	86.3%
Food production stability	Stability (predictability) in the production of vegetables (excluding energetic crops) from UA	Percentage (accumulated share)	0	100	Increasing utility	48.9%	36.4%
Food self-sufficiency	Share of total annual household consumption of vegetables (excluding energetic crops) from UA	Percentage (accumulated share)	0	100	Increasing utility	41.4%	9.0%
Food waste generation	Share of participants in community garden initiatives that declare to throw food produced in the UA, at production, transport, storage or consumption stages	Percentage	0	100	Decreasing utility	71.4%	90.9%
Active learning	Participation in formal and informal UA education schemes targeting food production practices	Weighted score	0	4	Increasing utility	26.9%	27.2%
Fees and costs	Total amount spent by participants on garden-related activities per year, including fees, services, supplies, etc.	Weighted score based on monetary units	0	5	Decreasing utility	51.9%	84.1%
Financial stability of the garden	Income balance last year: garden's capacity to generate enough income to cover ordinary costs and generate a surplus to cope with future investments or unexpected expenses	Percentage (surplus over total budget)	0	100	Increasing utility	54.5%	62.5%
Perceived public utility	Perceived public utility, reveals the type of land (e.g., marketable, or non-marketable) in which the garden is located. It is a proxy of competing uses for land in cities.	Weighted score	0	3	Increasing utility	0.0%	100.0%
Accessibility	Means of transport vs travel time to reach the garden	Weighted score	0	11	Increasing utility	57.6%	95.5%

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Relief of urban density	Population density in the area where the garden is based (1sq km grid)	Persons/km^2	1	24167	Increasing utility	1.1%	24.8%
Land access & tenure	Secure access to land in the UA granted to participants via formal documents released by authorities (e.g. lease or property contracts)	Weighted score	0	3	Increasing utility	66.7%	100.0%
Policy formalization	UA's explicitly acknowledged in city planning documents (strategic plans, urban city plans, etc.)	Weighted score	0	3	Increasing utility	100.0%	100.0%
Civil steering	Active role of civil society organisation's role in driving UA in the city	Weighted score	0	3	Increasing utility	100.0%	66.7%

Table 10. Scores assigned on the different dimensions in Turunçlu Greenhouse

Indicator	Definition	Units	Min	Max	Transformation method	Hatay
Renewable energy	Renewable energy as a proportion of total energy use	Weighted score	0	4	Increasing utility	0,0%
Organic fertilizer	Organic matter as a proportion of total fertiliser use	Weighted score	0	4	Increasing utility	100,0%
Recycled water	Recycled / wastewater as a proportion of total water use	Weighted score	0	4	Increasing utility	100,0%
Upcycling materials	Infrastructure constructed from recycled / repurposed materials	Weighted score	0	4	Increasing utility	0,0%
Soil sealing	Share of UA initiative space covered by permeable material or bare soil	Percentage	0	100	Increasing utility	76,0%
Water reduction	Water use compared to traditional agriculture	Weighted score	0	4	Increasing utility	100,0%

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Active engagement	Existence of participation mechanisms for all members	Weighted score	0	2	Increasing utility	0,0%
New relationships	New relationships developed through the garden	Percentage	0	100	Increasing utility	76,0%
Community pride	Extent to which participants feel proud of what they have achieved with the garden	Percentage	0	100	Increasing utility	80,0%
Environmental stewardship	Extent to which participants have environmental motivations and attitudes	Percentage	0	100	Increasing utility	78,0%
Job creation	Number of direct and indirect jobs created through the initiative	Weighted score	0	3	Increasing utility	100,0%
Donating food	Donation of food	Weighted score	0	2	Increasing utility	100,0%
Participation cost	Cost of participation in the initiative	Weighted score	0	2	Increasing utility	100,0%
Active learning	Number of aspects covered by existing training programmes: food production (gardening methods) and/or food sharing and/or food preparation and/or financial management	Weighted score	0	4	Increasing utility	75,0%
Chemical use	Prevalence of herbicide and pesticide use	percentage	0	2	Increasing utility	100,0%
Food safety	Existence of general food safety assurance mechanisms	Weighted score	0	2	Increasing utility	50,0%
Harvest predictability	Stability (predictability) in the production of vegetables (excluding energetic crops) from UA	Weighted score	0	3	Increasing utility	100,0%

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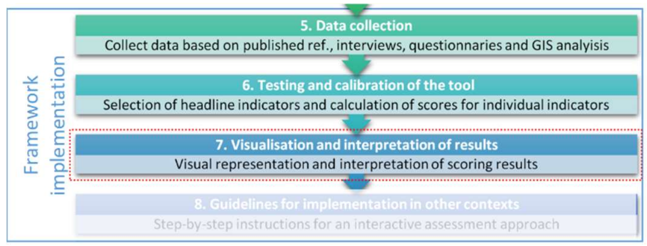
Financial stability	Proportion of the garden's operational costs covered by external sources	Weighted score	0	5	Increasing utility	20,0%
Accessibility / Openness	Presence of physical elements (e.g. fences, walls, gates) defining the limits of the garden.	Weighted score	0	2	Increasing utility	0,0%
Facilities & infrastructure	Existence of facilities/infrastructures in the UA (e.g., toilets, storage room, kitchen)	Weighted score	0	4	Increasing utility	100,0%
Accessibility / mobility	Transport + travel time	Weighted score	0	6	Increasing utility	33,3%
Land security & tenure	Secure access to land in the UA granted to participants via formal documents released by authorities (e.g. lease or property contracts)	Weighted score	0	3	Increasing utility	100,0%
Supportive funding context	Receives funding from external sources	Weighted score	0	2	Increasing utility	100,0%
Partnership approach	Involvement of actors from different spheres (e.g., private, public, community)	Weighted score	0	2	Increasing utility	0,0%

3.3) Visualisation and interpretation of results



This section describes the results of the evaluation gardens' contribution to urban sustainability. We first focus on the contribution of each garden to each of the four SiEUGreen pillars. A final section demonstrates how the tool can be used to compare gardens that share similar characteristics based on the performance of the two Aarhus gardens.

3.3.1) Brabrand performance assessment

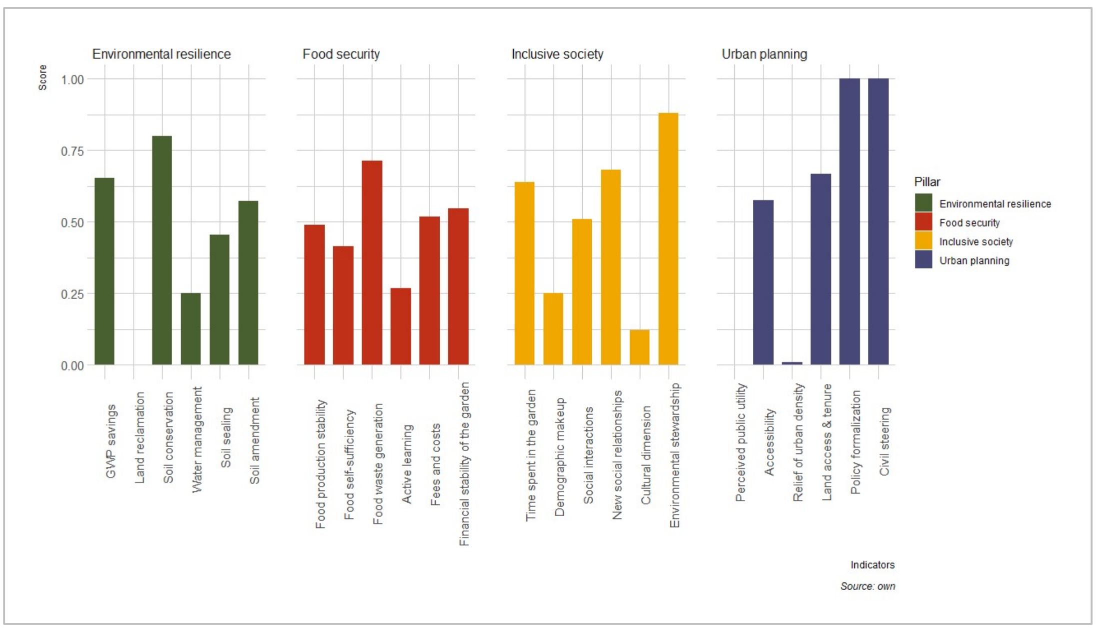


Figure 31: Performance Brabrand (Aarhus, DK) by SiEUGreen pillars (data for 2020)

The **environmental resilience** performance of Brabrand is somewhat unbalanced. Of the six environmental resilience indicators, the strongest performance is on *soil conservation*. Crop rotation is a widely used organic farming method in the garden, and the majority of respondents (71,4%) reported changing what they grow every year. The garden also performs fairly well with respect to *soil amendment.* The use of pesticides or herbicides is prohibited in the garden, which has drawbacks such as potential toxicity to human health and other species. All the respondents from the garden use fertilizers with diversified types. The most common fertilizer used in Brabrand is animal manure, which

61,1% of respondents reported the usage. Waste resources such as food waste also are served as fertilizer and soil amendment by some farmers (12,5%) in Brabrand. Other organic fertilizers are widely used to improve soil fertility and nutrient level in the garden, with 20,8% of respondents reported the usage.

Another area where Brabrand performs well is in relation to *GWP savings*. Production and distribution of crops in Brabrand result in 65,3% lower GHG emissions than in the conventional food supply system, according to our estimation based on the vegetables and fruits cultivated in the garden. It indicates that the establishment of Brabrand contributes to significant potential savings of food related GHG emissions compared to the conventional way of production and supply of food.

At the other end of the scale, Brabrand has the lowest possible score when it comes to *land reclamation*. This is due to the fact that Brabrand is a peri-urban garden, and the land was already used for agriculture before the UA initiative was established. Therefore, the garden doesn't contribute specifically to the utilisation of previously vacant or idle land. The garden also scored poorly on *water management*. The major water source for irrigation is groundwater, though rainwater is collected and used in winter. Wastewater is neither treated nor recycled in the garden and becomes groundwater directly following use. The performance is somewhat better, though still below 50%, on the *soil sealing* indicator. The large space occupied by the greenhouses, together with the other on-site amenities (e.g., shared kitchen, storage room and toilets), result in less than half of the land at Brabrand (45,5%) being covered by bare soil or other permeable surfaces.

From a **food security** perspective, Brabrand performs relatively well on most parameters. The best performing indicator in this pillar was *food waste generation*. Here, only a small share of participants (29%) reported that they "sometimes" throw away food. Most respondents (71%) reported that they "never" or "rarely" throw away food produced in their garden. This may be an indication that excess or low-quality production is not the norm or that people find alternatives for dealing with surplus food. It is possible that this is a reflection of the greater connectedness respondents reported having with the food they consume (see section 3.1.2)). When participants understand the amount of work that goes into the food production process, and when they undertake this work themselves, they likely ascribe a higher value to the food and are less likely to throw it away.

In terms of both *food production stability* and *food self-sufficiency*, the garden performs just below the average score of 50%. Although one might expect a higher value here based on the relatively large size of the beds (50m^2), this value can still be deemed an acceptable when considered in the context of the main motivations reported by participants (stress relief). Accessing fresh food ranks second, while other frequently cited motivations include reducing environmental impact and enjoying outdoor activities. When asked about the predictability of their vegetable harvests, around half of the total participants declared that yields were very or quite predictable. Such a relatively high confidence on own yields implies that gardeners have reasonable control over crop methods and agricultural techniques in general. In terms of *food self-sufficiency*, 32% of gardeners reported satisfying most of their needs in the growing season (7% year-round). Again, this seems a decent performance for a garden where participants are driven by leisure and relax as much as by food production.

In financial terms, participants do not report any major expenses resulting from the *fees and costs* of garden participation. Still, 40% report spending more than 500 DKK per year (approx. 65 Euro) on different aspects including annual fees, seeds and fertilizer and other supplies. The *financial sustainability of the garden* as a whole is relatively well safeguarded, with a 10% budget surplus last year.

The poorest score within the food security pillar was on the *active learning* indicator (27%). This is largely due to the absence of formal training undertaken by respondents. Interestingly, know-how seems to be based on informal exchanges of knowledge among participants (33%), self-training (33%) and learn by doing (33%), rather than on established courses (only 1 participant declared to have participated in formal training activities).

From a **social inclusion** perspective, Brabrand performs quite well. Environmental stewardship is the highest performing indicator, with the majority of gardeners reporting a strong sense of pride in their garden, both at the individual plot level and in terms of the contribution of the garden to the neighbourhood as a whole. Members also report a considerable amount of *time spent in the garden,* with most visiting once a week (44%) or more (50%). The duration of visits ranged from less than 1 hour (6%) to over 4 hours (10%), with the majority of respondents reporting visits of 1-2 hours (44%) or 2-4 hours (38%).

The development of *new social relationships* is fairly common, as are *social interactions between gardeners*. The *demographic makeup* of the garden community is similar to that of Aarhus Municipality with respect to the place of birth[4] but cannot be considered representative in the other respects measured. Gardeners at Brabrand are more likely to be older, educated and female than members of the general population. The garden also scores poorly on the c*ultural dimension*, with cultural or religious expression not a strong motivator for gardeners at Brabrand.

[4] Based on two categories: Born in Denmark and born outside Denmark

When it comes to **urban planning,** Brabrand performs somewhat unequally across the six indicators. The most robust performance is evident in the indicators related to *civil steering* and *policy formalisation*. The strong performance on the *civil steering* indicator is largely explained by the engagement of Brabrand in demonstrating and testing one of the SiEUGreen technologies and its involvement in the Taste Aarhus Program. The strong performance on the *policy formalisation* relates to the way Aarhus Municipality regards UA in legally binding and non-legally binding planning documents and programs rather than to the garden itself. The land-use plan of the municipality acknowledges and safeguards allotment gardens, which are part of the urban structure of the city. This follows a tradition that was established in Denmark at the beginning of the 20th century when the Allotment Garden Union became institutionalized (Jensen, 1996). Usually, the municipality owns the land and rents it out to associations that manage the allocation of the plots to their members. Compared with the market, the prices are much lower and, thus, the allotments became a viable and popular alternative for people who enjoy growing food within the city. The Taste Aarhus Program also contributes to the maximum performance as it supports more than 200 gardens in the municipality.

