Urban Forestry & Urban Greening 94 (2024) 128257

Contents lists available at ScienceDirect

Urban Forestry & Urban Greening

journal homepage: www.elsevier.com/locate/ufug

Urban greening co-creation: Participatory spatial modelling to bridge data-driven and citizen-centred approaches

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ARTICLE INFO

Handling Editor: Cecil Konijnendijk van den Bosch

Keywords:
Smart cities
Collaborative governance
Spatial planning
Participatory GIS

ABSTRACT

The unprecedented growth of metropolitan areas creates challenges for maintaining liveable and biodiverse cities. Urban areas face multiple demands on sparse space whilst various stakeholders similarly aim to promote greening efforts. In this context, authorities need to balance various policy objectives with demands from diverse urban stakeholders. Part of this challenge is the question how generalized data-driven green space planning approaches can be connected to local, contextualized understandings, practices and values related to green space.

In this paper, we present a participative application of GIS that contributes to bridging the gap between data-driven and citizen-centred approaches in urban greening. Through an empirical study in Amsterdam, we show how this can link local priorities with larger-scale policy frameworks through deliberative and data-driven co-creation. In our case study, local stakeholders and researchers jointly identified criteria for greening, translated these into indicators and eventually identified potential locations for small-scale greening. Site visits by local experts helped to validate the model results and translate this into concrete plans for greening several locations.

Our approach promoted a dialogue between stakeholders, linking spatial data with practical experiences and aligning local priorities with policy programmes. Combining various knowledges from involved stakeholders also contributed to the quality of analysis and validation of modelling results. By increasing transparency and inclusiveness of planning, it also contributed to acceptance of process outcomes and empowering local stakeholders. With increasing urgencies for environmental measures in many cities, we emphasize the potential of transdisciplinary GIS-approaches to navigate different interests and integrate various types of valuable knowledge. We suggest that similar approaches may be applied to other environmental challenges that have a strong spatial character.

1. Introduction

1.1. Urban greening as a complex governance challenge

Green spaces play a key role in the quality of urban life for humans and other living beings. Although this is widely recognized, creating and maintaining healthy, liveable and biodiverse green cities has proven to be a challenge. Across the planet, urban densification and expansion are putting pressure on the quantity and quality of green spaces (Elmqvist et al., 2013). At the same time, many citizens and NGOs demand greening efforts from authorities, who are usually responsible for planning and maintenance of public urban green spaces and often have their

Abbreviations: ANMEC, Amsterdam Natuur en Milieu Educatie Centrum *Amsterdam Nature and Environment Education Centre*; CBS, Central Bureau voor de Statistiek *Central Statistical Office*; GIS, Geographic Information Systems; GGD, Gemeentelijke Gezondheidsdienst *Municipal Health Service*; GPA, Groen Platform Amsterdam *Green Platform Amsterdam*; IVN, Instituut voor Natuureducatie en Duurzaamheid *Institute for Nature Education and Sustainability*; NGOs, Non-Governmental Organizations.

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https://doi.org/10.1016/j.ufug.2024.128257
Received 17 July 2023; Received in revised form 9 February 2024; Accepted 10 February 2024
Available online 13 February 2024
1618-8667/

own departments and strategies for this purpose (Hansen et al., 2022). In many cities stakeholders and citizens actively engage in various greening movements, resulting in a shift towards hybrid or mosaic governance approaches with increasing interactions between authorities and other stakeholders (Buijs et al., 2019).

In this background, urban greening often becomes a complex governance challenge. Activities and interests from a various stakeholders, policy ambitions on different levels of scale, and the social, economic and environmental characteristics of the city all determine the complexity regarding greening efforts. In this light, a top-down policy approach towards urban greening is no longer seen as effective for implementing policy as it insufficiently connects to efforts from stakeholders and citizens (Buijs et al., 2019). Data-driven approaches often insufficiently recognize and incorporate the expertise of diverse stakeholders (Dijkshoorn-Dekker et al., 2020), while initiatives by local stakeholders have difficulty to realize impact on a larger spatial scale (Buijs et al., 2023). Local initiatives often lack strategic information on multiple levels of scale to make informed decisions (Mattijssen et al., 2018); have insufficient knowledge on or access to policy, planning and legal frameworks (Mattijssen, 2022); encounter power imbalances and a limited recognition of local forms of knowledge (van Maurik Matuk et al., 2023); and sometimes lack resources for green space maintenance as well as access to land (Mattijssen et al., 2018).

Aligning the priorities and efforts of various stakeholders, linking different types of knowledge, and connecting this to diverse urban infrastructures can therefore be seen as an important challenge for optimizing urban greening efforts in public space (Buijs et al., 2019) as well as for providing inclusive green spaces (Murphy et al., 2023) and promoting multifunctional spaces that include green infrastructure (Hansen and Pauleit, 2014). The optimal organization and actual realization of impactful greening thus requires cooperation and an exchange of knowledge between stakeholders, connecting practical and lived knowledge of citizens with professional expertise, policy knowledge and spatial data.

1.2. A gap between data-driven and citizen-centred approaches to urban greening

Green infrastructure planning in many Western cities benefits from extensive geographical information systems (GIS) due to the many available geodata which describe the urban configuration in high detail (Ryan, 2011). These GIS generally contribute to effective planning strategies based on quantifiable, formalized and standardized geodata. However, they also tend to reinforce top-down planning strategies (Rall et al., 2019). Furthermore this data often lacks important social and normative perspectives (Hubacek and Kronenberg, 2013) and does not always provide the required level of detail (Feltynowski et al., 2018). Top-down approaches towards urban planning may also result in a lack of public support, hindering the embedding of bottom-up approaches in existing green infrastructure and potentially inciting resistance (Buijs et al., 2016).

In this context, many scholars already argued for a more participatory use of GIS in planning practices in order to better incorporate knowledge, preferences and expertise of local stakeholders (Maurer et al., 2023, Bąkowska-Waldmann and Kaczmarek, 2021, Corbett et al., 2016, Rall et al., 2019). Citizens' practical and contextualized knowledge is often difficult to incorporate in decision making processes and GIS-models (Rantanen and Kahila, 2009); and linking urban green infrastructure policies with grassroots initiatives is often also a difficult challenge (Buijs et al., 2016, Mattijssen, 2022). Debates on environmental justice and inclusiveness also highlight the difficulties of empowering local citizens and representing their interests in green space planning and governance (Baker and Mehmood, 2015).

1.3. The need for transdisciplinary approaches to planning urban green spaces

Bridging the gap between data-driven and citizen-centred approaches to retrofit urban neighbourhoods calls for transdisciplinary approaches to green space planning, linking local understandings to spatial data (Maurer et al., 2023, Huang and London, 2016). In this context, the creation of new participatory GIS avenues to co-create urban green can benefit inclusive and effective greening efforts (Rall et al., 2019). It is now acknowledged that incorporation of local values, knowledge and expertise is essential for successful, publicly supported urban greening efforts (Bennett et al., 2018). This requires a move from uniform top-down approaches towards linking urban planning with diverse efforts by local stakeholders (Buijs et al., 2019); a recognition of the values that people assign to green space and the relationships which they hold with it (Mattijssen et al., 2020); and also the incorporation of knowledge and preferences of stakeholders to pave a way for more informed decision making (Rantanen and Kahila, 2009, Rall et al., 2019).

Summarizing the above discussion, we identify three key principles for meaningful, transdisciplinary collaboration between planners and citizens in participatory GIS for urban greening:

1) The efforts of local stakeholders should be linked to strategic planning approaches and green space policies (Hubacek and Kronenberg, 2013, Buijs et al., 2019, Mattijssen, 2022, Murphy et al., 2023, Rall et al., 2019).
2) Local knowledge and experiences should be linked with data-driven approaches towards space (Hubacek and Kronenberg, 2013, van Maurik Matuk et al., 2023, Feltynowski et al., 2018, Rantanen and Kahila, 2009, Huang and London, 2016, Bennett et al., 2018, Maurer et al., 2023).
3) Collaboration should be co-creative in order to build trust, empower local stakeholders and promote the acceptance of outcomes (van Maurik Matuk et al., 2023, Murphy et al., 2023, Buijs et al., 2016, Baker and Mehmood, 2015, Rall et al., 2019).

1.4. Small-scale greening in the city of Amsterdam

Empirical studies that provide insight into transdisciplinary, co-creative GIS-approaches for bridging the gap between data-driven and citizen-centred urban greening are very few. This article documents the employment of such a transdisciplinary approach in promoting local greening in small-sized spaces in the Dutch capital city of Amsterdam.

