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Greening cities through urban planning: A literature review on the uptake of concepts and methods in Stockholm

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ABSTRACT

Nature-based solutions (NBS) represent the most recent of several "greening" concepts proposed to support spatial planning and decision-making towards sustainable metropolitan regions. Despite similarities, the concepts stem from different disciplines and policy arenas and reflect various models of people-nature relations. This paper aims to analyze the uptake of greening concepts in scientific planning literature focusing on (urban) nature and landscape in the metropolitan region of Stockholm, Sweden, over the last three decades. It investigates what changes this evolution has brought in terms of the topics adopted, methods applied, and types of planning support put into practice. We identified 574 articles that reflect substantial research on greening concepts in the Swedish planning context. The articles demonstrate an initial prevalence of biodiversity with later increases of interest in ecosystem services and NBS. A detailed analysis of the studies focusing on Stockholm revealed Population growth/densification, Green space management and Biodiversity conservation as the most commonly addressed societal challenges. The most frequently mentioned type of green and blue element is Parks and (semi-)natural urban green areas, including urban forests. Methods applied were mostly quantitative, while mixes with qualitative approaches were only apparent in ecosystem services articles. Half of the studies involved practitioners or decision-makers, but only four seemed related to real-life planning processes. Taken together, the influence of scientific literature on the uptake of greening concepts in spatial planning seems to have been limited. Future mainstreaming of greening concepts in Stockholm and beyond could benefit from available data, methods and experiences, but will require more active translation and boundary management. Further research into science-policy-planning interfaces at city scale is thus imperative to advance more sustainable pathways for people and nature in metropolitan regions.

1. Introduction

Greening cities and metropolitan regions has long been acknowledged as a planning strategy to meet people's needs while enhancing or protecting biodiversity (Andersson et al., 2014; Geneletti et al., 2020; TEEB, 2011; Xie and Bulkeley, 2020). Green and blue areas in cities and metropolitan regions contribute to regulating water and climate and provide other ecosystem services that are of great importance to human well-being (Adem Esmail and Geneletti, 2017; Cortinovis and Geneletti, 2019; Taylor and Hochuli, 2017). The United Nations' *New Urban Agenda* – as well as other initiatives by international bodies, including the European Union (European Commission, 2020; European Environment Agency, 2009), World Bank (White et al., 2017), and OECD (2012) – recognises the importance of public green spaces and nature in cities

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and the need to safeguard and enhance the ecosystem services they provide (UN-Habitat, 2020). Therefore, to foster transformative change towards positive futures for people and nature, green and blue areas must be integrated into urban and spatial planning at all levels (Albert et al., 2020; European Commission, 2020).

Biodiversity is in rapid decline due to the loss, fragmentation and degradation of natural habitat (Leclère et al., 2020). Biodiversity and urbanisation hotspots often coincide (McDonald et al., 2018; Wilkinson et al., 2013). However, cities and metropolitan regions present both a threat to biodiversity and an opportunity for innovation (Albert et al., in review). Urbanisation has enormous impacts on biodiversity within the urban fabric (e.g. increase of exotic species), in nearby surroundings (e.g. habitat fragmentation and degradation) and in distant regions (e.g. appropriation of large amounts of resources and teleconnections) (Alberti, 2005; Balfors et al., 2020; Elmqvist et al., 2013). At the same time, studies have shown that when spatial planners intervene to create, expand, enhance or protect green and blue elements, cities provide habitat for many native plant and animal species, including a number of endangered species, highlighting the under-utilised urban opportunities for biodiversity conservation (e.g. Ives et al., 2016; Planchuelo et al., 2019). Therefore, there is a growing consensus that cities and metropolitan regions are one of the most promising policy arenas for fostering transformative change towards a 'good Anthropocene' where both people and nature thrive (Alberti et al., 2020; Elmqvist et al., 2019; Jeanson et al., 2020; McPhearson et al., 2021; Nagendra, 2016).

Several approaches have been adopted over the years in urban planning to increase and enhance green and blue space in cities, and contribute to nature protection, ecological connectivity and the delivery of ecosystem services to citizens. Approaches inspired by biodiversity conservation targeted mainly the identification of key habitat patches for plant and animal species, and the subsequent establishment of protected areas (or other forms of land use and land management restrictions) (e.g. Savard et al., 2000), ecological corridors (e.g. Peng et al., 2017; Vergnes et al., 2013), as well nature restoration interventions (Elmqvist et al., 2015). Approaches inspired by the concept of ecosystem services (e.g. Cortinovis and Geneletti, 2019; Geneletti et al., 2020; Haase et al., 2014) assessed the importance of green and blue space in terms of supplying provisioning, regulating and cultural services to citizens. Approaches inspired by the concept of green infrastructures (e.g. Albert and von Haaren, 2017; Pauleit et al., 2019) - and the closely-related concepts of green wedges (Lemes de Oliveira, 2019, 2014) and green belts (Amati and Taylor, 2010; Thomas and Littlewood, 2010) - embrace both objectives, introducing a strong spatially-oriented perspective, deeply interlinked with other related planning issues, such as the improvement of walking and cycling infrastructures, the protection of cultural landscapes and the identification of urban boundaries (Ignatieva et al., 2011; Opdam et al., 2006).