Regarding *accessibility*, the garden performs just above average. Despite the majority of the survey participants (58%) reporting travelling to the garden by bicycle, a significant number still use private cars (35,4%). Almost half of the survey participants (46%) reach the garden with the travel time between 10 – 20 minutes, and 20% of the participants reported that takes more than 30 minutes to reach the garden from their homes. With the exception of one respondent who reaches the garden under 10 minutes, these results seem to suggest that most of the participants of the survey live in places situated at a considerable distance from the garden.

With respect to *land access and tenure*, the existence of an annual rental agreement between the garden association and the private owner offers some security to use the land for gardening, resulting in a fairly good score on this indicator. At the same time, the low score on *perceived public utility* highlights the precariousness resulting from a combination of private land ownership and location in an attractive development area. In fact, at the time of writing, we were informed by the manager that the garden is facing eviction by the end of 2021. This reflects a well-known dilemma for urban gardening. Despite the benefits it delivers, the prioritisation of land for UA still conflicts with the local government prerogative to use land for the activity, which will result in the highest economic return for the city.

Brabrand also receives a very low score on the indicator *relief of urban density* due to its peri-urban location. The garden neighbour’s farmland and the ongoing urban developments in the surroundings are mainly single-family dwellings which do not add a significant number of inhabitants in the area; thereby, the garden performs a minor role in alleviating urban density.

3.3.2) Pier 2 performance assessment

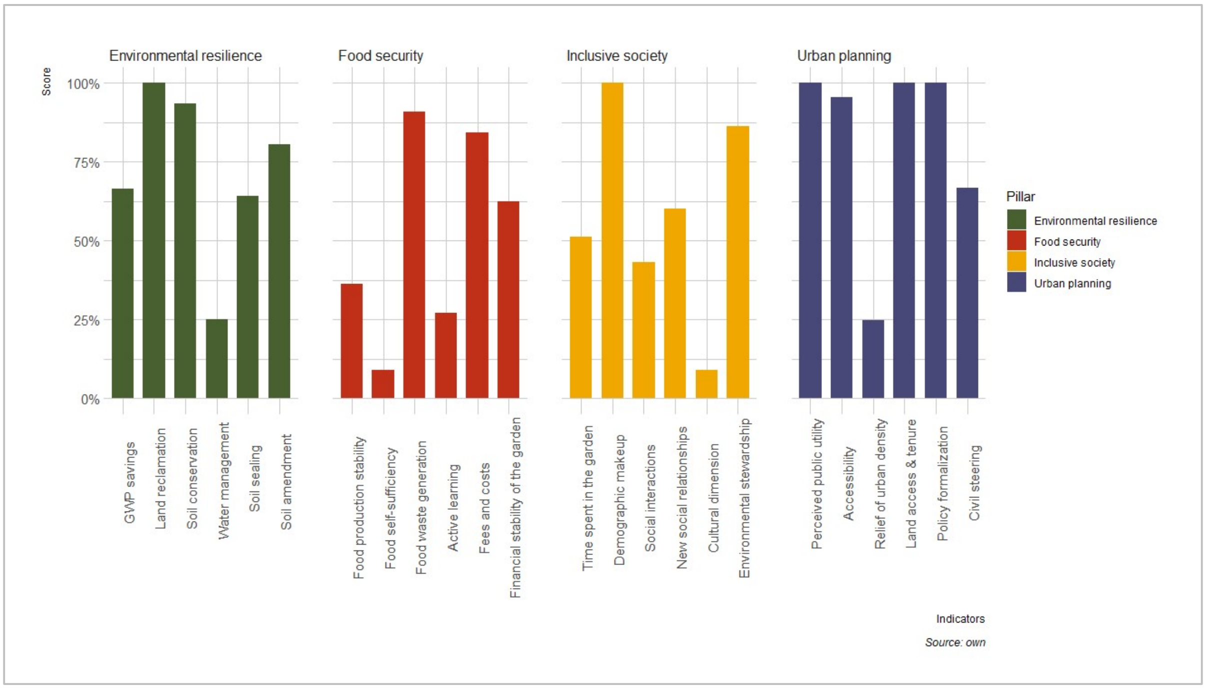


Figure 32: Performance Pier 2 (Aarhus, DK) by SiEUGreen pillars (data for 2020)

Pier 2 performs relatively well in most parameters measuring **environmental resilience**. The strongest performance is on *land reclamation* (100%). Pier 2 is situated on the harbour, and the land was vacant before the community garden was established. Thus, the UA initiative has successfully repurposed previously unused land for food production in the centre of Aarhus Municipality. The performance of Pier 2 on *soil conservation* is also outstanding. Crop rotation is a common organic farming practice in the garden. Eighty-two per cent of respondents reported changing the products they grow every year, and the remaining 18% reported changing what they grow every two years. This can, at least in part, be explained by the way that Pier 2 is organised. Each urban farmer has a bed of $4m^2$, making it relatively easy to change the crops annually.

Pier 2 also performs well on *soil amendment* (80.6%). Although the use of pesticide or herbicide is not officially prohibited, none of the respondents reported using them in cultivation. The most common fertilizer used in the garden is organic fertilizer (e.g., household waste). Twenty-five per cent of the respondents reported using no fertiliser at all, and none reported using chemical fertilizer. The land on which Pier 2 is located is covered with gravel, making it relatively impermeable (total area $500m^2$). Thus the addition of 45 beds of $4m^2$ each, has increased the permeability and stormwater infiltration substantially, resulting in *soil sealing* score of 64% and enhancing the environmental resilience of the site.

The garden has the potential for *GHG savings* of 66,5% compared to conventional food production and supply methods. This suggests that Pier 2 fulfils the aim of producing more sustainable food for citizens. The lowest environmental performance of the garden relates to *water management* (25%). The main water source is grid water, and wastewater is not recycled or reused in Pier 2. If realised, the plans to install a rain-water tank in 2021 will contribute to more sustainable water use in the garden and thus a better score on this indicator.

In terms of **food security and income generation**, Pier 2 shows a relatively unbalanced indicator-wise performance. This may be a result of the small sample (11) used to build most of the indicators, as well as by the small overall size of this garden (60 members and 45 beds) and the relatively small size of the plots (4m^2 each). Consistent with this, the food-related indicators suggest that the food production capacity of Pier 2 is quite limited. *Food self-sufficiency* was the poorest performing indicator in the pillar. The only categories where a relevant share of respondent's report satisfying all or most of their household needs were herbs and tubers (18% and 27% of respondents, respectively). However, *food production stability*, measured in terms of harvest predictability, seems to be comparatively higher than total production capacity. Around 36% of participants reported that the yield from their garden is predictable from year to year. Pier 2 also had a modest score on *active learning*, with the majority of respondents reporting obtaining knowledge about gardening through informal pathways such as exchanging knowledge with other people (39%), using external resources (30%) or learning by doing (30%).

Food waste generation is the single indicator where Pier 2 gets the highest score in the food security and income generation pillar. This suggests that the participants in Pier 2 are rather conscious of the need to prevent food waste and/or the garden generates a small amount of food surplus. In financial terms, Pier 2 shows a positive performance, with very limited maintenance costs and rather comfortable finances. In terms of *fees and costs* for participants, no participant in Pier 2 reported spending more than 500 DKK per year in any of the budget lines assessed (garden fee, energy, water seeds and fertilizers and other supplies). This clearly indicates that participating in this garden is accessible to most people. At the same time, this accessibility does not appear to come at the cost of the *financial stability of the garden* as a whole, which has a relatively high budget surplus of approximately 25%. However, based on the interview held with the garden manager, it seems that this surplus is more likely to be attributable to unfulfilled tasks by the different working groups, rather than successful financial management.

From a **societal inclusion** perspective, Pier 2 performs well. The *time spent in the garden* by members is around average. Though most visit the garden once a week (27%) or more (54%), visits tend to be fairly short. Just under half of the respondents spent less than 1 hour (45%) on an average visit, and just over half reporting spending 1-2 hours (55%). The *demographic makeup* of the garden community was found to be like that of Aarhus Municipality with respect to all four demographic indicators. It is likely, however, that this result is due to statistical error caused by the very small sample size.

The garden appears to be quite social, with many gardeners reporting having frequent and diverse *social interactions* with others. Over 60% also reported having developed *new social relationships* through their involvement in the garden. Except for the demographic indicator (which is likely unreliable in this instance), the highest societal inclusion score is for the indicator *environmental stewardship*. Most gardeners reported a strong sense of pride in their garden, both at the individual plot level and in terms of the contribution of the garden to the neighbourhood as a whole. Cultural or religious expression was not a strong motivator for respondents, resulting in a low score on the *cultural dimension*.

When it comes to **urban planning**, Pier 2 performs quite well, getting the maximum score in three out of six indicators. The location in a left-over space explains the high performance on the *perceived public utility* parameter. As the Taste Aarhus Program manager explained, this area was assigned by the municipality as one of the options for the establishment of an urban garden, to address the great demand for places to grow food in the city centre. As the garden is on pubic land, an official agreement has been made between the government and the garden association which specifies the period of concession and the conditions for using the area. As such, Pier 2 performs very well on the *land access & tenure* parameter. As explained above in the performance assessment of Brabrand, the perfect score on the *policy formalisation* indicator reflects legislation and other mechanisms established by Aarhus Municipality to encourage urban gardening (e.g., the recognition and protection of allotment gardens in the land use plans and Taste Aarhus Program).

When it comes to *accessibility*, the scores are also high (95.5%). This possibly reflects that all the participants in the survey reach the garden by bicycle or walking. The travel time of 10-20 minutes reported by four respondents and 20-30 minutes by one respondent to reach the garden explains why this indicator has not attained the maximum score. The score of 66.7% on the *civil steering* indicator is due to the partnership with the Taste Aarhus Program and the close collaboration with the other two gardens/UA initiatives (e.g., Dome of Visions and the 'Coffee grounds to Gourmet'). Despite its inner-city location, the garden scores relatively poorly (24.8%) on *relief of urban density*. This is due to its location in the harbour area, which means that the 1 km^2 grid cell in which the garden is located is at least partially occupied by water. This implies, for example, that the garden does not contribute substantially to reducing urban heat islands.

3.3.3) Turunçlu Greenhouse performance assessment

Figure 33 shows the results of the assessment of Turunçlu Greenhouse based on the 24 selected headline indicators.

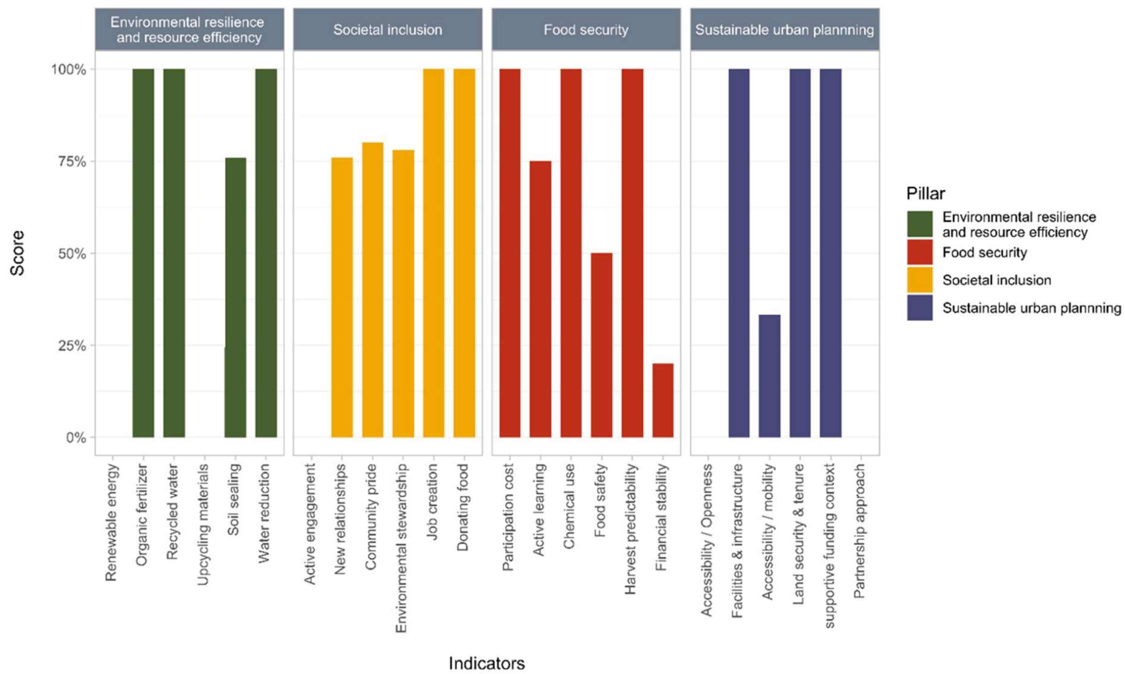


Figure 33: Turunçlu greenhouse score

As can be seen in Figure 33, Turunçlu Greenhouse performs strongest on the aspects related to societal inclusion and food security. With respect to societal inclusion, the initiative has been successful in creating jobs and providing access to fresh food to those who may not otherwise have access by donating food. In addition, participation in the courses has resulted in the development of new relationships and participants display signs of environmental stewardship at both the local and the global levels. One area for improvement from a societal inclusion perspective is with regards to active engagement. Community members do not have the opportunity to provide any input into how the initiative operates. Engagement at this level has been found to be important in promoting positive social outcomes for participants in UA (Glover et al., 2005), as well as the longevity of the initiatives themselves (Kingsley and Townsend, 2006; Teig et al., 2009) and thus could be an important consideration for Turunçlu Greenhouse.

A similarly strong performance is found with relation to the food security pillar. The program is accessible to all, with no cost to participate and results in active learning about how to grow healthy food. The harvest is predictable, and no chemicals are used in the food production process. Though basic safety inspections have been carried out, a stronger performance on food safety could be ensured by putting in place more stringent and frequent quality controls. Similarly, the initiative does not generate much of its own revenue, relying on public funding for over 75% of its operations.