A local ambition for small-scale greening is the starting point for this study. Previous research in Amsterdam indicated that small green spaces offer a relatively high societal and economic value to the city (Bos and Vogelzang, 2018). In this article, we typify these kind of spaces as 'pocket parks' and 'neighbourhood gardens' – terms adopted from local stakeholders (blinded for review). A pocket park is a small public urban green space which is publicly accessible and can be used by the community in different ways (as a meeting place, to rest, exercise, etc). A neighbourhood garden is a small-sized public green space where citizens garden and/or grow food together.

1.5. Research objective and research questions

Departing from the three key principles, the objective of this research is to study how participatory geodata modelling contributes to bridging the gap between data-driven and citizen-centred approaches to green space retrofitting. We do so through an empirical study in the city of Amsterdam where we have worked together with local stakeholders in a research project. In line with the key principles, we focus on three research questions:

1) In what ways does participatory spatial modelling contribute to linking local initiatives and municipality policies?
2) How does the linking of participatory spatial modelling and local knowledge contribute to the integrality, validity and practical applicability of findings?
3) How does the employment of co-creation lead to more acceptance of the research and of local greening efforts?

2. Methodology

2.1. Background: urban greening in the city of Amsterdam

Amsterdam is the capital of the Netherlands and its' largest city with about 860.000 inhabitants, situated in a metropolitan region which has about 2.500.000 inhabitants (Metropole Region Amsterdam, 2023). As shown in Fig. 1, a lot of the land in Amsterdam has a residential function and there is also quite some water in and around the city. Near the harbour in the North-West, the land use is dominated by industry while a predominantly agricultural area is situated in the North-East.

In the metropolitan region of Amsterdam, population growth has been almost double that of the Dutch average since 2005, mostly due to immigration (Metropole Region Amsterdam, 2023). Local demand for housing overshoots the supply and property prices have been rapidly increasing. There is a high building ambition to solve housing shortages and the political decision has been made to build within current city borders to maintain larger green areas outside of the city. The following densification increases the urgency to green small, now sealed spaces for keeping the city liveable.

In this context, the municipality of Amsterdam is actively working to promote local greening efforts. Thousands of citizens and many local NGOs in Amsterdam are also actively working on greening their neighbourhoods. A survey by the Municipality of Amsterdam showed that in 2018 61% of citizens visited small green spaces, up from 54% in 2013 (Municipality Of Amsterdam, 2019). Through the 'Green in the Neighbourhood' program, the municipality of Amsterdam aims to stimulate local greening initiatives.

2.2. A co-creative GIS approach towards urban greening

This research project used a participatory GIS-approach in order to combine data-driven approaches to urban planning with community perspectives and preferences (cf. Maurer et al., 2023, Rall et al., 2019). Aim of this project was to jointly identify criteria for urban greening and to identify priority locations for new pocket parks and neighbourhood gardens. As local stakeholders observed, bottom-up initiatives by citizens assure support for greening to a certain extent (cf. Buijs et al., 2023). However, they do not assure a just and inclusive division of access to green spaces in the city, nor do they take into account where the urgency is highest from for instance a climate adaptation perspective (cf. de Vries et al., 2020). Therefore data-driven perspectives needed to be added to help the involved stakeholders in identifying priorities.

The project was co-created and co-designed by local stakeholders from Amsterdam and researchers from Wageningen University and Research. The research was funded by the Science Shop from Wageningen University and Research, as local NGOs themselves did not have resources for commissioning the project. A cooperation was then set up where researchers collected available spatial data and provided an approach in order to detect potentially interesting spaces for greening. Local NGOs were involved for identifying criteria to discern the most suitable spaces and in linking the project with policy agendas and stakeholder activities. The involved experts included representatives from organizations that are members of GPA (Green Platform Amsterdam, a local cooperation of environmental NGOs). Added to this, municipality officials and a local consultant on urban greening were also involved (see Table 1 for a list of the represented organizations).

The co-creation aspect accounts for the writing of this research article as well: the authors include both researchers and representatives of local stakeholders. In order to answer the three research questions, several sessions were organized amongst the authors. In these sessions, the author team jointly reflected on the findings and implications of the research, discussed the academic relevance of this project and the key findings. In this way, a combination of expert judgment by local stakeholders, a review of literature by academic experts and evaluative talks with a small number of involved people was used to operationalize the research question and discuss the findings as part of a qualitative,

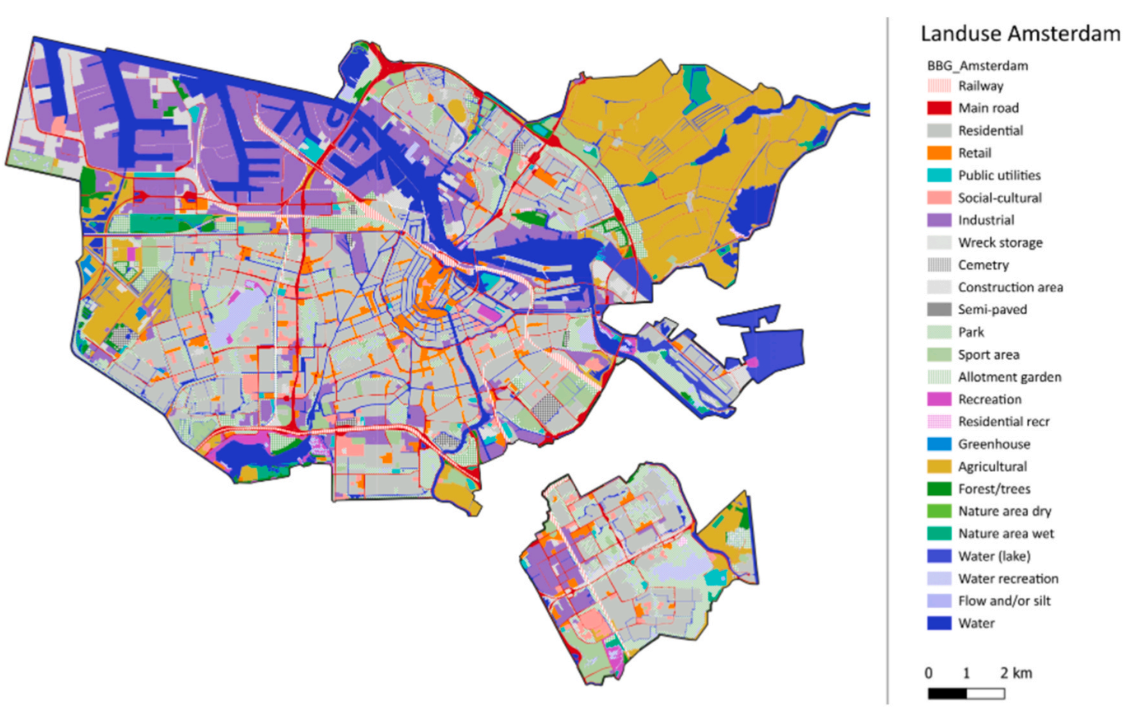

Fig. 1. Land use map of Amsterdam (CBS, 2023).

Table 1
organizations involved in this project.

Organization	Description
Groen Platform Amsterdam	Cooperation of environmental NGOs representing over 10.000 active citizens
De Gezonde Stad	Local NGO initiating and supporting community projects for making Amsterdam healthy and sustainable
Amsterdam Rainproof	Local initiative involving citizens, municipality and businesses in promoting climate resilience
ANMEC	Local institute for environmental education
Buurtgroen020	Interactive online platform linking over 140 local green initiatives
Bloei en Groei	Women community aiming to create urban gardens for personal growth
IVN Amsterdam	Amsterdam department of the Dutch institute for nature education; aiming to (re)connect people to nature
Municipality of Amsterdam	Formal administrative body governing the city of Amsterdam; department space and sustainability
Wageningen Science Shop	Part of Wageningen University and Research organizing and funding transdisciplinary research commissioned by non-profit civil society organisations

interpretive inquiry (similar approaches have been used by Mattijssen et al., 2020, Frantzeskaki et al., 2016). Draft versions of the article were shared with a number of colleagues as well as with stakeholders from Amsterdam in order to collect their feedback and improve the results and discussion sections of this article.

2.3. The use of Global-Detector

In Amsterdam, the spatial-economic approach *Global-Detector* (Hennen et al., 2017) was employed for detecting potentially interesting spaces for greening. *Global-Detector* is a knowledge-based GIS-method (see Appendix 1), in which experts or specific stakeholders are involved to jointly convert spatial data into concrete, relevant indicators. Basic principle behind *Global-Detector* is the idea that mobilizing the knowledge of experts for interpreting values and identifying optimal conditions for a specific cause leads to the co-creation of fit-for purpose indicators (Hennen et al., 2017).