More recently, the concept of nature-based solutions (NBS) has emerged as a potentially important component of the desired transition towards sustainable societies (Albert et al., 2021; Geneletti et al., 2016; Kabisch et al., 2016). As defined by the European Commission, NBS are 'solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience' (European Commission, 2016; Maes and Jacobs, 2017). Hence, NBS constitute an umbrella concept that include the previously described approaches, and promote assessments of the social and economic benefits of resource-efficient and systemic solutions that combine technical, governance, regulatory and social innovation (Raymond et al., 2017; Schmidt et al., 2022). Operationally, NBS have been defined as actions that fulfil three core criteria, namely 'challenge orientation', 'ecosystem process utilisation', and 'practical viability' (Albert et al., 2017).

Despite evident similarities and overlaps among the different concepts, they embody different visions of the relationship between people and nature, and their evolution in recent decades has reflected shifts in the policy relevance of several issues (e.g. air pollution, climate change adaptation) (Heymans et al., 2019; Mace, 2014). Hence, the implementation of the different concepts in urban planning resulted in different types, design and spatial arrangements of "greening interventions": from the creation of protected areas to the design of human settlements surrounded by green belts or penetrated by green wedges (Duvall et al., 2018).

Several studies have explored the adoption and evolution of urban greening concepts in spatial planning (Hansen et al., 2015; Lemes de Oliveira, 2014; Longato et al., 2021; Taylor and Hochuli, 2017; Wang et al., 2019). The methods range from eliciting the views of stakeholders and involved decision-makers (e.g. Albert and von Haaren, 2017; Moosavi et al., 2021) to analysing the content of plans (e.g. Cortinovis and Geneletti, 2018; Geneletti and Zardo, 2016) or both (e.g. Khoshkar et al., 2020a), to reviewing policy documents and discourses in selected countries and cities (Amati and Taylor, 2010; Thomas and Littlewood, 2010). Nevertheless, to our knowledge, no study has performed a case study analysis based on a systematic review of the evolution and uptake of greening concepts in the scientific planning literature. Baravikova (2020) performed a similar analysis on the adoption of greening strategies in Polish cities, but the method was based on an analysis of policy documents and interviews with practitioners and activists. Recently, Karlsson and Bodin (2022) analysed project reports to assess uptake of ecological connectivity analysis in the Swedish urban planning practice in the past decade.

This paper aims to analyse the uptake of greening concepts in scientific planning literature focusing on (urban) nature and landscape in the metropolitan region of Stockholm, Sweden, over the last three decades. It investigates what changes this evolution has brought in terms of topics adopted, methods applied, and types of planning support put into practice. The term "greening concept" is used here broadly to refer to a conceptual approach used in (urban and regional) spatial planning as a framework to guide interventions to create, expand, enhance or protect both natural and artificial green and blue space in cities. Three research questions guided the analysis: (1) How has the uptake of greening concepts evolved in scientific papers addressing spatial planning in Stockholm and, more generally, in Sweden? (2) What societal challenges and types of green and blue elements are linked to the different concepts presented in the papers? (3) What methods have been adopted to operationalise the different concepts and what evidence have been produced to support spatial planning?

The Metropolitan Region of Stockholm or Greater Stockholm (hereafter referred to as 'Stockholm') was selected as an informative case study because it has faced the typical challenge of increasing population and urban growth in the context of scarce spatial resources, but is also a pioneer for greening research and planning efforts. In its capacity as Europe's first 'Green' as well as fastest-growing capital, Stockholm saw its urban areas increase by 15% between 2005 and 2015, even along the borders of nature reserves, resulting in threats to biodiversity and losses of ecosystem services (Furberg et al., 2020, 2019). Environmental justice issues, including unequal access to benefits from nature and exposure to environmental hazards, are yet another rising challenge to social cohesion in Stockholm (Ernstson, 2013; Gunnarsson-Östling and Höjer, 2011). At the same time, Stockholm is home to several universities and research institutes, which together with the general availability of resources and political support (e.g. through national environmental quality objectives and strategic research agendas for sustainable development and for trans-disciplinary research) have facilitated the uptake and mainstreaming of novel urban greening concepts. Apparently, in Stockholm there is a long tradition of reflecting urban or regional planning concepts in the planning science literature - perhaps more so than in many other cities - which allows for our analyses (e.g. Chien, 2021). Research-driven greening concepts have been widely implemented in the Swedish planning system thanks to the development of methods directly applicable to planning practice through practitioner collaboration and co-creation (Bergsten and Zetterberg, 2013; Brokking et al., 2021; Kaczorowska and Pont, 2019; Karlsson and Bodin, 2022;