Poorer performances can be found with respect to the sustainable urban planning and environmental pillars. With respect to sustainable urban planning, the initiative contributes to the overall urban environment by providing considerable facilities and infrastructure. This is offset however, by the fact that the initiative is fenced in and not accessible to the public. The substantial investment of the landowner (the municipality) in the initiative, results in fairly secure land tenure and also ensures a supportive funding context. At the same time, the lack of involvement of other actors makes the initiative quite vulnerable should the priorities of the municipality change.

With respect to environmental resilience and resource efficiency, the initiative scores well on indicators related to water management and use. All water used is recycled and the water required for food production is up to 90% less than under traditional agricultural conditions. In addition, 76% of the space utilised by the initiative is covered with permeable material and organic fertiliser is used. Areas of environmental performance that demonstrate room for improvement include the use of renewable energy and the use of recycled materials in the infrastructure of the initiative itself.

3.3.4) Comparing the performance of two community gardens: Brabrand and Pier 2

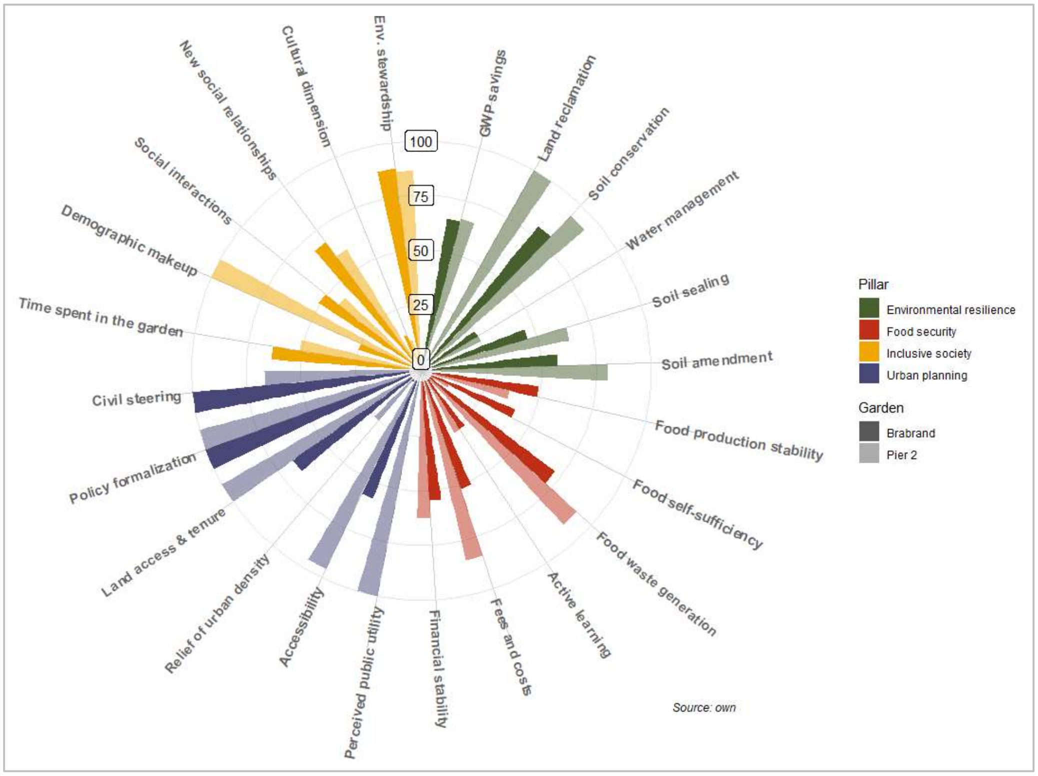


Figure 34. Comparison of the performance of the Brabrand and Pier 2 urban gardens located in Aarhus, Denmark (data for 2020)

Pier 2 outperforms Brabrand on five of the six indicators related to **environmental resilience**, and the two gardens share the same score on the remaining indicator (*water management*). The superior environmental performance of Pier 2 can largely be explained by the location of the two gardens. Pier 2 is located in an environment which contained no green infrastructure prior to the establishment of the garden. In contrast, Brabrand is built on land that was historically used for agricultural. Thus, in the case of Brabrand, the land-use transformation is less dramatic than in the case of Pier 2. Consistent with this, the largest performance difference between the two gardens is found on the indicator land *reclamation*, where Brabrand obtained the lowest possible score and Pier 2 the highest.

The organisation also has an impact on environmental performance. UA practitioners at Pier 2 change their crops more frequently and use fewer fertilizers. Members in Brabrand have a cultivation land of at least 50m^2, while the bed for members in Pier 2 is only 4m^2. The choice of products can explain why Pier 2 has slightly higher estimated global warming potential (GWP) savings than Brabrand. Different types of products grown in the gardens have different potentials to reduce GHG emissions (e.g., the potential of lettuce is considerably higher than that of carrot). The performance of the indicator of soil sealing mainly depends on the built facilities in the garden, and infrastructure like greenhouses is a counteractive factor. Accommodating several greenhouses, Brabrand has a lower score than Pier 2 on the share of permeable surface or bare soil.

When it comes to **food security and income generation**, Brabrand and Pier 2 appear to be strong in different aspects. Brabrand is by far the better performing garden on the *food self-sufficiency* indicator. It is also stronger on *food-production stability*, though to a lesser degree. This is not surprising considering the larger plots, traditional ground-based agriculture and access to greenhouses in the peri-urban garden of Brabrand, in contrast to the inner-urban container-based gardening practice in Pier 2. Similarly, fewer yields reduce the likelihood of food production surpluses, potentially explaining why Pier 2 outperforms Brabrand in *food waste prevention*.

In terms of *active learning*, the gardens rank very closely. In both gardens, the majority of learning occurs through informal channels, and there is very limited penetration of formal training programmes. Regarding financial indicators, Pier 2 appears to outperform Brabrand in the two dimensions, namely *fees and costs* for participants and overall *financial stability* of the garden. Participation fees in Pier 2 are smaller than in Brabrand, and the economic balance of the garden seems to be slightly better overall. Still, it is important to recognise that budget surpluses in Pier 2 may hide systematic underspending based on lack of accomplishment of investment plans during previous years.

From a **societal inclusion** perspective, Brabrand performs marginally better than Pier 2. The amount of *time spent in the garden* is greater, both in terms of frequency and duration of visits. Gardeners at Brabrand are also more likely to report *social interactions* and the development of *new social relationships* through their involvement in the garden. This supports the findings of previous research that community gardeners who spend more time in their gardens are more likely to develop new social relationships, both within the garden and beyond (Glover, Parry, et al., 2005). Cultural or religious expression was not a strong motivator in either garden, resulting in low scores on the *cultural dimension*. At the other end of the scale, *environmental stewardship* was a top-performing indicator for both gardens. The make-up of the garden community at Pier 2 appears from the score to be significantly more representative than that of Brabrand. As noted above, this is likely due to a statistical error caused by the small sample size in the case of Pier 2.

Concerning **urban development**, Pier 2 outperforms Brabrand on most indicators. The location on public land in a left-over space, along with the existence of a formal tenure agreement, results in a stronger performance on the parameters *perceived public utility* and *land access & tenure*. Due to its central location, Pier 2 also outperforms Brabrand on *accessibility* and *relief of urban density*. One area where Brabrand scores higher is in relation to *civil steering*. This can be explained by the engagement of Brabrand in testing SiEUGreen technologies. The gardens perform equally well on the *policy formalisation* indicator. The reason for the similarity is that this indicator concerns to local planning directives which are applicable to any garden in Aarhus.

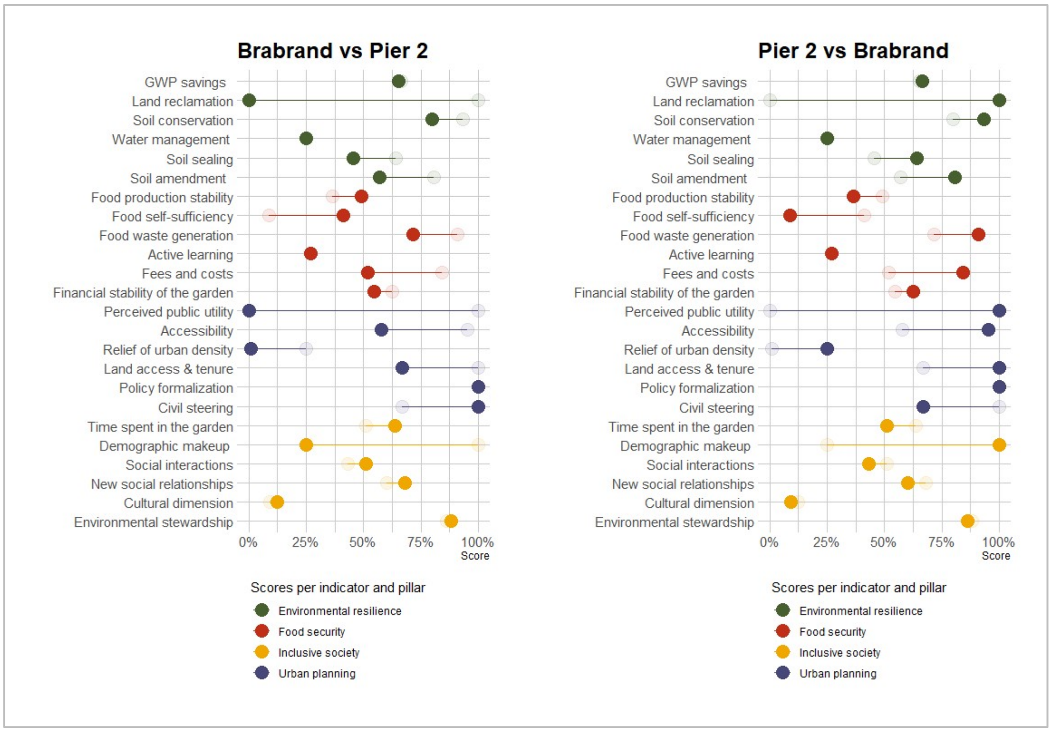
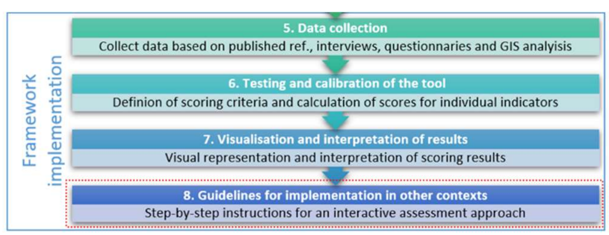


Figure 35. Side-by-side comparisons of the sustainability performance of the Brabrand and Pier 2 urban gardens, by Pillar (data for 2020)

3.4) Guidelines for implementations in other contexts



The aim of this task was to develop guidelines for new interactive impact assessment approaches for UA. Thus far, this report has focused on detailing the process through which this goal was achieved. This description becomes somewhat technical at times and may be challenging for some readers (e.g. UA practitioners, urban planners). As such, the aim of this section is to provide a simplified explanation of the tool, aimed at those who wish to replicate it in another context but who do not necessarily have a background in quantitative assessment approaches. Although our aim here is to make the tool as accessible as possible, it is still important to be aware that a certain degree of expertise is necessary to ensure its effective application. Particularly important is that the user has good knowledge of the garden/s under assessment. This knowledge is vital in ensuring accurate selection and interpretation of indicators.

3.4.1) Step 1: Determining which aspects to measure

The first step in implementing the tool is to determine which indicators to use. The full list of indicators can be found in Annex 6.6). The selected indicators should:

1) be relevant to measuring the urban sustainability performance of the specific garden/s that will be assessed
2) be realistic from the perspective of data availability
3) be distributed across all four pillars
4) have a complexity rating consistent with the data handling skills of those who will perform the assessment.

The selected indicators will become **headline indicators** in the assessment. There is no hard and fast rule about how many headline indicators are required. For a comprehensive assessment, however, it is important to cover as many of the **pathways** as possible. This should be balanced with the capacity to collect and process the data. Our assessment included 24 headline indicators, six in each pillar. This worked well and could be considered a rough guide for the appropriate number of headline indicators.

Ideally, headline indicators should be selected through an interactive process involving the relevant stakeholders. For example, the board or steering committee of the garden could work together to identify the key priority areas for the garden, and these could be used as a basis for selecting the aspects to be monitored. In the case where the tool is being used to make comparisons between several gardens within a single city, it may be useful to gather urban planners and other relevant municipal staff to consider the indicators in light of the city’s overall sustainability goals. In the case where the tool is being used for benchmarking between cities, a joint workshop could be incredibly valuable in sharing and contrasting different ideas about the contribution of UA to urban sustainability.

3.4.2) Step 2: Collecting data

Data collection tools are provided in the annexes to this report, including:

- Potential survey questions for participants in UA initiative/s (Annex 6.1)
- Interview guide for the leader of the UA initiative/s (Annex 6.2)

- Interview guide for urban planners in the municipality/region where the UA initiative/s is/are located (Annex 6.3)

These tools are designed to cover the whole suite of indicators, so it may be necessary to adjust them based on your selected headline indicators. While it may be tempting to collect as much information as possible from respondents, it is important to bear in mind that the length of the survey may affect the overall response rate. In small gardens of less than 30 persons, you will need responses to the survey from virtually all of the members of the garden to be confident that the responses are representative of the garden population as a whole (with high confidence level and a small margin of error). For gardens up to 100 participants, you should sample around 80 per cent of them. For larger gardens, the percentage would be significantly smaller.[5] If your sample size is smaller, you should be aware that the results may not be completely representative and hence you should try to validate them with interviews or other methods.

Surveys and interviews should be conducted in the local language wherever possible, and other cultural considerations should also be taken into account. For example, if digital access or literacy level among garden participants is low, it might be more appropriate to conduct the surveys on-site or via mail, rather than using an online survey tool.

GIS and remote sensing techniques may also be used as supplementary data sources to survey and interviews. With these techniques, more accurate data can be calculated for some specific indicators. Photo interpretation, network analysis, and other GIS methods can be applied to identify the land cover type, retrieve population density data, and calculate the proximity indicators. In addition, remote sensing methods are particularly useful for environmental indicators such as vegetation index and temperature measurement.