In the context of our work in Amsterdam, this assumes that the organizations involved in urban greening are best able to (co-)create relevant indicators that provide them with an action perspective to create new pocket parks and neighbourhood gardens. The use of GIS-methods, participation processes and the co-development of knowledge were therefore strongly interlinked in how researchers and local stakeholders cooperated in this project. This approach was co-created during the research process and is therefore integrated in the results section of this article.

3. Results

In Amsterdam, four process steps were co-created together with the involved stakeholders (Fig. 2). By using these steps, *Global-Detector* has been employed to identify promising locations for creating new pocket parks and neighbourhood gardens (Hennen and Mattijssen, 2020). The four steps are discussed in the next four paragraphs of this results section before Section 3.5 discusses the aftermath and implementation.

3.1. Step 1: data collection

As a starting point for using *Global-Detector*, an inventory of available spatial datasets needed to be made (Hennen et al., 2018). As different stakeholders (such as the municipality of Amsterdam) had access to various datasets, joining forces in this led to a long list of potential indicators (see Appendix 2 for an overview of main sources and how these were transformed into stackable indicators).

Furthermore, a definition of the spatial dimensions of pocket parks and neighbourhood gardens needed to be developed in order to identify areas with potentially suitable shapes and functions. To come to a joint understanding, an assessment was conducted where involved stakeholders set the criteria for areas suitable for pocket parks or neighbourhood gardens. The minimum and maximum surface area (all public areas that fit these initial criteria set by stakeholders) was set between 100 and 3000 m^2. Areas that have undesirable shapes for a pocket park or neighbourhood garden (e.g. roadsides which are very narrow but long) were excluded. Following this, all locations that have a suitable shape and current function (based on land cover data from BGT (Kadaster, 2021) were identified with the use of ArcGIS and R. The result of this step is a list of 3045 potential locations based on spatial dimensions.

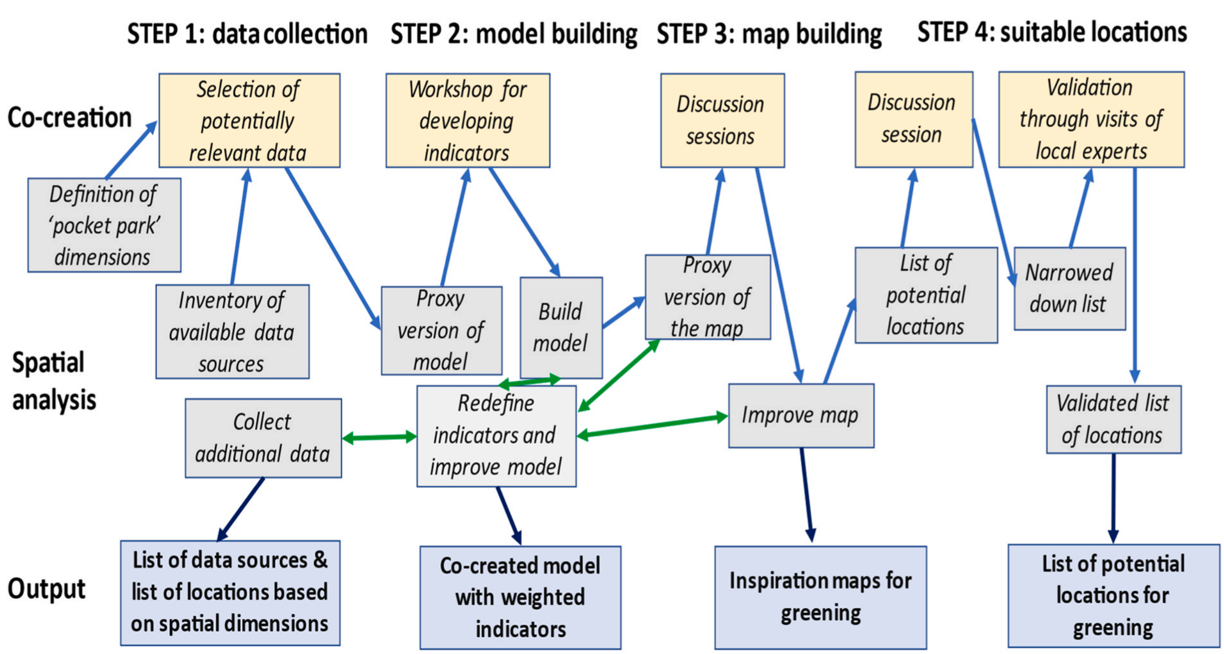

Fig. 2. flow-chart of the research process in four steps: (1) data collection; (2) development of indicators; 3) map building; and 4) identifying the best locations for greening. The process was iterative in nature as illustrated by the green arrows.

3.2. Step 2: building Global-Detector model for Amsterdam

In this step, indicators and exclusion criteria were formulated so that each land-based grid cell of 50×50 m in Amsterdam could be evaluated on its indicator-based score for greening. First, areas that were considered as unrealistic or undesired needed to be excluded. Through emails, meetings and phone calls between those involved, potential exclusion criteria were identified. In a joint workshop session, decisions were then made about what areas would not be considered for greening. Early on, an important decision was made to only focus on public space in or nearby residential areas. This decision was made because of the type of green spaces that was aimed for and also because the municipality had resources available for greening public spaces. Input of local experts and their knowledge of the policy context and the local circumstances was vital to develop additional criteria for spaces that are considered undesirable or unrealistic for greening. For instance, stakeholders mentioned that regulations do not allow most forms of greening within 6 m of railroad infrastructure and therefore considered pocket parks or neighbourhood gardens near railroads as unrealistic. Table 2 provides an overview of the exclusion criteria.

Similar to the exclusion criteria, the identification and selection of indicators and the choice of parameter values were discussed with local stakeholders – first through small meetings, emails and phone-contact and later in two workshops. For certain indicators, additional discussion sessions with specific stakeholders were organized to for instance discuss how an indicator for heat stress could be optimized. In this way, the indicators could be made fit-for purpose based on insights from literature, expertise from stakeholders and alignment with local policy frameworks. In the heat stress example, locations with higher maximum temperatures were identified as more suitable for greening due to the role of green in locally mitigating heat stress. The calculations for assigning a score within this range were set through a discussion with experts and study of literature. Above what maximum temperatures does heat stress become a serious problem? How should we then convert local maximum temperatures into a score? During and after such sessions, indicators were often projected on maps of Amsterdam to validate and fine-tune them.

Eventually four main indicators have been identified (Table 3). These indicators function to indicate which areas are most suited for greening with a neighbourhood garden or pocket park. As suggested by the involved stakeholders, the main indicators are linked with the Municipalities' green vision, reflecting the embedded 'values of green' for which a consultation of stakeholders had already taken place at an earlier point. For each of the four indicators, a number of sub-indicators has been identified in order to translate the available datasets into relevant criteria for scoring and ranking. The weights for these sub-indicators were assigned in a joint meeting with local experts. A more detailed description of indicators and their weight is included in Appendix 3.

Table 2
exclusion criteria for urban greening, formulated in co-creation with local experts.

Criterion for exclusion	Reasons for exclusion for pocket park or neighbourhood garden
Private property	This study exclusively focuses on public space
Already green	Improving quality of existing green is no focus of this study
Water	Water is not considered as suitable for greening
Railroads	Greening near a railroad track is difficult because of regulations
Roads	Roads are not suitable for greening
Market squares	Due to their weekly use not suitable for greening
Metro and tram rails	Not suitable due to traffic regulations and safety issues
Industrial areas	This study focuses on peoples' living environment
Commercial centres and retail	This study focuses on peoples' living environment
Sporting fields	Not considered a desirable location
Cemetery	Not considered a desirable location
Several specific locations	Manually excluded: hospital sites, large parking lots and a public zoo were not considered as suitable locations

Table 3
indicators to assess the need for urban greening, formulated in co-creation with local experts.

Indicator	Sub-indicators	Weight
Climate adaptation	Vulnerability to heavy rainfall	High
Climate adaptation	Drought	High
Climate adaptation	Heat stress	Normal
Nature	Ecological structure	High
Nature	Main green structure	Normal
Nature	Availability of green within 500 m	Low
Social wellbeing	Number of inhabitants within 500 m	High
Social wellbeing	Access to green within 250 m	High
Social wellbeing	Income	Normal
Social wellbeing	Age	Normal
Social wellbeing	Diversity of population	Low
Public health	Health perception	High
Public health	Obesity	Normal
Public health	Level of education	Normal

3.3. Step 3: map building

In this step, sub-indicators were stacked in order to build citywide priority maps for each of the four main indicators (Fig. 3). These maps indicate which locations in Amsterdam have the highest ranking (urgency for greening) per indicator. After creating these four maps, they were discussed with stakeholders and fine-tuned before combining them into a final 'inspiration map' that also includes the exclusion criteria.