Löfvenhaft et al., 2002; Mörtberg et al., 2012; Page et al., 2020; Zetterberg et al., 2010).

2. Swedish spatial planning system and greening concepts

In Sweden, spatial planning mainly takes place at the level of municipalities, which hold a 'planning monopoly' regulated by the Planning and Building Act (PBL, 2018). While the national level provides steering documents and guidelines, interpretations and decisions are mainly conducted at the municipal level. According to the legislation, municipalities make decisions on directions for overall land use, development of housing, and municipal infrastructure (The Swedish National Board of Housing Building and Planning, 2011). Municipal planning takes place mainly through comprehensive plans, covering the entire municipality, and detailed development plans. Comprehensive plans are not legally binding, while they contain the municipality's view on how to pursue sustainability including through green and blues areas (Khoshkar et al., 2018; Persson, 2013). They indicate the overall direction of the municipality over time and guide in the development of detailed development plans (National Board of Housing Building and Planning, 2021). Within municipal planning, the detailed development plans are legally binding and regulate the development of land and water (PBL, 2018).

Concerning the regional level, there are only two regions with mandatory regional planning in PBL, namely the metropolitan regions of Stockholm and Skåne, while it is voluntary in other regions. The regional plan indicates the basic features of land and water use, and the localisation of built-up areas, thus guiding municipal decisions on comprehensive and detailed plans, but is not legally binding. The regional plan for Region Stockholm includes a system of green wedges complemented with designated peri-urban areas of high nature, recreation and cultural value (GRPA, 2018). The national level is represented by the County Administrative Boards (CAB) that safeguard and coordinate state interests in the planning process. Counties have the same administrative borders as the regions. The CABs have the responsibility of drafting green infrastructure plans, which target biodiversity and ecosystem services, such as the action plan for green infrastructure in Stockholm (CAB, 2019). These are applied at the county level under national coordination and guidelines (SEPA, 2017), based on the EU Biodiversity Strategy (European Commission, 2020, 2010) and the EU strategy and guidelines on green infrastructure (European Commission, 2019, 2013). More detailed information about the Swedish spatial planning system is provided in the SM including a sample of significant case studies that exemplify the uptake of greening concepts and methods in spatial planning in the Stockholm region.

3. Methods

This paper's methods combine a systematic literature mapping with in-depth analysis and interpretation of published case studies. Fig. 1 provides an overview of the four main steps of the systematic review, described in more detail in the following sections.

First, articles relevant to Swedish spatial planning were identified through a search in Web of Science, performed in June 2020. Different urban greening concepts including 'green infrastructure', 'green wedge', 'green belt' and 'nature-based solution' and as well other relevant related concepts such as 'ecosystem services' and 'biodiversity' were used as search keywords. The search was limited to Sweden and, in the case of 'ecosystem services' and 'biodiversity', was further limited to planning contexts (Supp. Material, Section 2). We assume here that, in the context of spatial planning, the concepts of 'biodiversity' and 'ecosystem services' can contribute, among others, by supporting the definition of local and regional targets and indicators and the assessment of design options (e.g. Longato et al., 2021; Mörtberg et al., 2012). Therefore, they can be associated with urban "greening concepts" as defined herein.