3.4.3) Step 3: Data processing and scoring

Once the data has been collected, it should be processed according to a scoring criterion similar to that outlined in sections 0 and 0. This is perhaps the most challenging aspect of the assessment process for those not accustomed to working with quantitative assessment tools. The first step is to identify the data that will feed each indicator. For example, in our assessment, the indicator "new social relationships" is informed by responses to the survey question "I have made new friends through my involvement in the garden". Other indicators may be fed by the interviews or by GIS work (see section

[5] A simple tool to calculate sample sizes is available here: https://www.surveymonkey.com/mp/sample-size-calculator/

3.1) for a full description of the methodology). Some indicators are fed by a combination of data sources. As noted above, these indicators are more complex to calculate and should be avoided by those who do not have the required skills.

The second step is to identify minimum and maximum limits for each indicator. For quantitative indicators, minimum and maximum values are typically defined based on any of the following methods:

- Theoretical minimum and maximum thresholds: for example, in the case of percentages, these values could be 0 and 100.
- Historical records: one could also define maximum and minimum thresholds based on observed data from time series or similar sources.
- Values-based on the literature: maximum and minimum thresholds can also be defined based on reference values provided by previous scientific works. This was, for example, the strategy used to determine the indicator of GWP savings.
- Policy targets: for instance, one could establish a maximum for GHG emissions per capita equivalent to the national values defined by the Paris Agreement.
- Aspirational values reflecting stakeholders' views: minimum and maximum values can also base on the objectives or goals defined by the garden participants.
- Contextual minimum and maximum values: correspond to the thresholds that expose specific properties of the city/country where the tool is being tested. For example, the minimum and maximum values of the indicator 'U80 Population density' was settled based on the minimum and maximum data for Denmark.

The definition of minimum and maximum values is very useful to ensure comparability across various evaluations, as they help maintain the stability of the scoring system. For discrete survey-based indicators, the task is slightly more complex, as it requires defining a whole scoring scale based on the possible values of the indicators. This is done by transforming potential answers to survey questions in scores based on ranked scales.

In the case of questions with multiple choices, one simple approach would be to calculate the **percentage** of people who responded to a question in a particular way. For example, we could calculate the proportion of respondents who responded positively to the statement (either by choosing "agree" or "strongly agree").

Another option is to calculate the score by assigning a ranking for each possible response. For instance, in the example given above "I have made new friends through my involvement in the garden", there were five possible responses: Strongly agree, agree, unsure, disagree, strongly disagree. Here, we chose to assign values between -2 and 2 to account for the negative, neutral, and positive nature of the responses. This value is called a **weighted score**. Calculating a weighted score was a common approach to the survey questions.

The main difference between the **percentage** and the **weighted score** approaches is that the latter defines a scale based on the extent to which respondents agree or disagree with the statement. This may be useful in cases where most responses go in the same direction (either positive or negative), and you wish to make a distinction between the extent of the positive (or negative) sentiment.

These strategies are also useful for assigning scores to interview data. Here, the scale is defined in a similar way, with different values attributed depending on the response to one or more questions. For example, in the case of the indicator *access to land*, ranks were defined based on a basic typology combining two of the questions from the interviews with the garden leaders: "Who owns the land where the garden is? " and "Is there a formal agreement in place that allows you to use this land as a garden?". Responses were scored according to the following scale: (0): the land is private with no formal agreement; (1): the land is public with no formal agreement; (2): the land is private with a formal agreement; (3): the land is public with a formal agreement. The theoretical minimum for this indicator is 0, and the theoretical maximum is 3.

Once maximum and minimum scores and/or reference scales have been determined for all indicators, the third step is to calculate the score, based on the relevant data. In the first example above, "new social relationships", this meant assigning a score to each respondent based on their response to the question "I have made new friends through my involvement in the garden". Those who responded "strongly disagree" received a score of -2, those who disagree a score of -1, and so on. All scores were then added together and divided by the total number of responses. In the case that only one value is available (i.e. the data is based on data from a single respondent or calculation), this value is the score. In practice, this operation defines a weighted score for each individual indicator. All the scores should fall between the minimum and maximum values defined in the previous step.

Once the score has been calculated, the final step is normalisation. That is, transforming all the scores to percentages based on the minimum and maximum scores determined earlier. This is a vital step, as it allows comparisons to be made between the indicators. It is done using a simple calculation:

% = (SCORE - MIN)/(MAX - MIN) for increasing utility indicators (where a higher score indicates better performance, marked as beneficial in the performance matrix)

% = (SCORE- MAX)/(MAX - MIN) for decreasing utility indicators (where a lower score indicates better performance, marked as detrimental in the performance matrix)

Following this step, all scores should be expressed as a percentage, with a score of 100% representing the best possible performance on a given indicator and a score of 0% representing the worst possible performance.

If the assessment relies upon the same headline indicators as those used here, it may be possible to utilise the scoring criteria and calculation methods outlined in section 0 and 0. Several considerations must be taken into account, however. First, for the indicator "relief of urban density", the theoretical maximum for people per km^2 is based on the population density in the city centre of Copenhagen Municipality, the capital city of Denmark, which is deemed to be the most populated grid of 1km*1km for the country. The minimum value refers to the least populated population grid in Denmark. This was considered a relevant benchmark for the population density of the gardens being measured, given they are both located in Denmark. It would not be appropriate for a garden located in, for example, Beijing.

3.4.4) Step 4: Interpretation of results

The final step in implementing the tool is to interpret the results. As stated at the beginning of this section, this should be done by, or in partnership with, someone who has good knowledge of the garden/s in question.

Some aspects to keep in mind when interpreting the results include:

- The interpretation of the results may vary depending on who analyses them. For example, a planner may focus on the impact the garden has for the city, and thus the SiEUGreen indicator panel can assist decision-making (e.g., allocation of financial support). For a UA practitioner, it can be used as a checklist that informs relevant aspects that may help improve the performance of the garden concerning the different pillars.
- Keep in mind the purpose of the garden. This will help to put the results into perspective, as it will be possible to compare the results obtained with the expected.
- The lowest scores pinpoint issues that can be improved to strengthen the sustainability of the garden further.
- Consider the value of an interactive approach. For example, bringing in garden participants themselves to reflect on the results may bring a richness that is difficult to find in numbers alone.
- The results can be used to mediate discussions, settle priorities, draw recommendations, and action plans that identify what should be done, when and by whom.

4) Final considerations

This report has demonstrated the value of the SiEUGreen UA monitoring tool for analysing the contribution of UA activities to urban sustainability. The initial iteration of the tool proved to be highly effective in delivering a synthetic, yet comprehensive, overview of the sustainability performance of two gardens in Aarhus, Brabrand and Pier 2. Virtually all the design criteria introduced in Section 2.1) were met. Further testing of the tool in Turunçlu Greenhouse and Company X was useful in validating the effectiveness of the approach as well as simplifying the framework and improving its responsiveness to a more diverse range of UA approaches.

The main strengths of the tool included:

- **Comprehensiveness.** The adoption of a multi-dimensional perspective allowed us to overcome the tendency for research in this area to focus on a single angle (social, food security, environmental, etc.). Our tool encompasses four distinct areas within a single framework, allowing for a comprehensive picture of the contribution of a garden to the various sustainability spheres in a selected urban context. Particularly novel is the inclusion of indicators relating to the contribution of UA to sustainable urban planning. Aspects such as the contribution of urban gardens to urban morphology and urban functions, as well as its implications for strategic planning, have been neglected by most evaluations to date.
- **Comparability.** The transparent and stable scoring system allows for comparisons between gardens and even between dimensions within a single garden. In the case of the gardens compared here, for example, we can easily see that the approach performs well in highlighting critical performance differences.
- **Flexibility.** The tool is designed for used in a wide range of contexts. The incorporation of a broad range of indicators within clearly defined pathways allows the user to adjust the headline indicators according to the specific context. In this way, the tool is responsive to data availability, as well as to specific circumstances that may result in particular indicators being more or less relevant. For example, a prerequisite for inclusion in the Taste Aarhus program is the existence of a board or steering committee which meets regularly. As such, it did not make sense to include this as a headline indicator when comparing two gardens that are both part of this program. In another context, this could be a highly important indicator of social engagement and could be included as a headline indicator.
- **Multiple applications.** The tool has applicability for a wide variety of potential users. Moreover, the ability to tailor the tool to different contexts also presents an opportunity for

stakeholder engagement at different levels. Criteria, processes, and monitoring methods can be determined in consultation with the relevant stakeholders, accommodating perspectives from different groups as appropriate. The tool also includes a combination of qualitative and quantitative indicators, designed to be fed by a diverse range of data collection methods. As such, the tool is sensitive towards the less tangible aspects of UA.

- **Alignment with accepted sustainability appraisals**. Of particular note is the links between the tool and the SDGs. Even though the SDG framework has not been specifically designed to focus on the urban setting, our framework is anchored on the SGDs and operationalises effective links to it. This alignment increases the relevance and legitimisation of the evaluations and at the same time, allows it to be easily adopted as part of broader monitoring and evaluation activities at city level.

Of course, as with any such framework, there are also weaknesses to be taken into account. These include:

- **Limited scope for retrospective cross-case comparisons**. The high degree of flexibility built into the tool also has a downside. Allowing users to adapt the tool to their own specific context means that, in a scenario where the tool becomes widely used, it would be difficult to synthesis the results in a meaningful way. The variation in the selection of headline indicators would likely be too great.
- **Data and expertise requirements.** Despite our considerable effort to assure flexibility and ease of use, the tool does require at least some data to be effective. This data can be challenging and/or costly to collect, produce and interpret.
- **Subjectivity in interpretation.** The scoring system has been deliberately designed to ensure transparency. Despite this, it is important to acknowledge that indicator-based sustainability assessments have a tendency to hide relevant details crucial for proper interpretation of results. This was exemplified, for example, by the indicators on soil fertilization, demographic makeup and financial surplus in the case of Pier 2. As such, it is vitally important that the assessment is performed in collaboration with someone who is familiar enough with the garden to spot any anomalies in the scoring and interpret them effectively.
- **Broad and static snapshot.** As with most indicator-based assessment frameworks, the tool provides a broad and static snapshot of sustainability aspects. This cannot replace deeper evaluations of the environmental, social and economic impacts of UA initiatives. The testing and calibration phase showed how important it is to support and complement the insights provided by the tool with other contextual information.

The experience gained during testing and calibration of the SiEUGreen monitoring tool for UA initiatives provides useful insights to support the future implementation of the tool to other contexts. The tool is a very effective way of producing a synthetic yet comprehensive overview of the performance of UA initiatives. By design, however, it focuses on a selection of critical aspects that need to be properly identified and interpreted.

This requires domain knowledge and a significant amount of background information. Contextual information and domain knowledge are vital in deciding on the type of indicators to use (headline vs standard vs background). The performance matrix includes a long list of indicators that can seldom be calculated together due to data limitations and implementation costs. Hence, the selection of the most relevant indicators to focus on (i.e., headline indicators) requires a careful evaluation of the various options based on a good knowledge of the UA initiatives and domains being analysed. Domain knowledge is also essential to identify the utility direction of the indicators (detrimental vs beneficial vs contextual). Remarkably, indicators can behave in opposite directions based on the context. For example, from an urban planning perspective, the location of the garden in relation to other areas in the city can be beneficial or detrimental depending on the specific conditions of the area and the nature of planning strategies and regulations.

Proper interpretation cannot be made unless those applying the tool and assigning scores are familiar with the garden and its dynamics. This is illustrated by the example of the budget surplus in Pier 2, where the good performance may hide underspending due to unfulfilled investment plans. Another example could be food production indicators, that can only be understood if anchored on local conditions. These indicators simply do not bear the same meaning when applied to vulnerable communities as to when they are calculated in affluent contexts. In sum, the flexibility of the tool requires that all its components are selected, fine-tuned and interpreted based on the specific conditions where the tool is applied.

Local knowledge is also vital in planning the data collection strategy. Desk research and literature review shall be the general starting point, as they provide considerable empirical evidence on data collection methods of certain indicators. A combination of qualitative (e.g., survey, in-depth interview, focus group) and quantitative (e.g., GIS, remote sensing, modelling) methods is recommended. They function as complementary parts in most cases.

The trade-off between the accuracy of data and the complexity of data collection is another crucial consideration. Though quantitative methods may be deemed as more accurate, obtaining reliable quantitative data at an individual garden level can be complex. A good example is the headline indicator on greenhouse gas (GHG) emission reduction within the environmental pillar. The optimal method for calculating potential GHG emission savings due to the garden is life cycle assessment (LCA). Given the high resource-demands of the LCA method, we instead chose to take empirical values from literature and apply them to the two case studies. It is a compromised method with certain limitations, e.g., the climate conditions are different in gardens located in different countries. It was, nonetheless, deemed the most appropriate trade-off between complexity and accuracy in this case.

The unique combination of local knowledge and scientific expertise required to apply the tool makes it well suited to use in science-society partnerships, such as those found in SiEUGreen. As such, the research team do not believe it is appropriate to develop an online platform where UA practitioners can access and apply the tool. Such a platform has the potential to undermine the deliberative and interactive approach that is the richest part of the assessment process. Here, determinations are made about the aspects of urban sustainability most relevant to each initiative, promoting spirited debate among actors. These discussions form a basis for improvement that is far more meaningful than that which could be achieved by simply generating a plot through an online tool. Further, development of such a tool was not part of the work outlined in the proposal and, as such, there are not sufficient resources available for this work.

Instead, the research team have dedicated resources to dissemination of the tool among the scientific community and with practitioners, including

- The following publications:
  - In English: Tapia, C., Randall, L., Wang, S.; Borges, L. A. (2021): Monitoring the contribution of urban agriculture to urban sustainability: an indicator-based framework. *Sustainable Cities and Society*. In press, https://doi.org/10.1016/j.scs.2021.103130
  - In Danish: Nilsson, Kjell. 2021. Bylandbrug bidrager til bæredygtige byer. Grønt miljø 39(10), 14-16.
- A workshop held with planners in Aarhus in September 2021, looking at how the results of the assessment can be used in making determinations about which UA initiatives to support.
- A workshop planned with NMBU masters students in the spring 2022.
- Inclusion of a guide to the tool in a Nordregio digital publication. This publication will be based on the D1.3 Whitepaper with best practices. It is designed to disseminate the complete work of WP1 and is expected to be published in late 2022.