The four main indicators that were identified are: (1) climate adaptation, (2) nature, (3) social wellbeing and (4) public health. The indicator *climate adaptation* assesses the potential impact of urban greening on reducing climate stress in extreme weather events. The highest ranking areas are those where water causes problems after heavy rainfall. Areas in the centre of the city have a high score on the sub-indicator drought. The indicator *nature* assesses the potential impact of urban greening for providing a habitat to flora and fauna. Especially those locations that are situated between other green infrastructure have a high score as they can function as a stepping stone for biodiversity. The indicator *social wellbeing* assesses the potential impact of greening on the living environment and social contacts of citizens. As some of the data used for this indicator was only available on the neighbourhood level, the view here is less detailed then for the previous two indicators. Densely populated areas with relatively few green spaces have the highest scores. The indicator *public health* assesses the potential impact which greening can have on the health of citizens. Neighbourhoods where most impact can be made through greening are mostly situated on the outskirts of the city where the health perception amongst the population is often lower and obesity rates are often higher.

Fig. 4 offers the combined weighted view for all four indicators with incorporation of the exclusion criteria (white areas). Combining these indicators shows areas across almost all neighbourhoods that appear to be moderately to well-suited for greening with a neighbourhood garden or pocket park. The focus can slightly differ between areas: for instance, in some areas the score for climate adaptation is high while in others this might be the case for social wellbeing. The result in Fig. 4 shows the ranking for each 50×50 grid cell – not yet combined with the list of 3045 potential locations. The white areas were considered unfeasible due to the exclusion criteria, for instance because they are private spaces or already green.

3.4. Step 4: identifying the best locations for greening

In order to identify the highest ranking locations for greening with a pocket park or neighbourhood garden, findings from step 1 (potential

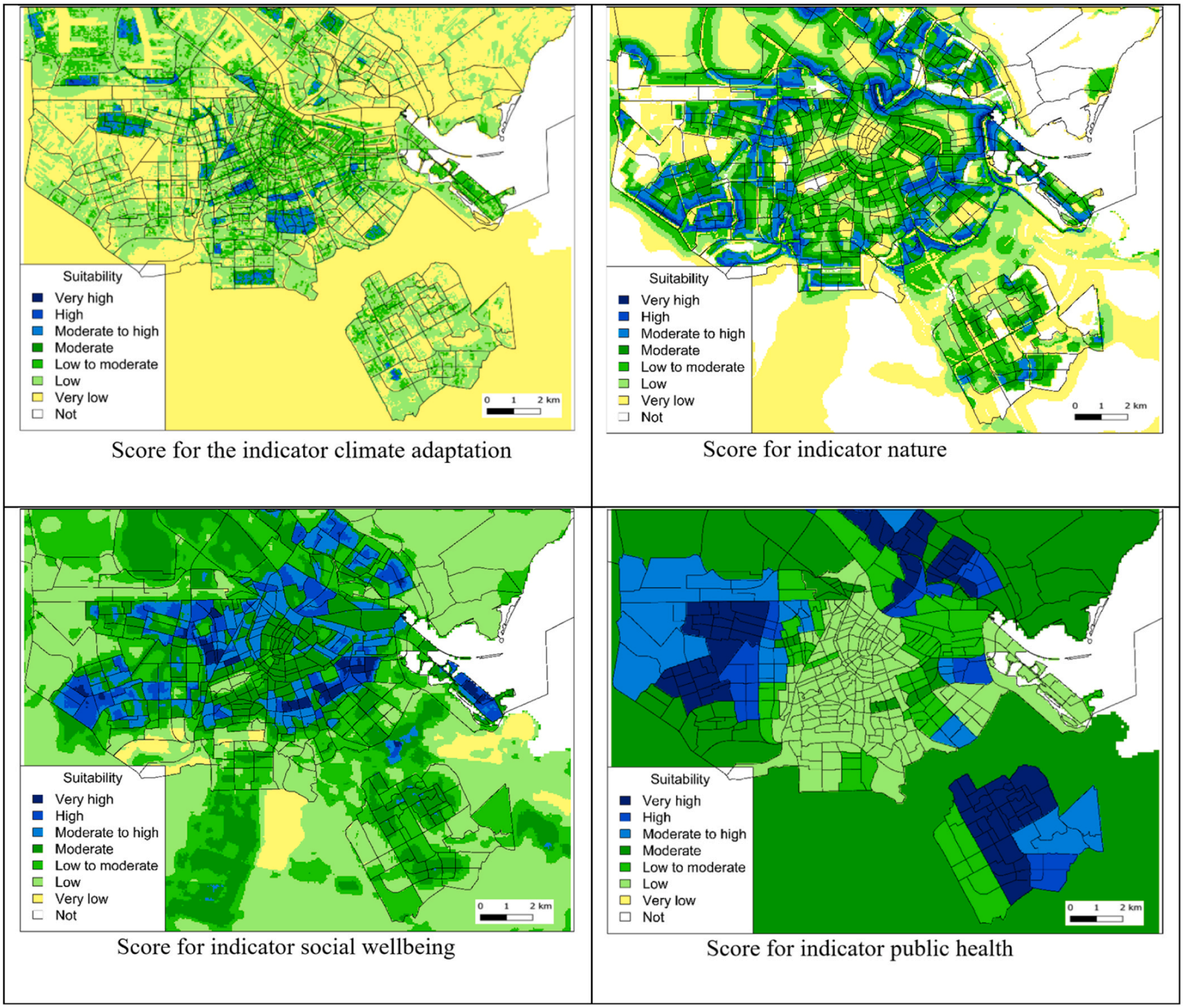

Fig. 3. score for selected indicators. For higher scores, more impact can be expected from greening efforts based on this indicator.

locations based on shape and function) were integrated with the indicators and exclusion criteria. In effect, this means that all 3045 areas were first assessed to see whether they are considered as unsuitable because of the exclusion criteria. The remaining locations were then assigned a score for each indicator. Because stakeholders wanted to focus on areas where most impact could be realized, the areas with the bottom 50% of scores were then excluded as well.

The remaining locations were then assessed in two ways. First, recent satellite imagery was used by the researchers to check face validity of maps, as data are not always sufficiently detailed or fully up to date (Feltynowski et al., 2018). This became visible when for instance new construction had been realized. A list of 86 locations then remained. Because of the reliance on spatial data for the analysis thus far, on-site validation was considered necessary to locally assess the opportunities for greening these locations. This was organized by the organizations involved in the project. With a standardized assessment form developed by GPA and ANMEC, stakeholders visited all 86 locations to assess whether they could be considered for greening, and they also took on-site photographs. In this step, 26 locations were excluded for one or more reasons (Table 4).

After this step, 60 locations remained that are considered as promising for greening. Fig. 5 shows how these areas are situated across Amsterdam. The green circles were considered to be 'most promising' by local experts. For the yellow locations, greening is considered to be possible but there are challenges for integrating this with the current function for e.g. art or as a children's playing ground.

3.5. Aftermath and implementation

After completion of Step 4, local stakeholders used the results of this project in their efforts for local greening in Amsterdam. GPA engaged in a further scrutiny of the most suitable locations and narrowed this down to a 'top 40'. Buurtgroen020 published a list of these 40 locations on their platform and De Gezonde Stad sent out an open invitation to local residents for jointly greening these locations. Several local media published about the research: the largest local newspaper and television channel both included an item about urban greening and interviewed involved stakeholders. Various involved stakeholders also posted on social media and an online event was organized (with about 85 attendants) where the researchers presented their work. In this period, Buurtgroen020 reported several thousand 'extra' views on their webpage compared to regular visitor numbers.