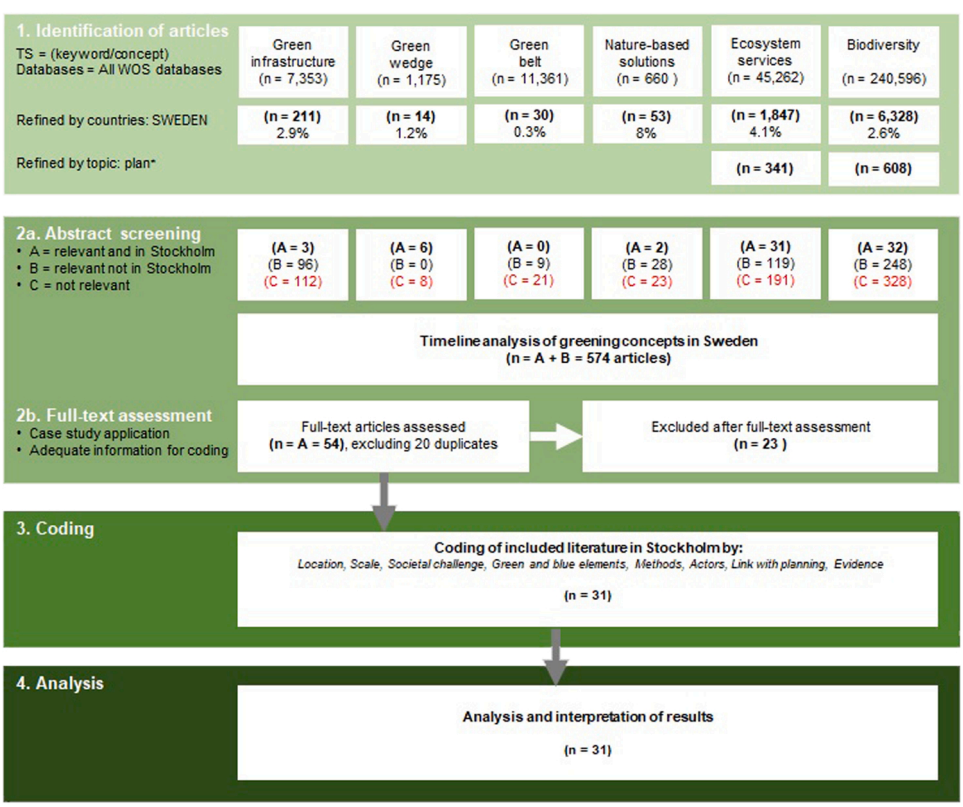

Fig. 1. Flow diagram illustrating the four main steps of the literature review and the classifications of scientific publications: 1) Identification of articles, 2) Screening, 3) Coding, and 4) Analysis and interpretation.

The second step consisted of abstract screening and full-text assessment to identify two samples for the analysis. The abstracts were scored based on their topical (i.e. generally dealing with greening concepts) and geographical relevance (i.e. empirical application in Stockholm) and were divided into three subsets: relevant and in Stockholm region (A = **74** articles), relevant but not in the Stockholm region, (B = **500**), and not relevant (C = **683**). Then, to explore the timeline of application of different greening concepts in Sweden, a larger sample was identified including all relevant articles (A and B, totalling **574** articles). A second sample was identified dealing with case study applications of urban greening concepts in the Metropolitan Region of Stockholm. This second sample initially consisted of **54** articles, excluding **20** duplicates from the 74 articles of subset A. Next, based on full-text assessment of each document to check for relevance (i.e. to see if a case study application of a greening concept was reported, excluding qualitative studies based on interviews and documentary analysis, and was actually located in Stockholm), the same sample was further reduced to **31** articles (Supp. Material, Section 3). A list of the articles and the reason for their exclusion is provided in the Supp. Material.

In the third step, the sample of **31** articles was systematically analysed using the framework in Table 1. The information extracted included the location, spatial scale, type of societal challenges, type of green and blues elements and related greening intervention of the case study. In particular, we considered the ten key societal challenges identified by Raymond et al. (2017), to which we added two more challenges – population growth/densification and biodiversity conservation – which strongly emerged from the reviewed papers (see also Babí Almenar et al., 2021). The green and blue elements addressed in the articles were classified based on earlier efforts by the Naturvation project (Almassy et al., 2018), which recognised seven categories of urban settings as 'ecological domains', excluding green indoor areas, where NBS are physically implemented. To these, we added two categories, i.e. forests, agricultural, and other open areas, given the metropolitan scale of the case study. Furthermore, we extracted information about different greening intervention measures described in the articles. The methods applied and the types of actors involved in the study (i.e. those mentioned in the article as contributing either actively or passively to the research) were also analysed, as well as any links of the study to real-life planning, and evidence of the intervention's effectiveness as reported in the articles. The final step of our methodology consisted of organising the systematic review results according to the greening concepts.

Table 1
Review framework. Societal challenges are classified following Raymond et al. (2017) and Babí Almenar et al. (2021). Green and blue elements are adapted from (Almassy et al., 2018).