The SiEUGreen monitoring framework for UA provides a comprehensive approach to monitoring the contribution of UA to urban sustainability. The initial work with the two community gardens aided the identification of a broad suit of indicators, along with a toolkit through which to monitor these. Applying the framework in two new contexts has resulted in further refinement of these tools, making the framework both easier to use and responsive to a more diverse range of UA initiatives. We look forward to further disseminating the tool though the Nordregio Report and other scientific endeavours.

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6) Annexes

6.1) Survey for gardeners, Brabrand and Pier 2

Social, environmental and economic effects of UA	
Thank you for taking the time to share your experiences with UA in **place. The information will help us show how UA can have a positive impact on society, the economy and the environment. The information you share with us will be used in the EU project SiEUGreen (learn more: **add link) and will be shared with the leaders of the garden and representatives of the Taste Aarhus project. None of your responses will be linked to you personally. A summary of the results of the survey will be posted on the Facebook page soon after the survey closes. If you have any questions about the survey or the SiEUGreen project, please contact Luciane Aguiar Borges (email: luciane.aguiar.borges@nordregio.org). Please note: This survey is only for participants from **insert name of the garden. The survey will take approximately 10 minutes to complete.	
Question	Answer choices
Do you participate in gardening at **insert name of the garden?	Yes [move on to "About you" page] No [disqualification message]
Disqualification message: Thanks for your interest in our research! Unfortunately, this survey is only for gardeners from **insert name of the garden. Keep an eye on the Taste Aarhus Facebook page for more opportunities to get involved in our work: https://www.facebook.com/SmagPaaAarhus	
About you	
Question	Answer choices
What is your gender?	Male Female Non-binary
How old are you?	Under 18 18-29 30-49 50-65 65+
Where were you born?	Denmark Outside Denmark (please state your country of birth below)
What is your highest level of education?	Primary school Secondary school Post-secondary (vocational) Post-secondary (university) Masters degree or higher
What is your postcode?	
How many people live in your household?	1 2 3 4 5+
About your gardening	
Question	Answer choices
What is your main motivation for participating in the garden?	very important

Reducing the environmental impact of the food I eat To get access to fresh, organic food To save money by growing my own food To make money by selling my products Socialising with family and friends Meeting new people Improving my neighbourhood/city Exercise / outdoor activity Relaxation / stress relief Cultural or religious expression Other (please specify)	somewhat important not important
In an average month (during the growing season), how often do you visit the garden?	Less than once per month Once per month 2-3 times per month Once per week 2-3 times per week More than three times per week
How much time do you spend in the garden on an average visit (during the growing season)?	Less than 1 hour 1 - 2 hours 2 - 4 hours More than 4
How do you usually travel to the garden?	Walk Cycle Take public transport By car (alone) By car (with others) Other (please state)
How long does it take you to get to the garden?	Under 10 minutes 10-20 minutes 20-30 minutes Over 30 minutes
Tell us about the interactions you have with other gardeners (please note: “other gardeners” does not include people you visit the garden with, e.g. family members or close friends) I talk with other gardeners about issues relating to the maintenance and management of the garden I talk with other gardeners about gardening I talk with other gardeners about food (e.g. exchanging recipes) I give, receive, or exchange food with other gardeners I talk with other gardeners about other aspects of life (e.g. family, work, other interests) I meet other gardeners outside of the context of the garden	very often often sometimes not often never
About your garden	
Question	Answer choices
What type of garden do you have?	Traditional soil cultivation on ground Greenhouse (natural heat) Greenhouse (artificially generated heat) Rooftop garden Vertical garden / Vertical space to grow food Balcony garden Hydroponic system

	Aquaponic system (fish and plants) Paper-based plant growing system (e.g. sprouts) Other (please specify)
How often do you change what you grow in your garden?	Never Yes, every year Yes, every two years Yes, every 3-6 years
What fertilizers do you use in your garden?	None Chemical fertilizer Household waste (e.g., food waste) Animal manure Urine water (e.g. urine mixed with water) Other organic fertilizer (e.g. bokashi) Other non-organic fertilizer
What type of irrigation method do you use in your garden?	None Drip Sprinkler Manual (watering can, hose or similar method) Furrow Other (please specify)
Do you use pesticides in your garden?	No Yes, I use pesticides (chemical) Yes, I use pesticides (organic)
About the food you grow – Vegetables	
Question	Answer choices
Do you grow vegetables in your garden?	Yes No [skip to “About the food you grow – Fruit”]
Approximately what share of your household VEGETABLE consumption is satisfied by your garden? Leafy vegetables (e.g., spinach, leaf beet, lettuce, celery) Solanaceous crops (e.g., tomato, chilli, bell pepper and eggplant) Root vegetables (e.g., radish, carrot, turnip, beetroot, parsnip) Tuber vegetables (e.g., potato, sweet potato, fennel, yams) Cole crops (e.g., cauliflower, cabbage, sprouting broccoli and Brussels sprouts) Cucurbit crops (e.g., melons, gourds, cucumber, pumpkin and summer squash) Pea and beans Bulb vegetables (e.g., onion, leek, garlic) Perennial vegetables (e.g. artichoke, asparagus) Herbs (e.g., mint, parsley, coriander) Other (please state below) If you selected "other" above, please tell us what you were referring to	I don’t produce this I produce a little I get most or all of what I need from the garden (in season) I get most or all of what I need from the garden (year-round)
About the food you grow – Fruit	

Co-funded by the Horizon 2020 programme of the European Union
Co-funded by the Chinese Ministry of Science and Technology

Question	Answer choices
Do you grow fruits in your garden?	Yes No [skip to "About the food you grow – Animal products"]
Approximately what share of your household FRUIT consumption is satisfied with your garden? Peaches and nectarines, plums, cherries, apricots Citric: oranges, tangerines and mandarins, clementines, limes, lemons, grapefruit and pomelo Pears, apples, quinces Berries: strawberries, raspberries, blueberries, cranberries, gooseberries, currants, kiwi, grapes, etc. Figs Persimmons Other (please state below) If you selected "other" above, please tell us what you were referring to	I don't produce this I produce a little I get most or all of what I need from the garden (in season) I get most or all of what I need from the garden (year-round)
About the food you grow – Animal products	
Question	Answer choices
Do you produce animal products in your garden?	Yes No [skip to "About the food you grow – Other products"]
Approximately what share of your household consumption of ANIMAL PRODUCTS is satisfied with your garden? Fish Meat Milk Eggs Other (please state below) If you selected "other" above, please tell us what you were referring to	I don't produce this I produce a little I get most or all of what I need from the garden (in season) I get most or all of what I need from the garden (year-round)
About the food you grow – Other products	
Question	Answer choices
Do you grow/produce any OTHER PRODUCTS in your garden? (e.g. seeds, nuts, honey, lentils)	Yes No [skip to "The economy of your garden"]
Approximately what share of your household consumption of OTHER PRODUCTS is satisfied with your garden? Cereals and cereal products (e.g., wheat, sorghum, maize) Sugar crops and sweeteners (e.g., sugar cane, honey) Nuts (e.g., chestnuts, walnuts, hazelnuts) Oil-bearing crops (e.g., soybeans, olives, sesame seed) Fibres of vegetal origin (e.g., flax, jute, sisal) Spices (e.g., pepper, ginger, thyme, rosemary) Other (please state below) If you selected "other" above, please tell us what you were referring to	I don't produce this I produce a little I get most or all of what I need from the garden (in season) I get most or all of what I need from the garden (year-round)
About the food, you grow	

Do you ever throw away food that was produced in your garden (considering production, storage, transport and consumption stages)?	Never Rarely Sometimes Often
How did/do you learn about gardening and food? (choose all that apply to you)	I attend formal courses, training sessions, events (offline) I attend formal courses, training sessions, events (online) I exchange knowledge with other people I train myself using external resources (social media, YouTube, Facebook, apps…) I learn by doing
The economy of your garden	
Question	Answer choices
Approximately how much does your garden cost you on an annual basis? Annual fees and/or maintenance costs Energy Water Seeds and fertilizers Other supplies	nothing under 100 DKK 100 - 500 DKK 501 - 1000 DKK 1001 - 2000 DKK Over 2000 DKK
Have you ever received any income from your garden?	No Yes, I sell fruit, vegetables or other crops Yes, I produce and sell products (e.g. sauces, jams, honey, yoghurt, preserves etc.) Yes, I prepare or re-sell hot meals, snacks, drinks for other participants while in the garden Yes, I provide training and/or advisory services to other gardeners Yes, I rent out my own tools or facilities to other gardeners
What share of your annual income comes from activities related to the garden?	None More than 0% but less than 2% 2% - 5% 5% - 10% 10% - 25% 25% - 50% 50% - 75% More than 75% but less than 100% The garden is my only source of income
Final thoughts	
Question	Answer choices
To what extent do you agree with the following statements The neighbourhood is improved by the garden I feel proud of my garden	strongly disagree disagree unsure agree strongly agree

I have made new friends through my involvement in the garden The garden is an important source of income for me The garden gives me a chance to spend time with family and friends The garden is a great source of stress relief The garden helps me to reduce my carbon footprint The City of Aarhus is an important source of support for the garden My diet has improved since I started the garden My overall health and fitness is improved by gardening	
Please tell us in your own words what you see as the main benefits of the garden for yourself and for the city.	*(free text response)*
Thank you for sharing your thoughts with us! A summary of the results of the survey will be posted on the Facebook page soon after the survey closes. If you have any questions about the survey or the SiEUGreen project, please contact Luciane Aguiar Borges (email: luciane.aguiar.borges@nordregio.org).	

6.2) Interview guide for garden leaders, Brabrand and Pier 2

Background	
Question	Answer (remove those which do not apply)
1. When was the garden first established?	
2. Who initiated the garden?	
3. What was the area used for before it became a garden?	
4. What is the size/ area (m^2 or hectares) of your garden?	
5. Is the garden fenced in any way (e.g. fences, walls, gates)	
6. What proportion of this area is occupied by greenhouses or other buildings and sealed soil (paved paths)?	
7. Which of the following facilities can be found in your garden? Tick as many boxes as needed	Drinking water Toilets (public toilets nearby from the Dome) Storage rooms (for tools) – roof no walls Storage rooms (for food) Kitchen Other (water tank)
8. How would you describe the physical characteristics of the garden	The terrain is flat The terrain is uneven
9. How many beds to grow food does the garden have? And what is the size/area (m^2 or hectares) of the bed on average?	
10. Where do the members of your garden grow food? Tick as many boxes as needed	Directly in the soil In pallets (boxes) Greenhouses Inside buildings (other than greenhouses) Rooftops Balconies

	Walls Other: different looks use of trees to increase biodiversity – use natural materials – volunteer work
Environment	
1. Have you conducted any professional laboratory and/or on-site test tracking potential soil contamination in the past five years?	YES/NO
2. If yes, please tell us about these tests:	i) chemical, [number of tests] microbial, [number of tests]
Garden members	
3. How many members are part of your garden?	60 members – 45 gardens – people share gardens, that is why the number is different. There are also friends of the members.
4. What is the main purpose of the garden?	Provide recreation A place to grow food (for themselves) A place to grow food (to sell) not allowed Educational (planning to do a composting project together with one of the other associations) For healing – enlarge the social network For social integration Greening the city Other:
5. Does the garden have a board or steering committee?	YES/NO
6. If so, how often do they meet?	
7. Do the garden's members participate in decisions? If they do, how?	Direct participation Through the elect board
8. How do non-members engage in the garden?	Dinners/Meals Events Training (not yet) Visits (partners, family, bring more people to the community) Recreation…
Food security	
1. Are chemicals allowed to be used in the garden?	YES/NO
2. If chemicals are allowed, are there specific safety regulations that should be followed?	YES/NO
3. Have you conducted any professional laboratory and/or on-site tests tracking potential food contamination pathogens in the past year?	YES/NO
4. If yes, please tell us about these tests:	ii) chemical, [number of tests] iii) microbial, [number of tests] iv) mycotoxin contamination [number of tests]
5. Does the garden have any general food safety assurance mechanisms?	YES/NO
6. If yes, please tell us about these	i. formalised food safety managing protocols and programs;

	ii. food traceability systems
7. Do you organise training sessions on how to grow healthy food?	YES/NO
1. If yes, how many participants were trained last year?	Number
2. If yes, which topics are normally addressed by the courses that you organise?	1. Growing techniques and methods (including, planting, irrigation, recollection, fertilizers, etc.) 2. Animal care and husbandry methods 3. Food manipulation and hygiene 5. Recipes and cooking 6. Food sharing and socialization events 7. Other (please tell us about it)
Economy	
1. What is the current annual budget in the garden? 2. What was the income balance last year? (considering all expenses and revenues) 3. Has the garden been in financial difficulties? If yes, please explain (How many income balances have been negative during the last three years if any?)	
4. Approximately how much was the initial set-up cost? 5. Who / how were these costs covered?	
6. What are the main operating costs in the garden (supplies, maintenance, security...)?	-
7. Is there any annual or monthly fee to be paid by participants? If so, how much is paid? 8. Does everyone pay the same? Is there any support scheme aimed at low-income groups?	
9. Do you have any external financial support from the public administration? If so, which one (local, regional, national)? 10. Is this support stable over time??	
11. Do you have any support from local businesses? If so, which type of support and from which companies? 12. Is this support stable over time?	
13. Does the garden have any employees?	YES/NO
14. If yes, what are their roles and how many hours per week do the employee/s work?	
Water and energy	
1. From where do you get the water for the garden? Tick as many boxes as needed	Groundwater Irrigation channels or pipelines Reticulated mains water Rainwater Recycled-, grey- or storm-water

2. Do you use recycled/recovered wastewater for the garden? If yes, what proportion does it account in the total water consumption?	
3. From where do you get the energy for the garden? (e.g. electricity, heating)	
4. What is the heating and electricity consumption per year? How much do you pay for heating and electricity per year, respectively?	
Sustainable urban development	
1. Who owns the land where the garden is?	Private Public Myself Other:
2. Is there a formal agreement in place that allows you to use this land as a garden?	YES/NO
3. If yes, please tell us about this agreement (e.g. length of time, conditions, etc.)	
4. How worried are you about being evicted from your garden?	Very worried Worried A little worried Not worried at all
5. Does your garden partner with any private or public stakeholder? For example, do you make use leftovers of restaurants as a compost for your garden? Or do the food produced in your garden is sold to any local food store, restaurant, school?	**YES/NO**

6.3) Interview guide for planners, Aarhus

1. Is UA acknowledged in the strategic planning (e.g. land use plan) documents of your city? If yes, can you name the documents?