The municipality of Amsterdam is currently working on a map with 100 locations for new green projects (Gemeente Amsterdam, 2021). For

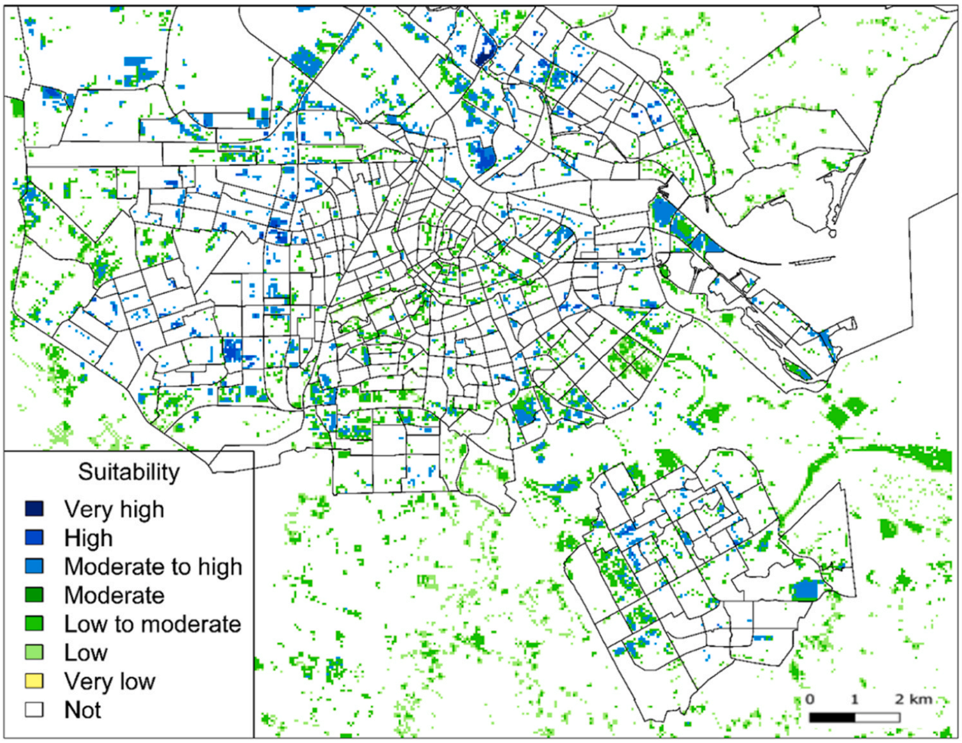

Fig. 4. score suitability for greening.

Table 4
reasons for exclusion of specific areas after validation by local experts.

Reason for exclusion	#
In use as footpath or cycling lane	5
Shape not suitable	5
Not publicly accessible or hard to access	4
Current function doesn't allow greening	4
Already green	3
Considered unsafe	3
High traffic intensity	3
No support for greening amongst local residents	2
Recently constructed	2
Remotely situated	1
Situated directly next to a park	1

this purpose, they adopted several 'top 40' locations. For a few specific locations, a session with representatives of the municipality and local stakeholders has already been organized to assess the potential for greening and also the desired type of green space. The results of this project are also an important input for a program by De Gezonde Stad aiming to co-create pocket parks with residents, municipality and private partners. At the time of writing, a big challenge is to arrange finances for maintenance as the budgets are limited. While there is political support for greening, it remains to be seen how this translates into support amongst public officials involved in the implementation and budgets for green space management.

4. Discussion

We have presented a transdisciplinary approach to combine and enrich the wealth of GIS-data with the practical knowledge of local experts and citizens for promoting small-scale urban greening in the retrofitting of urban neighbourhoods. Below, we discuss how this approach may contribute to closing the gap between data-driven and citizen-centric approaches to urban greening.

4.1. The efforts of local stakeholders should be linked to strategic planning approaches and green space policies

Navigating existing policies, identifying opportunities and barriers for greening and understanding socio-environmental priorities for climate change adaptation and ecological networks may be difficult for local citizens (Agger and Jensen, 2015, Buijs et al., 2016). Meanwhile, municipalities struggle to embed local knowledge and expertise in decision making, also because there are various green space related values and practices across the population. Several governance approaches have been suggested to strengthen collaborations between citizens and municipalities, to build trust and navigate the diversity of values across communities (Buijs et al., 2019, Toxopeus et al., 2020). Thus far, such governance approaches have not been connected to the issue of data-governance for sustainable smart cities and to participatory spatial modelling.

We show how a participatory spatial modelling approach, working with *Global-Detector,* has contributed to joint fact-finding amongst a diverse group of stakeholders, including public officials, local NGOs and scientists. For the specific 'top locations' the combination of GIS-analysis, stakeholder expertise and local site-visits contributed to the embedding of small local places in the larger urban infrastructure, where specific indicators could help to identify priorities for these sites. This process broadened the focus from the municipality and their professional knowledge and expertise to NGOs representing local residents. It likely also contributed to empowering NGOs and citizens represented by these organizations (Corbett et al., 2016). Practically, the approach provided local NGOs with concrete arguments to discuss upscaling of their own initiatives and also highlighted a potential to link specific places to larger city-wide policy priorities (cf. Buijs et al., 2019). Making local sustainability issues explicit through maps may also motivate local citizens that are not yet involved to contribute to urban greening (Rydin et al., 2003).

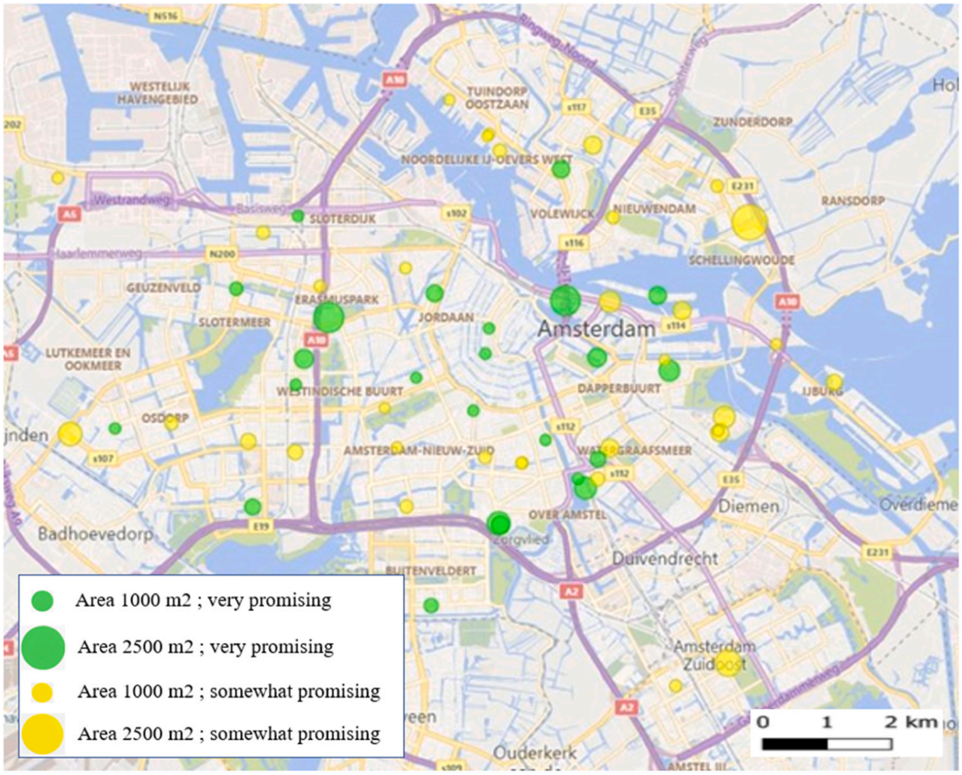

Fig. 5. promising locations for greening (60 locations, assessed by local experts).

4.2. Local knowledge and experiences should be linked with data-driven approaches towards space

The employed research approach was transdisciplinary as it linked scientific disciplines and societal stakeholders in developing and applying knowledge (cf. Kuhn, 2012), combining different perspectives on space. While in many participatory GIS projects citizens are asked to identify specific locations on a map (Rall et al., 2019, Maurer et al., 2023), our approach here is different. Citizens define criteria and indicators, and then based on their potential locations are identified. This put into view new spaces that experts and citizens had not yet considered, broadening the focus of assessment. It also allowed for a strategic, city-wide analysis of opportunities for greening by linking spatial data and an overall analysis of greening opportunities with local priorities and preferences.

As we show, the combination of generalized spatial data, knowledge about local policies and place-based knowledge from stakeholders offers important added values for the quality of analysis. For instance, the importance of on-site validation became very clear when 26 potential 'top locations' were excluded after local visits. This highlights how stakeholder involvement can improve the validity of results (Rall et al., 2019). As also highlighted in prior studies on participatory GIS, this contributes to alignment between different forms of knowledge as well as improved mutual understanding (Kwaku Kyem, 2004). Using spatial information in a transdisciplinary way requires more than collecting the correct 'facts' for research purposes: it means that this information can be used by stakeholders in problem solving (Kuhn, 2012). In our case, this is visible as the research findings are now being used in governance processes concerning urban greening.

4.3. Collaboration should be co-creative in order to build trust, empower local stakeholders and promote the acceptance of outcomes

For those involved in the project the co-construction of indicators led to an increased transparency, better understanding of findings and their implications and to a greater awareness of different options and needs for urban greening (Bąkowska-Waldmann and Kaczmarek, 2021). Transparency of the research process and the actual decision making process have been shown to build trust between stakeholders and policy officers as well as to contribute to acceptance of outcomes (Soma et al., 2016). In this context public participation should not only mean that citizens are consulted, but that there is an actual exchange of opinions and arguments to come to a substantive outcome that is acceptable to the broader public (Lafont, 2015). *Global-Detector* provided an important tool to promote co-creation in a way that led to a shared acceptance of the outcomes by those directly involved in the process. Stakeholders' involvement in the validation of results provided them with influence on the outcomes and the decisions how to apply them, contributing to ownership of results and increasing motivations for the greening of 'top locations'.