Scale	Local
	Municipal
	Regional
Societal challenges	Green space management
	Population growth and densification
	Biodiversity conservation, supporting ecosystem services
	Urban regeneration
	Participatory planning and governance
	Economic opportunities and green jobs
	Public health and wellbeing
	Climate mitigation and adaptation
	Water management
	Social justice and social cohesion
	Air quality
	Coastal resilience
Green and blue elements	Parks and (semi)natural urban green areas, including urban forests
	Blue areas, including rivers, lakes, and wetlands
	Urban green areas connected to grey infrastructure, e.g. alley and street trees, house gardens, green playground/ school grounds
	Allotment gardens and community gardens
	Building greens, such as green roofs and green walls
	Green areas for water management, e.g. rain gardens
	Derelict areas, abandoned spaces with patches of wilderness
	Forests
	Agricultural area and open land
Greening Intervention	(description of greening interventions)
Methods	Quantitative
	Qualitative
Actors involved	Scientists
	Practitioners and/or decision-makers
	Other stakeholders
Link to real-life planning	None – study provides no mention of planning implications
	Analysis/Support – study derives some recommendations for planning
	Integrated – study is part of and/or reports a real-life planning process
Evidence	Empirically measured
	Simulated
	Literature-derived or expert opinion

4. Results

4.1. Evolution of urban greening concepts in Swedish spatial planning

The sample of papers was classified according to the different greening concepts adopted, here represented by the keywords of biodiversity (**280**), ecosystem services (**150**), green infrastructure (**99**), NBS (**30**), green belt (**9**) and green wedge (**6**). A timeline of the articles and a cumulative graph are illustrated in Figs. 2 and 3, respectively.

The 31 articles selected for a detailed analysis (see Fig. 4 and Table A1 in Supp. Material) present empirical applications of different urban greening concepts in the Metropolitan Region of Stockholm. The first subset of these includes articles that address only one greening concept: ecosystem services (**10** articles), biodiversity (**6**), green infrastructure (**1**) or NBS (**1**). The second subset consists of articles that consider two greening concepts: biodiversity and ecosystem services (**7**), ecosystem services and green wedges (**1**) or green infrastructure and green wedges (**1**). Finally, the third subset includes articles that address three greening concepts: biodiversity, ecosystem services, and green infrastructure (**1**) or green wedges (**3**). The three subsets are crucial for our questions on how the scientific planning literature has integrated the different greening concepts and what changes this evolution has brought in terms of topics, methods and type of planning support in Stockholm.

4.2. Societal challenges and greening interventions in Stockholm

The societal challenges mentioned in the articles are shown in Fig. 5. The five most cited challenges are *Population growth/densification* (**21** articles), *Greenspace management*, including issues of fragmentation and connectivity (**20**), *Biodiversity conservation* and supporting ecosystem services (**17**), *Urban regeneration*, including growth and public space needs (**16**), and *Participatory planning and governance* (**11**). The least frequently mentioned challenges are related to *Coastal resilience* (**0**), *Air*

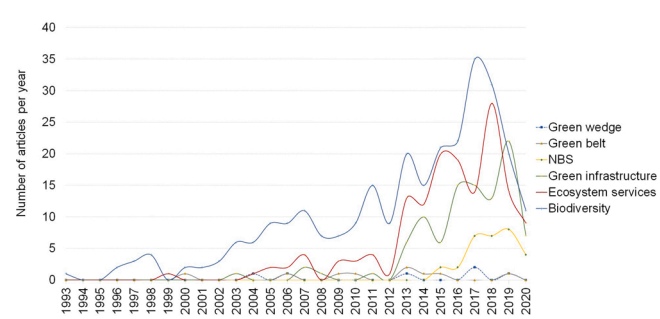

Fig. 2. Timeline of scientific articles reporting applications of greening concepts in Sweden (sample of 574 articles).

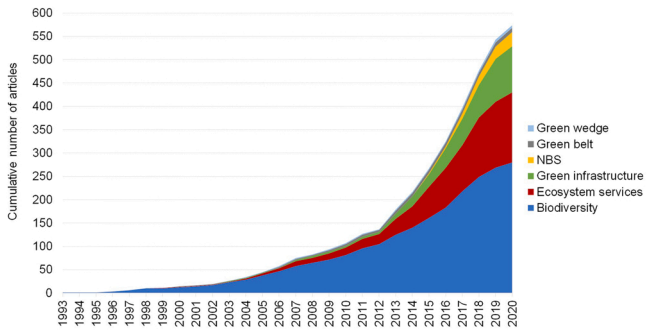

Fig. 3. Cumulative graph of the scientific articles reporting applications of different greening concepts in Sweden.

quality (**2**), *Social justice and social cohesion* (**3**), and *Water management*, including issues of eutrophication, water quality and flooding (**5**). Most of the articles mention several societal challenges. Overall, 17 out of 31 deal with four or more challenges, 6 articles mention three challenges and 8 articles address only one or two challenges.