2. Is UA acknowledged by the municipality in particular urban development (e.g. as a mean to increase green areas in detailed planning)?

3. Does your municipality carry out any public program that supports the implementation of urban gardens?

4. Is UA acknowledged in new urban developments (e.g. owned by private actors and non-official detailed development plans)?

5. Would you say that civil society plays an active role in driving UA in the city?

6.4) Survey for gardeners, Turunçlu Greenhouse

Social, environmental and economic effects of urban agriculture

Thank you for taking the time to share your experiences with urban agriculture in Turunçlu Greenhouse. The information will help us show how urban agriculture can have a positive impact on society, the economy and the environment. The information you share with us will be used in the EU project SiEU Green (learn more: **add link) and will be shared with representatives of Hatay Municipality. None of your responses will be linked to you personally. A summary of the results of the survey will be posted on the Turunçlu Facebook page soon after the survey closes.

If you have any questions about the survey, or the SiEUGreen project, please contact Luciane Aguiar Borges (email: luciane.aguiar.borges@nordregio.org).

1. **What is your gender?**

[ ] Male [ ] Female

2. **How old are you?**

[ ] Under 18
[ ] 18-29
[ ] 30-49
[ ] 50-65
[ ] 65+

3. **Where were you born?**

[ ] Hatay
[ ] Elsewhere in Turkey
[ ] Outside Turkey (please state your country of birth: ______________________________

4. **What is your highest level of education?**

[ ] No formal education
[ ] Primary school
[ ] Secondary school
[ ] Post secondary (vocational)
[ ] Post secondary (university)
[ ] Masters degree or higher

5. **What is your postcode?** ________________

6. **What was your main motivation for participating in the course?**

	Very important	Somewhat important	Not important
Learning how to reduce the environmental impact of the food I eat	[ ]	[ ]	[ ]

To get access to fresh, organic food	[ ]	[ ]	[ ]
To save money by growing my own food	[ ]	[ ]	[ ]
To make money by selling my products	[ ]	[ ]	[ ]
Socialising with familyand friends	[ ]	[ ]	[ ]
Meeting new people	[ ]	[ ]	[ ]
Improving my neighbourhood / city	[ ]	[ ]	[ ]
Exercise / outdoor activity	[ ]	[ ]	[ ]
Relaxation / stress relief	[ ]	[ ]	[ ]
Cultural or religious expression	[ ]	[ ]	[ ]
Learning how to grow food using other technologies (aquaponic, hydroponic)	[ ]	[ ]	[ ]

Other (please specify)

____

7. How did you travel to get to the greenhouse?

[ ] Walk
[ ] By car (alone)
[ ] Cycle
[ ] By car (with others)
[ ] Take public transport

Other (please state): ____

8. How long does it take you to get to the greenhouse from your home?

[ ] Under 10 minutes
[ ] 10-20 minutes

[ ] 20-30 minutes

[ ] Over 30 minutes

9. Tell us about the interactions you have had with other participants in the course (tick all that apply to you)

[ ] I talked with other participnats about matters related to the course

[ ] I talked with other participants about gardening

[ ] I talked with other participants about food (e.g. exchanging recipes)

[ ] I talked with other participants about other aspects of life (e.g. family, work, other interests)

10. How likely is it that you will meet any of the other participants again now that the course is over?

[ ] Very unlikely

[ ] Unlikely

[ ] Unsure

[ ] Likely

[ ] Very likely

11. To what extent do you agree with the following statements

	strongly agree	agree	unsure	disagree	strongly disagree
The neighbourhood is improved by Turunçlu Greenhouse	[ ]	[ ]	[ ]	[ ]	[ ]
I feel proud of what I have achieved in the course/ workshop	[ ]	[ ]	[ ]	[ ]	[ ]
I have made new friends through my participation in the course/ workshop	[ ]	[ ]	[ ]	[ ]	[ ]
Participating in the course/workshop helped me to feel connected to my home culture	[ ]	[ ]	[ ]	[ ]	[ ]
The skills I learned in the course/workshop will help me to earn an income	[ ]	[ ]	[ ]	[ ]	[ ]
The course/workshop gave me a chance to spend time with family and friends	[ ]	[ ]	[ ]	[ ]	[ ]
The course/workshop was a great source of stress relief	[ ]	[ ]	[ ]	[ ]	[ ]
The course/workshop was a great chance to exercise / engage in outdoor activity	[ ]	[ ]	[ ]	[ ]	[ ]

Please tell us in your own words what you thought about the training program

____
____
____
____
____

Thank you for sharing your thoughts with us!

6.5) Interview guide for garden leaders, Turunçlu Greenhouse

Social, environmental and economic effects of urban agriculture

Turunçlu Greenhouse: Survey for the Municipality / Greenhouse operators

Background	
Question	Answer (remove those which do not apply)
11. What type of greenhouse do you have?	Greenhouse (natural heat) Greenhouse (artificially generated heat)
12. When was the greenhouse first established?	
13. Who initiated the greenhouse?	
14. What was the area used for before it became a greenhouse?	
15. What is the size/ area (m^2 or hectares) of the plot where the greenhouse is located?	
16. Is the greenhouse and/ or the plot fenced in any way (e.g. fences, walls, gates)	
17. What proportion of this area is occupied by the greenhouse or other buildings and sealed soil (paved paths)?	
18. Which of the following facilities can be found in the greenhouse? Tick as many boxes as needed	a) Drinking water b) Toilets (public toilets nearby from the Dome) c) Storage rooms (for tools) – roof no walls d) Storage rooms (for food) e) Kitchen f) Other
19. How many beds to grow food does the greenhouse have? And what is the size/area (m^2 or hectares) of the bed on average?	

Environment	
1. From where do you get the energy for the greenhouse? (e.g. electricity, heating)	a) From the grid b) A mix of own production and grid (>50% grid) c) A mix of own production and grid (approx. 50% grid, 50% own production) d) A mix of own production and grid (>50% own production) e) Own energy generation

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1. What proportion of your total fertiliser use is organic matter?	a) We do not use fertiliser b) All fertiliser used is organic c) Over 75% of fertiliser used is organic d) Over 50% of fertiliser used is organic e) Less than 50% of fertiliser used is organic f) We use only non-organic fertilisers
2. What proportion of the greenhouse energy consumption is a by product of another use?	a) All of our energy use is a by product of another use b) Over 75% c) Over 50% d) Less than 50% e) None
3. What proportion of the greenhouse infrastructure has been developed using recycled/repurposed materials?	a) All of our infrastructure has been developed using recycled/repurposed materials b) Over 75% c) Over 50% d) Less than 50% e) None
4. What type of irrigation method do you use in the greenhouse?	a) None b) Drip c) Sprinkler d) Manual (watering can, hose or similar method) e) Furrow f) Other (please specify)
5. What proportion of your total water use is recycled / waste water? (Note: includes circulation within the food growing system, for example, reuse of water within a hydroponic system)	a) All of our water use is recycled / waste water b) Over 75% c) Over 50% d) Less than 50% e) None
6. How does water use in the greenhouse compare with water use in traditional agriculture for comparable products?	a) Similar b) Savings of up to 25% c) Savings of up to 50% or less d) Savings of up to 75% e) Savings of up to 90%
7. From where do you get the water for the greenhouse? Tick as many boxes as needed	a) Groundwater b) Irrigation channels or pipelines c) Reticulated mains water d) Rainwater e) Recycled-, grey- or storm-water

Societal inclusion	
1. How many people have taken part in the activities of the greenhouse in the past 12 months?	
2. How many activities or events have been offered by the greenhouse in the past 12 months?	
3. What is the main purpose of the greenhouse?	a) Provide recreation b) A place to grow food (for themselves)

	c) A place to grow food (to sell) not allowed d) Educational (planning to do composting projects together with one of the other associations) e) For healing – enlarge the social network f) For social integration g) Greening the city h) Other:
4. Does the greenhouse has a board or steering committee?	YES/NO
5. If so, how often do they meet?	
6. How do participants provide input into the management of the greenhouse?	a) They have the opportunity to participate on a board or steering committee b) They provide feedback through program evaluations or other single-point-in-time feedback mechanisms c) Participants do not have an opportunity to provide input into the running of the garden
7. How many people work at the greenhouse? (equivellent full-time)	
8. How many new jobs (EFT) have been created by the greenhouse?	
9. Does the greenhouse donate/give away food?	a) No b) Sometimes c) Regularly

Food security	
1. Please list all the different foods that the greenhouse produces and the quantity of each type produced per year.	
2. How does the cost of the product compare to an equivalent product produced outside the city?	a) The cost is lower than other comparable products b) The cost is similar to other comparable products c) The cost is higher than other comparable products
3. How predictable is your harvest?	a) Very unpredictable b) Somewhat unpredictable c) Quite predictable d) Very predictable
8. Are chemicals used in the greenhouse?	YES/NO
9. If chemicals are used, are there specific safety regulations that should be followed?	YES/NO
10. Do you conduct any professional laboratory and/or on-site tests tracking potential food contamination pathogens?	a) Never b) Occasionally c) Regularly d) Constant monitoring

11. Does the greenhouse have any general food safety assurance mechanisms?	YES/NO
12. If yes, please tell us about these	
13. What is the average time from harvest to consumption?	a) Most products are harvested directly prior to consumption b) Less than one day c) Less than two days d) Two days or more
14. What fraction of the greenhouse's operational costs were covered by external sources in the previous financial year (e.g. public grants, venture capital)	a) None b) Less than 25% c) 25-50% d) 50-75% e) Over 75% f) All
15. Do you organise training sessions on how to grow healthy food?	YES/NO
16. If yes, how many participants took part in the training sessions in the past 12 months?	Number
17. If yes, which topics are usually addressed by the courses/workshops that you organise?	a) Growing techniques and methods (including planting, irrigation, recollection, fertilisers, etc.) b) Animal care and husbandry methods c) Food manipulation and hygiene d) Recipes and cooking e) Food sharing and socialization events f) Other (please tell us about it)
18. Is there any annual or monthly fee to be paid by participants of the workshops/courses? If so, how much is paid?	
5. Do you use pesticides in the greenhouse?	a) No b) Yes, I use pesticides (chemical) c) Yes, I use pesticides (organic)
6. Do you use herbicides in the greenhouse?	a) No b) Yes, I use herbicides (chemical) c) Yes, I use herbicides (organic)

Sustainable urban development	
6. Who owns the land where the greenhouse is located?	7. Rented from a private entity 8. Rented from a public entity 9. Owned by the municipality Other:
10. Is there a formal agreement in place that allows you to use this land?	YES/NO
11. If yes, please tell us about this agreement (e.g. length of time, conditions, etc.)	
12. How worried are you about being evicted from the greenhouse?	a) Very worried b) Worried c) A little worried d) Not worried at all
13. Does the greenhouse provide the opportunity for urban dwellers to	a) Definitely b) To a large extent

connect with food production within the city?	c) To some extent d) Not at all
14. What is the primary land use in the area where the greenhouse is located?	a) Industrial b) Residential c) Commercial d) Recreational (e.g. greenspace) e) Mixed f) Other:
15. Has the greenhouse received any financial support to get started? (tick all that apply)	a) Municipal funding b) Government funding c) EU funding d) Venture capital funding e) None of the above (please specify how the activities are funded):
16. Does the greenhouse partner with any private sector or community stakeholders? (e.g. providing food to schools, collaborating with the municipality on local food policies, partnership with NGOs).	**a)** No private sector or community partners **b)** Yes, private sector partners **c)** Yes, community partners **d)** Yes, private sector and community partners

6.6) The performance matrix

Code	SiUEGreen Pillars (Endpoints)	Pathway	Specific aspect to monitor (Midpoints)	Indicator definition	Direction	Complexity	Units	Type of indicator	Potential data source	Link to SDGs	Ecosystem Services	References
E1	**Environmental resilience and resource efficiency**	**Climate regulation: GWP savings**	**GHG captured by UA**	**Estimated global warming potential (GWP) savings, according to the products cultivated in the garden**	**Beneficial**	**High**	**ton**	**Headline**	**GIS/spatial analysis, literature and surveys**	**13**	**Regulating: climate regulation**	**(Caputo et al., 2020; Kulak et al., 2013)**
E2	Environmental resilience and resource efficiency	Climate regulation: air purification	Estimated air purification capacity by UA	Vegetation Index (NDVI)	Beneficial	High	ton	Standard	Other	13	Regulating: air quality	(Cortinovis & Geneletti, 2019; Nowak et al., 2006)
E3	Environmental resilience and resource efficiency	Climate regulation: climate comfort	Urban temperature regulation by UA	Temperature reduction in UA area: temperature differential observed in the area in relation to city average, city centre or confining areas	Beneficial	High	Celsius degrees	Standard	Photo-interpretation or ground plot measurements	13	Regulating: air quality	(Habeeb, 2017; Hallett et al., 2016)
E4	Environmental resilience and resource efficiency	Energy balance	Heating intensity and energy balance	Net heating consumption per unit area per year (consumption - generation)	Detrimental	Average	kWh/m2	Standard	In-depth interviews	12	Regulating: climate	(Weidner & Yang, 2020)