Whether this approach also contributes to acceptance amongst the wider public (all residents of Amsterdam) is as of yet unclear. Critiques about the limited number of people involved in many participatory GIS-projects (cf. Bąkowska-Waldmann and Kaczmarek, 2021) can also be applied here, as only about ten people participated in the development of indicators and a similar number in the local validation of results. While the involved organizations represent a large number of citizens, the *Global-Detector* approach in its' current form does not allow directly involving many more citizens in the deliberative process (Hennen et al., 2017). Even so, based on previous studies, we can assume that the increased participation of local NGOs who represent a large number of citizens will also contribute to acceptance and support of finding by residents not involved in the process (Demidov, 2018). Improved quality of decision making through the transdisciplinary combination of knowledge and expertise can also be expected to contribute to public support because the findings address collective problems experienced by a broader population than those directly involved (Eshuis and Edwards, 2013).

5. Conclusion

We described and verified a methodology to strengthen transdisciplinary collaborations towards retrofitting green space in urban neighbourhoods. The methodology supported a co-creation process for combining community engagement and GIS-based spatial data. We presented that the participatory use of GIS-modelling links bottom-up initiatives and local priorities with policy programmes on a larger spatial scale and contributes to the embedding of small local places in the broader urban infrastructure. We also showed the improved quality of data and informed decision-making by this co-creation and joint deliberation in participatory GIS. Besides we indicated a higher acceptance, transparency and local ownership for small-scale greening in urban neighbourhoods through our approach.

We therefore conclude that participatory geodata modelling can indeed contribute to bridging the gap between data-driven and citizen-centred approaches to green space retrofitting. However, depending on the local context and involved stakeholders, some flexibility will be required for tailoring our approach to other research questions and for involving other stakeholders (van Maurik Matuk et al., 2023). And while our approach can contribute to bridging the abovementioned gap, it should not be expected to fully close it as meaningfully connecting authorities with local stakeholders will require a broader range of efforts from various sides (Buijs et al., 2019). We also need to be that our approach is not suited to include large numbers of stakeholders in deliberation. Yet at the same time, *Global-Detector* highly depends on the expertise and commitment of local experts over the course of the research process. Furthermore, the possibility to develop indicators depends on the availability of spatial data and also on the resolution on which this data is available. Also, the quality of findings will decrease when local validation through site visits is not feasible.

While our work focused on urban public green spaces, the methodology is also applicable to private green spaces – greening of which is also important for tackling many urban challenges – and to other green spaces types. It is also applicable to other environmental challenges that have a strong spatial character, including climate change mitigation and adaptation measures, green mobility solutions, etc. Cities all over the world face challenges of multifunctional demands on sparse space as well as on linking environmental policies with local communities. With the increasing urgency for environmental measures within densely populated cities, our paper shows that collaboration between policy makers, stakeholders and scientists can help to navigate between different interests and priorities and integrate different types of valuable knowledge. This can be of added value for promoting healthy, biodiverse and climate-smart urban futures.

A word of remembrance

We dedicate this article to the memory of our co-author Paul de Dooij, who passed away during the revision of the original manuscript. Without Paul, this research project and scientific article wouldn't have existed. We thank Paul de Dooij for the inspiring cooperation and for his vital role in connecting researchers and practitioners. Paul, you will be missed!

CRediT authorship contribution statement

hennen wil: Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **buijs arjen:** Writing – review & editing, Writing – original draft, Investigation. **mattijssen thomas:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Walet Lesley:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Conceptualization. **de Dooij Paul:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Funding acquisition, Formal analysis. **van lammeren ron:** Writing – review & editing, Writing – original draft, Validation.

Declaration of Competing Interest

The authors declare no conflict of interest

Appendix 1. Description of Global-Detector

Model basics

Global-Detector is a knowledge-based GIS-method that aims to perform spatial analysis based on knowledge form experts combined with a large set of available data. This generally happens through an interactive process where experts or specific stakeholders are involved to assess the relevance and application of available data. Together with these stakeholders, spatial data are converted into concrete, relevant indicators.

Global-Detector was originally developed for use on a global scale that and has for instance been used to identify optimal environmental conditions for growing certain crops (Hennen, Daane, and Van Duijvendijk, 2017) or to benchmark cities on different dimensions of food security (Hennen et al. 2018). The model contains worldwide data on grid level for climate, infrastructure, market density, land use, soil, geography, population, etcetera. The model can also be employed on different levels of scale, as long as sufficient spatial data is available for this purpose. In order to apply the method of Global-Detector for this study, relevant and detailed data for Amsterdam were collected, transformed and applied with a much larger resolution (50×50 meter).

Integrating expert knowledge into spatial modelling

Basic principle behind *Global-Detector* is that using and transforming data into indicators is done by mobilizing the knowledge of experts for interpreting values and identifying optimal conditions for a specific purpose. In the context of our work in Amsterdam, this means that the organizations involved in urban greening are best able to define the indicators that are relevant for the purpose of their work. These stakeholders choose indicators that are relevant for the case of interest and these are eventually transformed into maps that identify optimal locations for a certain land-use (such as urban green space). In this process, interactive workshops are necessary for discussing criteria for selection, the range and weight of indicators, for knowledge transfer and also for validation of the maps. In these workshops, the chosen indicators are shown, transformed (e.g. for an optimum map or excluding map), weighted and finally combined to yield an overall map.

Technical properties

As a preparation for the workshops with stakeholders, all relevant and available datasets have been processed by GIS methods and software, resulting in a set of sub-indicators (see Appendix 2) with the same size, resolution (50×50 meter) and geo projection. In this way, indicators can be overlapped and combined during the workshop.

After preparation by the GIS expert involved in this project, the sub-indicators are ready to be shown on the map of Amsterdam and applied in the workshops. In an interactive workshop a main indicator is chosen, e.g. 'Climate', and the local experts express their motivations for weighing the sub-indicators to yield the score for the main indicator. If a sub-indicator needs to be converted to an optimal, or needs to be truncated, or requires another desired calculation, then this can be programmed (in R) and shown on-the-fly by the GIS expert. Local experts can then see how it is calculated and which values are used, and finally validate on a large screen the resulting map (i.e. weighted combination all main indicators). Such *face validity* by experts is important in the *Global-Detector* method, and if the result is not as they expected, parameters and weights can be adapted directly to improve the result. In an interactive way, knowledge of experts is implemented in the calculation procedure and formulas. In this way the process is open and transparent.

Appendix 2. Description of Indicators

Main indicators

The main indicators and corresponding sub-indicators are:

- Climate adaptation: from a climate adaptation perspective a location is especially suitable for greening when having a high risk of flooding, drought and/or heat stress.
- Nature: from a nature perspective a location is suitable for greening when this could become a stepping stone for biodiversity, can contribute to connectivity to the Main Green Structure and when there is a lack of green nearby.
- Social wellbeing: from a social perspective a location is considered as suitable for greening when there are living many people nearby, when there is lack of green nearby, a lower income in the neighbourhood, a high percentage of children + elderly as prioritized user groups, and highly diverse population.
- Health: From a health perspective a location is most suitable for greening when the health perception is low, when there is a high degree of obesity and when there is a low average education level in the neighbourhood.

Weight of sub-indicators

The weight of sub-indicators is as follows: low = 0.5; normal = 1; high =2. This will mean that the weight of a sub-indicator ranked as high is twice as influential on the final score as a weight of normal. This ranking of priorities is not an output of scientific analysis, but a judgement by the involved experts on the relative importance of the specific sub-indicators. All four main indicators are weighted equally.

List of indicators

Table 6 provides a list of all indicators that were used. For each indicators, an explanation of why it was selected and how it has been weighted has been included.