The most common type of green and blue elements addressed in our sample are *Parks and (semi)natural urban green areas*, including urban forests and golf courses (**24** articles), followed by *Blue areas,* including rivers, lakes and wetlands (**19**), *Urban green areas connected to grey infrastructure*, such as alley and street trees, house gardens, green playground, and cemeteries (**13**), and *Allotment gardens* (**5**). Based on our sample, less frequently cited greening interventions are *Building greens*, such as green roofs and walls (**3**) – see Fig. 6. In addition, most of the studies considered *Forests* (**23**) and *Agricultural areas, open lands* (**18**) as greening elements, reflecting the metropolitan scale of the case study. Interestingly, most of the articles focus on either four types (**11**), or two types (**8**) of green and blue elements. Only one article presents a case study considering seven different types of green and blue elements and four articles discuss five types.

A diverse range of greening interventions have been identified that are recommended to support or integrate into urban planning processes to create, expand, improve or protect both natural and artificial green and blue space in Stockholm. Most of these measures take the form of recommendations and suggestions that are based on scientific analysis and studies. For example, Xiu et al. (2017) recommend developing a comprehensive green network plan for ecological and social needs at two levels: at city level, they identify 596 nodes of social and ecological importance of which 59 are selected as critical nodes, and at the neighbourhood level, they suggest new links between Hjorthagen and the Royal National City Park and provide an illustrative design of road greening integrating green and blue spaces. Again, Colding et al. (2006) highlight the crucial role of private gardens, golf courses, and allotment areas, which represent 18% of the total areas and twice as much as the protected areas and green wedges for biodiversity, and argue for the need to incorporate their stakeholders in the management of blue green spaces in Stockholm. Similar considerations are made by Andersson et al. (2007) who argue for improved and coordinated management of cemeteries, city parks, and allotment gardens that can improve ecosystem services. Bergsten et al. (2014) address the mismatches between ecological connectivity and land management, and advance spatially explicit proposals to increase social (e.g. collaboration between

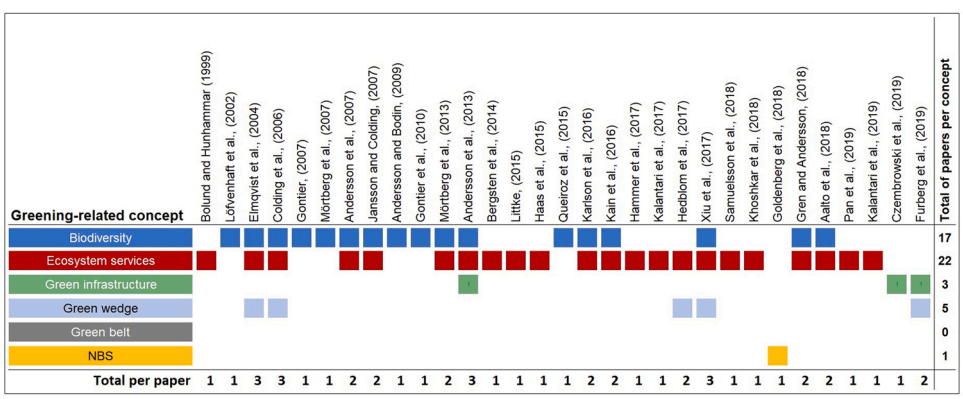

Fig. 4. Selected sample of 31 articles presenting applications of urban greening concepts in the Stockholm region.

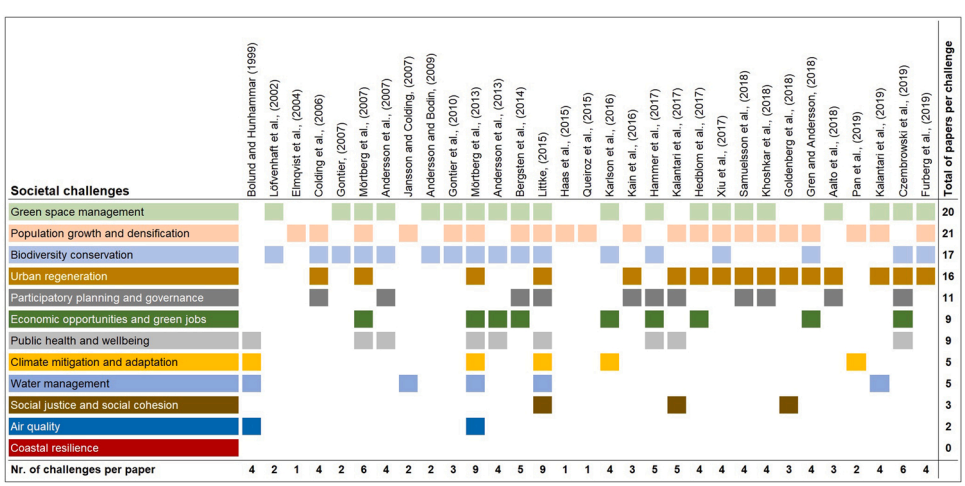

Fig. 5. Types of societal challenges mentioned in the analysed sample of 31 articles operationalising urban greening concepts in Stockholm.