E5	Environmental resilience and resource efficiency	Energy balance	Electricity intensity and energy balance	Net electricity consumption per unit area per year (consumption - generation)	Detriment al	Average	kWh/m2	Standard	In-depth interviews	12	Regulating: climate	(Weidner & Yang, 2020)
E6	Environmental resilience and resource efficiency	Energy balance	UA's contribution to energy efficiency of buildings	The prevalence of rooftop and vertical gardens in the community	Beneficial	Low	Qualitative	Background	Survey/questionnaire	12	Regulating: climate	(Hallett et al., 2016)
E7	**Environmental resilience and resource efficiency**	**Land reclamation**	**Repurposing vacant or idle land for UA**	**Area of previously vacant or idle land utilised for UA (e.g. abandoned lands, brownfields, etc.)**	**Beneficial**	**High**	**square metres**	**Headline**	**In-depth interviews**	**15**	**All**	**(Carlet et al., 2017; Lin et al., 2015; Schwarz et al., 2016)**
E8	**Environmental resilience and resource efficiency**	**Soil conservation**	**Adoption of organic farming practices aimed at soil conservation**	**Share of plots that adopt organic farming methods aimed at soil conservation, e.g. crop rotation/diversity methods, nitrogen fixation plants, etc.**	**Beneficial**	**Low**	**Qualitative**	**Headline**	**Survey/questionnaire**	**11. 12**	**Supporting: soil**	**(Tuğrul, 2019)**
E9	Environmental resilience and resource efficiency	Reduction of food packaging	UA's contribution to the reduction of food packaging	Share of locally produced food consumed per year	Beneficial	Average	Percentage	Standard	Survey/questionnaire	11. 12	Provisioning: food	(Hallett et al., 2016)
E10	Environmental resilience and resource efficiency	Water management	Water consumed in UA	Proportion of primary-sourced water consumed in UA per unit area per year	Detriment al	Average	cubic metres	Standard	In-depth interviews	6	Regulating: water	(Dalla Marta et al., 2019b)
E11	Environmental resilience and resource efficiency	Water management	Irrigation method used in UA	Main irrigation methods in UA: drip, sprinkler, furrow	Contextual	Low	Irrigation type	Standard	Survey/questionnaire	6	Regulating: water	(Dalla Marta et al., 2019b)
E12	**Environmental resilience and resource efficiency**	**Water management**	**Water sources in UA**	**Main water sources in UA: Groundwater, irrigation channels or pipelines, reticulated mains water, rainwater, recycled-, grey- or stormwater**	**Contextual**	**Low**	**Source type**	**Headline**	**In-depth interviews**	**6**	**Regulating: water**	(Dalla Marta et al., 2019b)

E13	Environmental resilience and resource efficiency	Water management	Wastewater reused in UA	Percentage of recycled/recovered wastewater used in UA	Beneficial	High	Percentage	Standard	In-depth interviews	6	Regulating: water	(Pollard et al., 2018)
E14	**Environmental resilience and resource efficiency**	**Soil sealing**	**Stormwater infiltration enhanced by UA practice**	**Share of land covered by permeable material or bare soil**	**Beneficial**	**High**	**square metres**	**Headline**	**GIS/spatial analysis**	**6**	**Regulating: water**	**(Hallett et al., 2016)**
E15	**Environmental resilience and resource efficiency**	**Soil amendment**	**Prevalence of using fertilizers in UA**	**Type of fertilisers used by garden participants in UA**	**Detrimental**	**Low**	**Percentage**	**Headline**	**Survey/questionnaire**	**3**	**Regulating: purification**	**(Van der Wiel et al., 2019; Wielemaker et al., 2019)**
E16	Environmental resilience and resource efficiency	Potential contamination	Prevalence of using pesticides and herbicides in UA	Percentage of farmers using pesticides and herbicides	Detrimental	Low	Percentage	Standard	Survey/questionnaire	3	Regulating: purification	(Aboagye et al., 2018)
E17	Environmental resilience and resource efficiency	Potential contamination	Concentration of heavy metals	Number of professional laboratory or on-site tests tracking potential: (1) chemical and (2) microbial contamination on soils (last five years)	Detrimental	Low	Number	Standard	Survey/questionnaire	3	Regulating: purification	(Aboagye et al., 2018)
E18	Environmental resilience and resource efficiency	Technology innovation: green technology deployment	Planting techniques' environmental impact	Use of water-based hydroponic culture (soilless) and aquaponics (fish and plant), paper-based plant-growing technology, greenhouse technology	Beneficial	Average	Qualitative	Background	Other	9	Regulating	(European Commission, 2017)
E19	Environmental resilience and resource efficiency	Technology innovation: blue technology deployment	Waste and water management techniques' environmental impact	Use of water and waste recycling, water recovery technology	Beneficial	Average	Qualitative	Background	Other	9	Regulating	(European Commission, 2017)

E20	Environmental resilience and resource efficiency	Technology innovation: yellow technology deployment	Renewable energy techniques' environmental impact	Use of biogas production from waste resources, seasonal solar storage, combined heat and power, and photovoltaic generation of electricity	Beneficial	Average	Qualitative	Background	Other	9	Regulating	(European Commission, 2017)
S21	Inclusive society	Community engagement: Participation	number of members	Number of participants involved in the initiative	Beneficial	Low	number	Standard	Interviews	11	Cultural: Mental & physical health; Recreation & ecotourism	(Davidson, 2017)
S22	Inclusive society	Community engagement: Participation	frequency of visits by members	Average frequency of visits during an average month in the growing season	Beneficial	Low	Weighted score	Standard	Survey	11 & 3	Cultural: Mental & physical health; Recreation & ecotourism	(Davidson, 2017; Glover, Parry, et al., 2005)
S23	Inclusive society	Community engagement: Participation	average length of visit by garden members	duration of an average visit to the garden	Beneficial	Low	Weighted score	Standard	Survey	11 & 3	Cultural: Mental & physical health; Recreation & ecotourism	(Davidson, 2017; Glover, Parry, et al., 2005)
S24	**Inclusive society**	**Community engagement: Participation**	**Time spent in the garden**	**Overall time spent in the garden (during the growing season) including number and duration of visits**	**Beneficial**	**Average**	**Weighted score**	**Headline**	**Survey**	**11 & 3**	**Cultural: Mental & physical health; Recreation & ecotourism**	(Davidson, 2017; Glover, Parry, et al., 2005)
S25	Inclusive society	Community engagement: Participation	broader community participation	Number of ways in which non-members participation in garden activities	Beneficial	Average	number	Standard	Survey	11	Cultural: Mental & physical health;	(J. Y. Kingsley & Townsend, 2006)

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											Recreation & ecotourism	
S26	Inclusive society	Community engagement : Participation	Longevity of UA initiative	time since the garden was first established	Contextual	Low	number	Background	Survey	11	Cultural: Mental & physical health; Recreation & ecotourism	(ioby, 2018)
S27	Inclusive society	Community engagement : Participation	Main motivation(s) of participants	Proportion of participants who report (1) growing food, (2) socialising with others, (3) some form of collective action, (4) religious, (5) aesthetic, (6) health (7) financial as their primary motivation for participation in the garden	Contextual	Low	Percentage	Background	Survey	12	Cultural: Mental & physical health; Recreation & ecotourism	(Christensen et al., 2019)
S28	Inclusive society	Community engagement : governance	Self-management	Existence of a board or steering committee which meets at least once per quarter	Beneficial	Low	yes/no	Standard	Survey	16		(Glover, Shinew, et al., 2005; J. Y. Kingsley & Townsend, 2006; Teig et al., 2009)
S29	Inclusive society	Community engagement : governance	Inclusive self-management	Existence of participation mechanisms for all members	Beneficial	Average	Qualitative	Standard	Interviews	16		(Glover, Shinew, et al., 2005; J. Y. Kingsley & Townsend, 2006; Teig et al., 2009)
S30	Inclusive society	Social capital: diversity	Cultural background of participants	Cultural diversity of garden participants is similar to that of the neighbourhood/city	Beneficial	High	Chi-square	Standard	Survey/questionnaire	10		(Christensen et al., 2019; Corcoran & Kettle, 2015; Davidson, 2017;

											J. Y. Kingsley & Townsend, 2006)
S31	Inclusive society	Social capital: diversity	socioeconomic background of participants	socioeconomic diversity of garden participants is similar to that of the neighbourhood/city	Beneficial	High	Chi-square	Standard	NSI (city) & survey (garden)	10	(Christensen et al., 2019; Corcoran & Kettle, 2015; Davidson, 2017; J. Y. Kingsley & Townsend, 2006)
S32	Inclusive society	Social capital: diversity	gender of participants	Gender spread of garden participants is similar to that of the neighbourhood/city	Beneficial	High	Chi-square	Standard	NSI (city) & survey (garden)	5	(Christensen et al., 2019; Corcoran & Kettle, 2015; Davidson, 2017; J. Y. Kingsley & Townsend, 2006)
S33	Inclusive society	Social capital: diversity	age of participants	Age spread of garden participants is similar to that of the neighbourhood/city	Beneficial	High	Chi-square	Standard	NSI (city) & survey (garden)	10	(Christensen et al., 2019; Corcoran & Kettle, 2015; Davidson, 2017; J. Y. Kingsley & Townsend, 2006)
S34	**Inclusive society**	**Social capital: Diversity**	**Demographic diversity of participants**	**Demographic makeup of garden participants is similar to that of the neighbourhood/city**	**Beneficial**	**High**	**Chi-square**	**Headline**	**NSI (city) & survey (garden)**	**10 & 5**	(Christensen et al., 2019; Corcoran & Kettle, 2015; Davidson, 2017; J. Y. Kingsley & Townsend, 2006)

S35	**Inclusive society**	**Social capital: Interactions**	**Evidence of social interactions between gardeners**	**Extent to which garden participants report interactions of any kind with other gardeners.**	**Beneficial**	**Average**	**Weighted score**	**Headline**	**Survey**	**11**		(Audate et al., 2019; Christensen et al., 2019; Firth et al., 2011; J. Y. Kingsley & Townsend, 2006; Shostak & Guscott, 2017)
S36	Inclusive society	Social capital: Interactions	Evidence of social interactions between gardeners in the garden setting	Extent to which garden participants report interactions with other gardeners in the context of the garden	Beneficial	Average	Weighted score	Standard	Survey	11		(Audate et al., 2019; Christensen et al., 2019; Firth et al., 2011; J. Y. Kingsley & Townsend, 2006; Shostak & Guscott, 2017)
S37	Inclusive society	Social capital: Relationships	Evidence of social interactions between gardeners beyond the garden	Extent to which garden participants report interactions with other gardeners outside of the context of the garden	Beneficial	Average	Weighted score	Standard	Survey	11		(J. Y. Kingsley & Townsend, 2006; Teig et al., 2009; Veen et al., 2016)
S38	**Inclusive society**	**Social capital: Relationships**	**New social relationships**	**Number of new relationships develop through participation in the garden**	**Beneficial**	**Average**	**Weighted score**	**Headline**	**Survey**	**11**		(J. Y. Kingsley & Townsend, 2006; Teig et al., 2009; Veen et al., 2016)
S39	**Inclusive society**	**Wellbeing: connection to culture**	**Cultural and religious expression**	**Extent to which the garden supports cultural and/or religious expression**	**Beneficial**	**Low**	**Weighted score**	**Headline**	**Survey**	**11**	**Cultural: Spiritual and religious values**	(Shostak & Guscott, 2017; Taylor & Lovell, 2015b)

S40	Inclusive society	Wellbeing: connection to culture	Cultural significance of gardening	Extent to which UA provides a connection to the place of origin	Beneficial	Low	Weighted score	Standard	Survey	3	Cultural: Spiritual and religious values	(Shostak & Guscott, 2017; Taylor & Lovell, 2015b)
S41	Inclusive society	Wellbeing: environmental stewardship	Environmental motivations	Extent to which participants have environmental motivations and attitudes	Beneficial	Low	Weighted score	Standard	Survey	11	Cultural: Aesthetic values	(Romolini et al., 2012)
S42	Inclusive society	Wellbeing: environmental stewardship	Ownership of space	Extent to which participants feel proud of what they have achieved with the garden	Beneficial	Low	Weighted score	Standard	Survey	3 & 11	Cultural: Aesthetic values	(Hawkins et al., 2011; Romolini et al., 2012; Svendsen, 2009; Van Den Berg et al., 2010)
S43	Inclusive society	Wellbeing: environmental stewardship	Community pride	Extent to which participants believe that the neighbourhood as a whole is improved by the presence of the garden	Beneficial	Low	Weighted score	Standard	Survey	11	Cultural: Aesthetic values	(Hawkins et al., 2011; Romolini et al., 2012; Svendsen, 2009; Van Den Berg et al., 2010)
S44	**Inclusive society**	**Wellbeing: environmental stewardship**	**Environmental stewardship**	**Extent to which the garden promotes environmental stewardship**	**Beneficial**	**Average**	**Weighted score**	**Headline**	**Survey**	**11 & 13 & 3**	**Cultural: Aesthetic values**	**(Hawkins et al., 2011; Romolini et al., 2012; Svendsen, 2009; Van Den Berg et al., 2010)**
F45	Food security and income generation	Food availability	Production of food: totals	Total amount of food produced, considering diversity of products: (1) Energetic crops: cereals, roots and tubers; (2) Vegetables, all kinds; (3) Fruits, all kinds; (4) Products of animal origin: milk, eggs, meat, fish	Beneficial	Low	Kilograms	Standard	Survey/questionnaire	2	Provisioning: food	(Edmondson et al., 2020b; Gregory et al., 2016b; Lynch et al., 2013; Sanyé-Mengual et al., 2018b; Tasciotti & Wagner, 2015b)