Table 6
list of indicators

Indicator	Subindicator	Explanation	Weight
Climate adaptation	Rainwater bottlenecks	Green can contribute to a reduction of flooding in events of extreme rainfall, something which has increasingly happened in many cities (McDonald, 2015). Various stakeholders in Amsterdam are currently working on reducing rainwater bottlenecks (Amsterdam Rainproof, 2020). The urgency for greening is therefore higher at locations with a high flooding risk.	High Amsterdam has multiple rainwater bottlenecks which can be (partly) tackled through greening.
Climate adaptation	Drought	In periods of long-term drought, groundwater levels can drop and the foundations of (old) buildings can be affected by rot. Green can contribute to higher groundwater levels by allowing infiltration of (rain)water in the soil (Elmqvist et al. 2013). On locations where there is a low groundwater levels in times of drought, the urgency for greening is therefore higher.	High In various parts of Amsterdam, drought is a serious problem which can damage buildings.
Climate adaptation	Heat stress	Urban green can contribute to a reduction of heat stress in periods of extremely high temperatures (Yin et al. 2018). On diverse locations in Amsterdam, the experienced temperatures can rise above 40 or even 50 degrees Celsius on warm days, especially in highly petrified locations. On locations with high heat stress, the urgency for greening is therefore higher.	Average *Global-Detector* gives a good estimate of heat stress, but a targeted approach requires a smaller resolution than 50×50 ms.
Nature	Ecological structure	The ecological structure consists of areas and corridors that play an important role in the biodiversity of Amsterdam (Gemeente Amsterdam 2020a). A neighbourhood garden or pocket park can function as an important stepping stone between these areas, helping species to migrate from A to B if the distance between those areas is not too small or too big (Beninde, Veith, and Hochkirch, 2015). For this reason, the urgency for greening is highest on location at a suitable distance of the ecological structure of Amsterdam.	High For biodiversity, the ecological structure consists of the most important green areas in Amsterdam. These are considered as most important for urban biodiversity in the city.
Nature	Main green structure	The main green structure consists of the most important (large) green areas of Amsterdam (Gemeente Amsterdam 2020c). While not specifically focused on ecology, the policy ambition is to make 50% of these areas ‘butterfly friendly’ and these areas do host many species. For these reasons, it is important to also assess the potential of neighbourhood garden or pocket park to function as an important stepping stone regarding these areas.	Average The main green structure is also of importance for urban biodiversity, but less so than the ecological structure.
Nature	Availability of green within 500 m	When the distance to existing green space is larger, it’s role as a stepping stone is less important, but it can still positively impact biodiversity. There is more to win if there is not much green space nearby. For this reason, priority is given to greening areas with little green space within 500 m.	Low On a strategic level this criterion is less important for urban biodiversity, but it is also important to green in areas where biodiversity is very low.

(*continued on next page*)

Table 6 (*continued*)

Indicator	Subindicator	Explanation	Weight
Social wellbeing	Number of inhabitants within 500 m	The more people living in the immediate vicinity of the location, the more potential users and visitors there are to this area and the more people enjoy the benefits of a green living environment. Therefore, priority is given to locations in areas where many people live within a radius of 500 m.	High The aim of this project is to create green for and with people, so it is important to realize this in areas where many people are living.
Social wellbeing	Access to green within 250 m	If there is little green space in the area, the social urgency for greening is greater (de Vries, Buijs, and Snep 2020). In its green vision, the Municipality of Amsterdam strives for everyone to live within 250 ms of a neighbourhood park (Gemeente Amsterdam 2020b). In line with this, priority is given to greening locations where little green space is available within 250 m.	High The social urgency for greening is most evident in areas where there is not much access to green space. Links with the green vision of the municipality of Amsterdam.
Social wellbeing	Income	In Amsterdams' neighbourhoods with a lower average income, less green space is often available and/or the available green space is of lower quality. Greenery can have a greater social impact as a result of this (de Vries, Buijs, and Snep 2020). Therefore, there is a greater urgency for greening in neighbourhoods where the average income is low.	Average Areas with lower average incomes were identified as priority spots for greening.
Social wellbeing	Age	Children and the elderly are seen as priority target groups for greening, also because these age groups often use this green space to play, walk or meet (Kabisch and Kraemer, 2020). Amsterdam neighbourhoods where many elderly people (65+) and/or children (0–15) live are therefore given priority as a potential location for greening.	Average These specific target groups are considered as priority groups for greening, but average weight because other user groups are also seen as important.
Social wellbeing	Diversity of population	Social cohesion can be lower in areas with a diverse population. Green projects can strengthen social cohesion if residents participate in them and the new neighbourhood greenery can serve as a meeting place (Veen, 2015). Greening therefore has priority in neighbourhoods with a diverse population.	Low Diversity of population is not seen as a primary criterion for greening, but included as it is nonetheless considered important.
Public health	Health perception	Green contributes to a healthy lifestyle (Hartig et al. 2014) and can also contribute to the perceived health or people. In areas where the perceived healthy amongst the population is low, the urgency for greening is therefore higher.	High Is seen as an important indication for where greening can have the most positive impact on health.
Public health	Obesity	In areas with a lot of greenery, the average BMI is often lower (Mena et al. 2015). Greening can make an extra contribution to a healthy lifestyle by promoting physical activities and a healthier living environment (Wolch, Byrne, and Newell, 2014) which invites people to go outside. In areas where more people are obese, there is therefore a greater urgency for greening.	Average The important of greening for health is seen here, but considered as somewhat less important than the health perception.
Public health	Level of education	There is a relationship between level of education and health in the Netherlands (CBS, 2017): the lower-educated are relatively often less healthy and have shorter lives. Greenery contributes to a healthy lifestyle and well-being of people (Hartig et al. 2014). There is therefore more urgency for greening in areas with a low average level of education.	Average The important of greening for health is seen here, but considered as somewhat less important than the health perception.

References

Agger, A., Jensen, J.O., 2015. Area-based Initiatives—and their work in bonding, bridging and linking social capital. Eur. Plan. Stud. 23, 2045–2061.

Amsterdam Rainproof. 2020. "Regenwaterknelpuntenkaart." accessed 27-08-2020. https://www.rainproof.nl/regenwaterknelpuntenkaart.

Baker, S., Mehmood, A., 2015. Social innovation and the governance of sustainable places. Local Environ. 20, 321–334.

Bąkowska-Waldmann, E., Kaczmarek, T., 2021. The use of PPGIS: towards reaching a meaningful public participation in spatial planning. ISPRS Int. J. Geo-Inf. 10, 581.

Beninde, J., Veith, M., Hochkirch, A., 2015. Biodiversity in cities needs space: a meta-analysis of factors determining intra-urban biodiversity variation. Ecol. Lett. 18 (6), 581–592. https://doi.org/10.1111/ele.12427.

Bennett, N.J., Whitty, T.S., Finkbeiner, E., Pittman, J., Bassett, H., Gelcich, S., Allison, E. H., 2018. Environmental stewardship: a conceptual review and analytical framework. Environ. Manag. 61, 597–614.

Bos, E. & Vogelzang, T. 2018. Groei versus groen - drie casestudy's over de waarde van het stadsgroen in Amsterdam. Wageningen: Wetenschapswinkel, Wageningen UR.

Buijs, A., Mattijssen, T.J.M., Van Der Jagt, A.P.N., Ambrose-Oji, B., Andersson, E., Elands, B., H.M., Steen Møller, M., 2016. Active citizenship and the resilience of urban green: fostering the diversity and dynamics of citizen contributions through mosaic governance. Curr. Opin. Environ. Sustain. 22, 1–6.

Buijs, A.E., De Koning, S., Mattijssen, T.J.M., Smeding, I.W., Smits, M.-J., Steins, N.A., 2023. Civil society for sustainable change: strategies of NGOs and active citizens to contribute to sustainability transitions. J. Environ. Plan. Manag. 1–22.

Buijs, A.E., Hansen, R., Van Der Jagt, S., Ambrose-Oji, B., Elands, B.H.M., Rall, E., Mattijssen, T.J.M., Pauleit, S., Runhaar, H.A.C., Stahl Olafsson, A., Steen-Moller, M., 2019. Mosaic governance for urban green infrastructure: upscaling active citizenship from a local government perspective. Urban For. Urban Green. 40, 53–62.

Cbs, 2017. Kwaliteit van leven in Nederland. Den Haag: Centraal Bureau voor de Statistiek.

Cbs, 2023. Basisbestand Bodemgebruik. In: STATISTIEK, C. B. V. D. (ed.). https://geodata.cbs.nl/files/Bodemgebruik/.

Corbett, J., Cochrane, L., Gill, M., 2016. Powering up: revisiting participatory GIS and empowerment. Cartogr. J. 53, 335–340.

De Vries, S., Buijs, A.E., Snep, R.P.H., 2020. Environmental justice in the Netherlands: presence and quality of greenspace differ by socioeconomic status of neighbourhoods. Sustainability 12, 5889.

Demidov, A., 2018. Partnership with civil society and the legitimacy of EU policymaking: exploring actors' normative arguments in four member states. J. Contemp. Eur. Res. 14, 169–186.

Dijkshoorn-Dekker, M., Linderhof, V., Mattijssen, T.J.M., Polman, N., 2020. Food secure metropolitan areas: the transition support system approach. Sustain. (Switz.) 12.

Elmqvist, T., Fragkias, M., Goodness, J., Güneralp, B., Marcotullio, P.J., Mcdonald, R.I., Parnell, S., Schewenius, M., Sendstad, M., Seto, K.C. & Wilkinson, C. 2013. Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities: A Global Assessment, Springer Nature.

Eshuis, J., Edwards, A., 2013. Branding the city: the democratic legitimacy of a new mode of governance. Urban Stud. 50, 1066–1082.