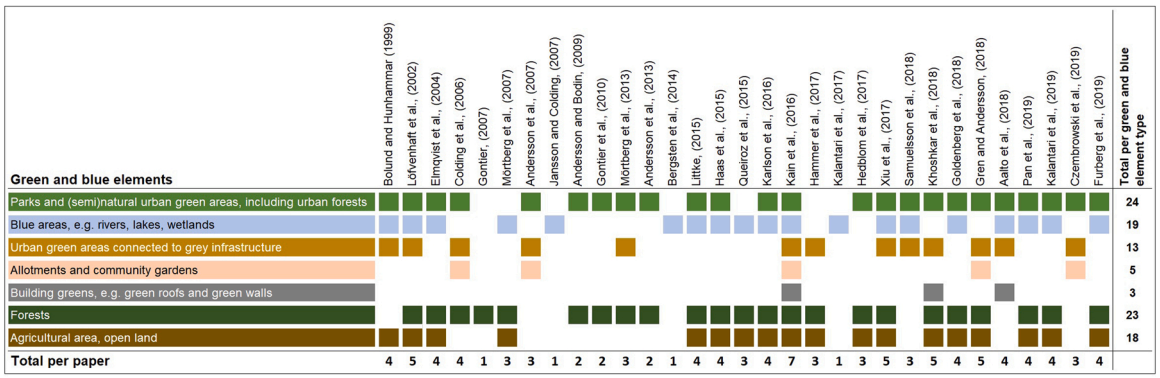

Fig. 6. Types of green and blue elements considered in the 31 articles operationalising urban greening concepts in Stockholm.

municipalities and coordinating role by regional actors) and ecological links (e.g. wetland restoration projects when collaboration exists without ecological link) between wetland systems. Some of the articles reviewed describe intervention measures that are integrated into urban planning processes, such as large green wedges to ensure the continuity of the natural and cultural environment (Elmqvist et al., 2004). A comprehensive list of the identified greening interventions is reported in Table A3 in the SM.

Fig. 7 shows the link between the types of societal challenges, blue and green elements, and the main urban greening concepts, as emerging from the sample. Articles adopting the concept of ecosystem services cover the whole range of eleven societal challenges, while those referring only to biodiversity conservation mention just five of them. On the other hand, studies integrating ecosystem services and biodiversity conservation are the only category dealing with all types of blue and green elements, including allotments and community gardens – generally disregarded by articles applying individually either of the two concepts - as well as building greens – generally overlooked by articles referring to green infrastructure or green wedges, or to biodiversity conservation only.

4.3. Spatial scale, applied methods and types of provided evidence

More than half of the articles focused only on one spatial scale: regional (**5** articles), municipal (**7**) or local (**3**). Ten articles analysed two different spatial scales simultaneously: municipal and regional (**9**), local and regional (**2**) or local and municipal (**2**). Only three articles considered all three spatial scales simultaneously. Our sample shows an increase of studies addressing two different scales – and, to a lesser extent, all three scales – since 2013. Based on our sample, biodiversity-related studies are more focused on the regional scale, while ecosystem services–related studies are conducted more frequently at the local scale.

Most of the analysed articles (**24** out of 31) apply quantitative methods, including surveys of local species, land use modelling, habitat suitability modelling and remote sensing (see Fig. 8). On the other hand, qualitative methods, such as literature reviews, interviews and documentary analyses, are applied in almost half of the sample (**14**). Ten articles combine qualitative and quantitative methods. A description of