F46	**Food security and income generation**	**Food stability**	**Production of food: stability**	**Predictability in the annual/seasonal production of food, considering the diversity of products: (1) Energetic crops: cereals, roots and tubers; (2) Vegetables, all kinds; (3) Fruits, all kinds; (4) Products of animal origin: milk, eggs, meat, fish**	**Beneficial**	**Low**	**Percentage**	**Headline**	**Survey/questionnaire**	**2**	**Provisioning: food**	(Dixon et al., 2007; Poulsen et al., 2015b)
F47	**Food security and income generation**	**Food accessibility**	**Production of food: self-sufficiency**	**Share of total annual household consumption of food obtained from own production, considering the diversity of products: (1) Energetic crops: cereals, roots and tubers; (2) Vegetables, all kinds; (3) Fruits, all kinds; (4) Products of animal origin: milk, eggs, meat, fish**	**Beneficial**	**Low**	**Percentage**	**Headline**	**Survey/questionnaire**	**2**	**Provisioning: food**	(Chiappe Hernández, 2019b; Furness & Gallaher, 2018; Khumalo & Sibanda, 2019b; Moucheraud et al., 2019b)
F48	**Food security and income generation**	**Food waste generation**	**Total food lost or wasted**	**Share of participants in community garden initiatives that declare to throw food produced in the UA, at production, transport, storage or consumption stages**	**Detrimental**	**Low**	**Percentage**	**Headline**	**Survey/questionnaire**	**2, 12**	**Provisioning: food**	(S. Brown & Goldstein, 2016; Zorpas et al., 2018)
F49	Food security and income generation	Food safety	Potential contamination of food due to growing practices	Type of pest and disease control, fertilisation practices used by participants in UA	Detrimental	Low	Percentage	Standard	Survey/questionnaire	3, 14, 15	Provisioning: food	(Audate et al., 2019; Igalavithana et al., 2017; Prudic et al., 2019)

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F50	Food security and income generation	Food safety	Potential contamination of food due to lack of safety protocols and measures	Existence of general food safety assurance mechanisms including: (1) formalised food safety managing protocols and programs, AND/OR; (2) food traceability systems, AND/OR; (3) compulsory food safety training programs addressed at participants	Beneficial	Low	Score based on dichotomous (Yes/No) answers to questionnaire	Standard	Questionnaire	3	Provisioning: food	(Audate et al., 2019; Gallaher et al., 2013)
F51	**Food security and income generation**	**Preparedness for food sovereignty**	**Training for food sovereignty**	**Share of participants in the UA trained to grow healthy food**	**Beneficial**	**Low**	**Percentage**	**Headline**	**Questionnaire**	**2**	**Provisioning: food**	(Gregory et al., 2016b)
F52	Food security and income generation	Preparedness for food sovereignty	Training for food sovereignty	Number of aspects covered by existing training programmes: food production (gardening methods) and/or food sharing and/or food preparation and/or financial management	Beneficial	Low	Ordinal number (min: 0, max: 4)	Standard	Questionnaire	2	Provisioning: food	(Gregory et al., 2016b)
F53	Food security and income generation	Financial resilience of households	Potential income generated by food production activities: total	Estimated market value of food and derivates produced in UA activities	Beneficial	Low	Monetary (local currency)	Standard	Survey/questionnaire	1, 10	Provisioning: food, and other tradeable resources (e.g. flowers)	(Holland, 2004b; Manikas et al., 2020; Moustier, 2014; Victor et al., 2018b; Zezza & Tasciotti, 2010b)
F54	Food security and income generation	Financial resilience of households	Stability of revenue generation potential	Estimated annual variability of income from food produced in UA activities, as a function of price and production variability	Detrimental	Low	Percentage	Standard	Questionnaire	1, 10	Provisioning: food, and other tradeable resources (e.g. flowers)	(Holland, 2004b; Manikas et al., 2020; Moustier, 2014; Victor et al.,

												2018b; Zezza & Tasciotti, 2010b)
F55	Food security and income generation	Financial resilience of households	Contribution of UA to household finances	Estimated income generated by activities performed in UA, including agriculture and other practices	Beneficial	Average	Monetary (local currency)	Standard	Survey or questionnaire	1, 10	Provisioning: food, and other tradeable resources (e.g. flowers)	(Holland, 2004b; Manikas et al., 2020; Moustier, 2014; Victor et al., 2018b; Zezza & Tasciotti, 2010b)
F56	Food security and income generation	Financial resilience of households	Relative contribution of food production to household finances	Percentage of annual household income obtained from UA initiatives (considering food production and other activities)	Contextual	Average	Percentage	Standard	Questionnaire	1, 10	Provisioning: food, and other tradeable resources (e.g. flowers)	(Holland, 2004b; Manikas et al., 2020; Moustier, 2014; Victor et al., 2018b; Zezza & Tasciotti, 2010b)
F57	**Food security and income generation**	**Financial resilience of the UA initiative**	**Financial sustainability**	**Income balance last year: garden's capacity to generate enough income to cover ordinary costs and generate a surplus to cover future investments or unexpected expenses**	**Beneficial**	**Low**	**Monetary (local currency)**	**Headline**	**Survey or questionnaire**	**1, 10**		(Haberman et al., 2014; Hashimoto et al., 2019)
F58	Food security and income generation	Financial resilience of the UA initiative	Financial stability	Number of negative income balances over the last three years	Detrimental	Average	Units	Standard	Survey or questionnaire	11		(Haberman et al., 2014; Hashimoto et al., 2019)
F59	Food security and income generation	Financial resilience of the UA initiative	Revenue: External financial support: self-sufficiency	Fraction of operation costs covered with external sources (average value; 3 years): administrations, charities, private sponsors, etc.	Contextual	Low	Percentage	Standard	Questionnaire	11		(Haberman et al., 2014; Hashimoto et al., 2019)

F60	Food security and income generation	Financial resilience of the UA initiative	Design costs & installation costs	Total costs per bed. Design costs associated with the establishment of UA activities, if any. Examples include the elaboration of feasibility and impact studies, production of blueprints, etc. Installation costs include all costs linked to the physical installation of the UA initiative, such as the construction of drainage systems, storage hatches, fences, paths, and any other fixed element.	Detrimental	Average	Monetary (local currency)	Standard	Survey or questionnaire	11	(Haberman et al., 2014; Hashimoto et al., 2019)
F61	Food security and income generation	Financial resilience of the UA initiative	Operation costs: garden	Direct operation costs per bed. Costs may include, e.g. annual fees or rentals, maintenance of infrastructures, acquisition of fertilisers and seeds, etc. Operation costs are distributed among participants based on share ownership, plot size or similar criteria	Detrimental	Low	Monetary (local currency)	Standard	Survey or questionnaire	11	(Haberman et al., 2014; Hashimoto et al., 2019)
F62	**Food security and income generation**	**Financial resilience of the UA initiative**	**Operation costs: participants**	**Direct operation costs per bed. Costs may include, e.g. annual fees or rentals, maintenance of infrastructures, acquisition of fertilisers and seeds, etc. Operation costs are distributed among participants based**	**Detrimental**	**Low**	**Monetary (local currency)**	**Headline**	**Survey/questionnaire**	**11**	**(Haberman et al., 2014; Hashimoto et al., 2019)**

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				on share ownership, plot size or similar criteria								
F63	Food security and income generation	Job creation	Direct jobs created	Number of direct jobs created by UA initiatives in activities such as gardening, maintenance, conservation, etc.	Beneficial	Low	Units	Standard	Survey/questionnaire	1, 8		(Bohm, 2017)
F64	Food security and income generation	Job creation	Indirect job effects	Number of indirect jobs (i.e. supplier and induced jobs) associated with UA initiatives. The indicator is calculated through employment multipliers for local or representative economies in the EU and China.	Beneficial	High	Units	Standard	Economic modelling	1, 8		(Bohm, 2017)
U65	Sustainable urban development	The garden as an element of the urban structure	Characteristics of the garden	Type of garden concerning the need for land. For example, traditional gardening demands land while zero-acreage (e.g. gardens in buildings, walls, rooftops, balconies) does not.	Contextual	Low	Qualitative	Background	Survey or questionnaire	11	Regulating: air quality, climate	(Piorr, 2018; Thomaier et al., 2014)
U66	Sustainable urban development	The garden as an element of the urban structure	Characteristics of the plot/garden	Size of the plot/garden	Contextual	Low	m^2	Background	Survey or questionnaire	11	Regulating: air quality, climate, noise	(Bokalders & Block, 2014; Piorr, 2018)
U67	Sustainable urban development	The garden as an element of the urban structure	Characteristics of the plot/garden	Number of beds in the garden.	Beneficial	Low	Number	Background	Survey/questionnaire	11		(Krafta, 1994; Mougeot, 2000)

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U68	Sustainable urban development	The garden as an element of the urban structure	Characteristics of the plot/garden	The topography of the plot/garden (e.g., flat, inclined)	Contextual	Low	Qualitative	Background	Survey/questionnaire	11	Regulating: air quality, climate	(R. G. Davies et al., 2008; Eizenberg et al., 2019)
U69	Sustainable urban development	The garden as an element of the urban structure	Characteristics of the plot/garden	Existence of facilities/infrastructures in the garden (e.g., toilets, storage room, kitchen)	Beneficial	Low	Qualitative	Standard	Survey/questionnaire	11		(Krafta, 1996)
U70	Sustainable urban development	The garden as an element of the urban structure	Characteristics of the plot/garden	Presence of physical elements (e.g. fences, walls, gates) defining the limits of the garden. It is a proxy of the openness of the garden to visitors.	Detrimental	Low	Qualitative	Standard	Survey or questionnaire	11		(Andrade et al., 2018)
U71	Sustainable urban development	The garden as an element of the urban structure	Characteristics of the plot/garden	Primary purpose of the garden (e.g., gardening, recreational, educational, mental health, social integration).	Beneficial	Low	Qualitative	Background	Survey or questionnaire	11	Cultural: recreation Provisioning: food	(Krafta, 1994)
U72	Sustainable urban development	The garden in relation to other elements of the urban structure	Garden proximity of the city centre	Distance from the city centre	Contextual	Low	km	Background	Spatial analysis	11	Regulating: air quality, climate	(EPRS, 2017; Mougeot, 2000; Opitz et al., 2016; Piorr, 2018)
U73	**Sustainable urban development**	**The garden in relation to other elements of the urban structure**	**Perceived public utility of the land**	**Type of land (e.g., marketable or non-marketable) in which the garden is located. It is a proxy of competing uses for land in cities.**	**Beneficial**	**Low**	**Qualitative**	**Headline**	**Survey/questionnaire**	**11**		(Borges et al., 2019; Fernandez Andres, 2017; Heather, 2012; Horst et al., 2017; La Rosa et al., 2014)

U74	Sustainable urban development	The garden in relation to other elements of the urban structure	Garden proximity of other green areas	Distance from green areas. Indicates the potential of the garden to deliver access to recreational facilities	Contextual	Average	km	Standard	Spatial analysis	11	Cultural: recreation	(Bowman et al., 2009; Eggermont et al., 2015; Lin et al., 2017; Peschardt, 2014; WHO, 2017)
U75	Sustainable urban development	The garden in relation to other elements of the urban structure	Garden proximity of busy roads	Distance from busy roads. It is a proxy on the potential of the garden to minimize pollution (air, noise)	Detrimental	Average	km	Standard	Spatial analysis	11	Regulating: climate, air quality	(Hallett et al., 2016; Lopez & Souza, 2018; Van Renterghem et al., 2012)
U76	**Sustainable urban development**	**The garden in relation to other elements of the urban structure**	**Accessibility to the garden**	**Means of transport vs travel time to reach the garden**	**Detrimental**	**Low**	**min**	**Headline**	**Survey/questionnaire**	**11**	**Regulating: climate; air quality**	(Olofsson et al., 2011)
U77	**Sustainable urban development**	**The garden in relation to other elements of the urban structure**	**Garden contribution to relief urban of density**	**Population density in the area where the garden is based (1sq km grid)**	**Beneficial**	**High**	**Inh/km²**	**Headline**	**GIS/spatial analysis**	**11**	**Regulating: climate, air quality**	(Arama et al., 2019; DeKay, 1997a; Eizenberg et al., 2019)
U78	Sustainable urban development	The garden in relation to other elements of the urban structure	Garden contribution to a mixed neighbourhood	Positive or negative contribution of the garden to the mixed-use of the neighbourhood. Indicates if the function the garden perform (see U71) conflicts or supplement the other activities located in the neighbourhood	Beneficial	High	unknown	Standard	Spatial analysis	11		(Deelstra et al., 2001; Krafta, 1996; Poulsen et al., 2017)

U79	**Sustainable urban development**	**The garden from an institutional perspective**	**Land security and tenure**	**Access to land via formal documents (e.g., lease or property contracts)**	**Beneficial**	**Low**	**Qualitative**	**Headline**	**Survey/questionnaire**	**11**		(J. Davies et al., 2020; Opitz et al., 2016; Taylor & Lovell, 2015b; Viljoen et al., 2015; Wekerle & Classens, 2015)
U80	Sustainable urban development	The garden from an institutional perspective	Land value	Comparative evolution of land prices in the area in relation to the city as a whole	Detrimental	Average	Differential	Standard	Other	11		(Taylor & Lovell, 2015b; Viljoen et al., 2015; Voicu & Been, 2008; Wekerle & Classens, 2015)
U81	**Sustainable urban development**	**The garden from an institutional perspective**	**Top-down initiatives to support urban gardening**	**Official (sanctioned by law) and non-official policies and strategies adopted to support urban gardening (e.g., strategic planning, design regulations, thematic plans and programs)**	**Beneficial**	**Average**	**Qualitative**	**Headline**	**Other**	**11**	**Regulating: climate; Provisioning: food, and other tradeable resources**	(Casazza & Pianigiani, 2016; Lohrberg et al., 2016; Martin & Wagner, 2018; Teitel-Payne et al., 2016)
U82	Sustainable urban development	The garden from an institutional perspective	Public budget	Funds allocated to support urban gardening in the municipal budget	Beneficial	Low	Qualitative	Standard	Other	11	Regulating: climate; Provisioning: food, and other tradeable resources	(Casazza & Pianigiani, 2016; Lohrberg et al., 2016; Teitel-Payne et al., 2016)
U83	**Sustainable urban development**	**The garden from an institutional perspective**	**Bottom-up initiatives to support urban gardening**	**Private sector and civil society efforts to support/implement urban gardening**	**Beneficial**	**Low**	**Qualitative**	**Headline**	**Other**	**11**	**Regulating: climate; Provisioning: food and other tradeable resources**	**(Casazza & Pianigiani, 2016; Lohrberg et al., 2016; Teitel-Payne et al., 2016)**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774233

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Co-funded by the Horizon 2020 programme of the European Union

Co-funded by the Chinese Ministry of Science and Technology