Feltynowski, M., Kronenberg, J., Bergier, T., Kabisch, N., Łaszkiewicz, E., Strohbach, M. W., 2018. Challenges of urban green space management in the face of using inadequate data. Urban For. Urban Green. 31, 56–66.

Frantzeskaki, N., Dumitru, A., Anguelovski, I., Avelino, F., Bach, M., Best, B., Binder, C., Barnes, J., Carrus, G., Egermann, M., Haxeltine, A., Moore, M.-L., Mira, R.G., Loorbach, D., Uzzell, D., Omann, I., Olsson, P., Silvestri, G., Stedman, R., Wittmayer, J., Durrant, R., Rauschmayer, F., 2016. Elucidating the changing roles of civil society in urban sustainability transitions. Curr. Opin. Environ. Sustain. 22, 41–50.

Gemeente Amsterdam. 2020a. "Ecologische passages en structuur." Gemeente Amsterdam. https://maps.amsterdam.nl/ecopassages/?LANG=nl.

Gemeente Amsterdam, 2020b. Groenvisie 2050 - een leefbare stad voor mens en dier. Gemeente Amsterdam,, Amsterdam.

Gemeente Amsterdam. 2020c. "Hoofdgroenstructuur." Gemeente Amsterdam, accessed 27-08-2020. https://maps.amsterdam.nl/hoofdgroenstructuur/.
Hansen, R., Buizer, M., Buijs, A., Pauleit, S., Mattijssen, T., Fors, H., Van Der Jagt, A., Kabisch, N., Cook, M., Delshammar, T., Randrup, T.B., Erlwein, S., Vierikko, K., Nieminen, H., Langemeyer, J., Soson Texereau, C., Luz, A.C., Nastran, M., Olafsson, A.S., Steen Møller, M., Haase, D., Rolf, W., Ambrose-Oji, B., Branquinho, C., Havik, G., Kronenberg, J., Konijnendijk, C., 2022. Transformative or piecemeal? Changes in green space planning and governance in eleven European cities. Eur. Plan. Stud. 1–24.
Hansen, R., Pauleit, S., 2014. From multifunctionality to multiple ecosystem services? A conceptual framework for multifunctionality in green infrastructure planning for Urban Areas. Ambio 43, 516–529.
Hartig, T., Mitchell, R., De Vries, S., Frumkin, H., 2014. Nature and health (in press.). Annu. Rev. Public Health. https://doi.org/10.1146/annurev-publhealth-032013-182443.
Hennen, W., Daane, A. & Van Duijvendijk, K. Global-detector - GIS-And knowledge-based tool for a global detection of the potential for production, supply and demand. GISTAM 2017 - Proceedings of the 3rd International Conference on Geographical Information Systems Theory, Applications and Management, 2017. 161-168.
Hennen, W.H.G.J., Diogo, V., Polman, N.B.P., Dijkshoorn-Dekker, M.W.C., 2018. Comparing cities of the world according to their food security risks and opportunities. WIT Trans. Ecol. Environ. 217, 953–962.
Hennen, W., Mattijssen, T.J.M., 2020. Postzegelparken en Buurttuinen - een zoektocht naar locaties voor vergroening van Amsterdam. Wageningen Science Shop Wageningen University Research.
Huang, G., London, J.K., 2016. Mapping in and out of "messes": an adaptive, participatory, and transdisciplinary approach to assessing cumulative environmental justice impacts. Landsc. Urban Plan. 154, 57–67.
Hubacek, K., Kronenberg, J., 2013. Synthesizing different perspectives on the value of urban ecosystem services. Landsc. Urban Plan. 109, 1–6.
Kabisch, N., Kraemer, R., 2020. Physical activity patterns in two differently characterised urban parks under conditions of summer heat. Environ. Sci. Policy 107, 56–65. https://doi.org/10.1016/j.envsci.2020.02.008.
Kadaster, 2021. Basisregistratie Grootschalige Topografie. Kadaster,, Apeldoorn. ⟨https://www.pdok.nl/downloads/-/article/basisregistratie-grootschalige-topografie-bgt-#7eedc55878c2562e833f17344aa78cf5⟩ (Available).
Kuhn, W., 2012. Core concepts of spatial information for transdisciplinary research. Int. J. Geogr. Inf. Sci. 26, 2267–2276.
Kwaku Kyem, P.A., 2004. Of intractable conflicts and participatory GIS applications: the search for consensus amidst competing claims and institutional demands. Ann. Assoc. Am. Geogr. 94, 37–57.
Lafont, C., 2015. Deliberation, participation, and democratic legitimacy: should deliberative mini-publics shape public policy? J. Political Philos. 23, 40–63.
Mattijssen, T., Buijs, A., Elands, B., 2018. The benefits of self-governance for nature conservation: a study on active citizenship in the Netherlands. J. Nat. Conserv. 43, 19–26.
Mattijssen, T.J.M., 2022. A synthesis on active citizenship in European nature conservation – social and environmental impacts, democratic tensions and governance implications. Ecol. Soc.
Mattijssen, T.J.M., Ganzevoort, W., Van Den Born, R.J.G., Arts, B.J.M., Breman, B.C., Buijs, A.E., Van Dam, R.I., Elands, B.H.M., De Groot, W.T., Knippenberg, L.W.J., 2020. Relational values of nature: leverage points for nature policy in Europe. Ecosyst. People 16, 402–410.
Maurer, M., Chang, P., Olafsson, A.S., Møller, M.S., Gulsrud, N.M., 2023. A social-ecological-technological system approach to just nature-based solutions: A case of digital participatory mapping of meaningful places in a marginalized neighborhood in Copenhagen. Den. Urban For. Urban Green., 89.
Mcdonald, R.I. 2015. Conservation for cities: How to plan & build natural.
Mena, C., Fuentes, E., Ormazábal, Y., Palomo-Vélez, G., Palomo, I., 2015. Role of access to parks and markets with anthropometric measurements, biological markers, and a healthy lifestyle. Int. J. Environ. Health Res. 25 (4), 373–383. https://doi.org/10.1080/09603123.2014.958134.
Metropole Region Amsterdam, 2023. Economische verkenningen. Metropole Region Amsterdam,, Amsterdam.
Municipality Of Amsterdam, 2019. Grote Groenonderzoek 2018. Onderzoek, informatie en statistiek,, Amsterdam.
Murphy, M.A., Parker, P., Hermus, M., 2023. Cultivating inclusive public space with urban gardens. Local Environ. 28, 99–116.
Rall, E., Hansen, R., Pauleit, S., 2019. The added value of public participation GIS (PPGIS) for urban green infrastructure planning. Urban For. Urban Green. 40, 264–274.
Rantanen, H., Kahila, M., 2009. The SoftGIS approach to local knowledge. J. Environ. Manag. 90, 1981–1990.
Ryan, R.L., 2011. The social landscape of planning: Integrating social and perceptual research with spatial planning information. Landsc. Urban Plan. 100, 361–363.
Rydin, Y., Holman, N., Wolff, E., 2003. Local Sustainability Indicators. Local Environ. 8, 581–589.
Soma, K., Macdonald, B.H., Termeer, C.J.A.M., Opdam, P., 2016. Introduction article: Informational governance and environmental sustainability. Curr. Opin. Environ. Sustain. 18, 131–139.
Toxopeus, H., Kotsila, P., Conde, M., Katona, A., Van Der Jagt, A.P.N., Polzin, F., 2020. How 'just' is hybrid governance of urban nature-based solutions? Cities 105, 102839.
Van Maurik Matuk, F.A., Verschuuren, B., Morseletto, P., Krause, T., Ludwig, D., Cooke, S.J., Haverroth, M., Maeesters, M., Mattijssen, T.J.M., Keßler, S., Lanza, T.R., Milberg, E., Ming, L.C., Hernández-Vélez, C.A., Da Silva, K.M.T., Souza, M.P.V., Souza, V.O., Fernandes, J.W., Dos Reis Carvalho, B.L., 2023. Advancing co-production for transformative change by synthesizing guidance from case studies on the sustainable management and governance of natural resources. Environ. Sci. Policy 149, 103574.
Veen, E.J. 2015. *Community gardens in urban areas: A criticial reflection on the extent to which they strengthen social cohesion and provide alternative food.* PhD Wageningen University and Research Centre.
Wolch, J.R., Byrne, J., Newell, J.P., 2014. Urban green space, public health, and environmental justice: the challenge of making cities 'just green enough'. Landsc. Urban Plan. 125, 234–244.
Yin, C., Yuan, M., Lu, Y., Huang, Y., Liu, Y., 2018. Effects of urban form on the urban heat island effect based on spatial regression model. Sci. Total Environ. 634, 696–704.