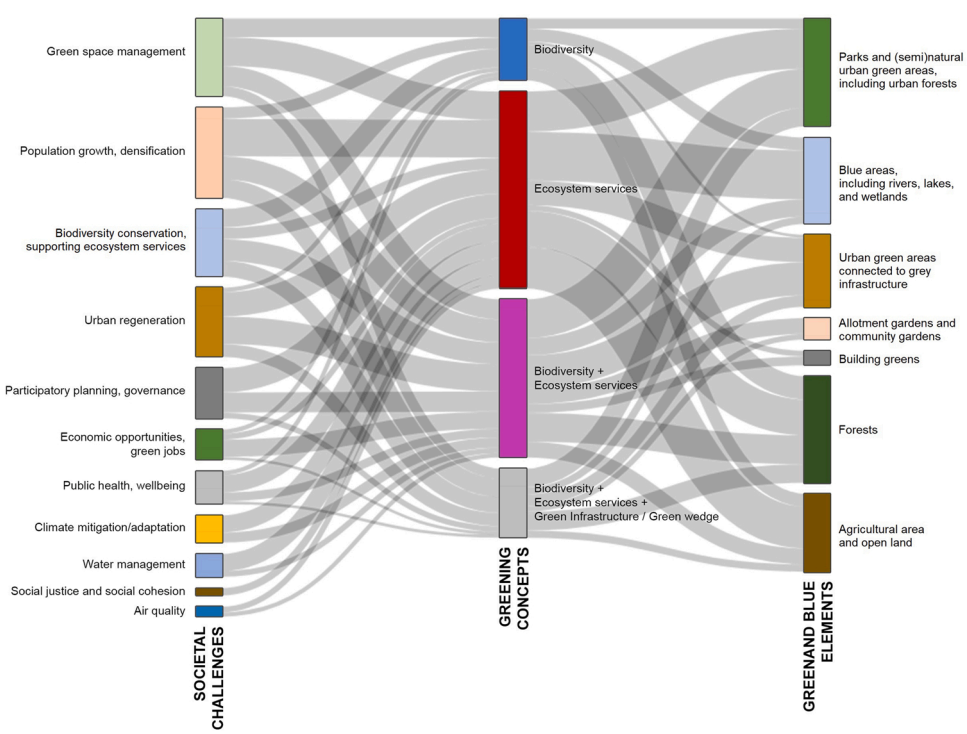

Fig. 7. Frequency of the combinations of societal challenges and types of green and blue elements concerning different urban greening concepts among the reviewed empirical applications in Stockholm.

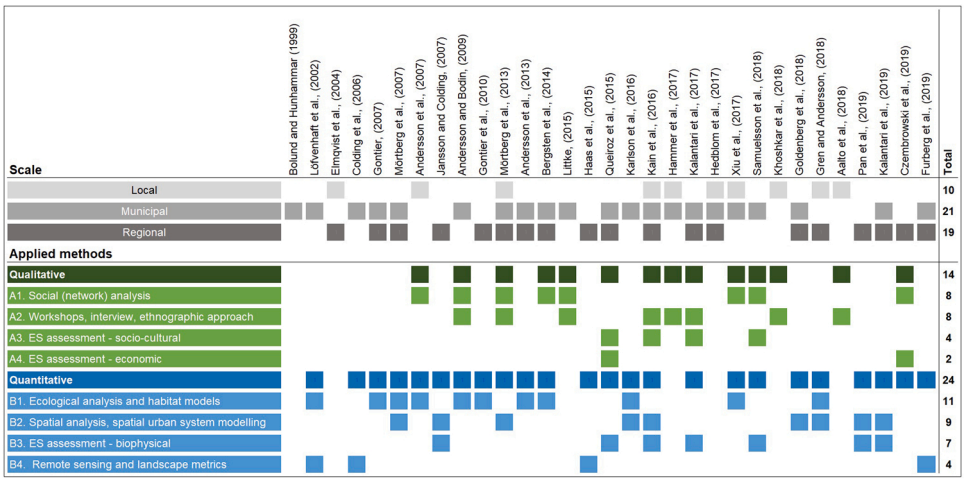

Fig. 8. Overview of the spatial scales and qualitative and quantitative methods applied in the analysed sample of articles (a brief description of the methods is reported in Table A2 6 in the Supp. Material).

the methods applied in the sample of 31 articles is provided in the Supp. Material, Section 3.

Only four case studies can be considered as integrated into planning processes: Löfvenhaft et al. (2002) focused on biotope patterns in urban areas, Hedblom et al. (2017) dealt with flexible land use and undefined governance in peri-urban landscape planning, Aalto et al. (2018) reported on co-producing knowledge through design in the Albano Resilient Campus Project in Stockholm, and Littke (2015) applied ethnographic approaches to exam the development of the Green Walkable City Programme in Stockholm. Most of the articles provided support (**14**) or general recommendations (**11**) to often hypothetical planning processes. Finally, in two cases, we could not find direct links to planning.

In about half of the papers (**14** out of 31), no other actors are involved besides the researchers themselves. In **15** cases studies, *Practitioners/Decision-makers* were engaged while **12** other articles considered stakeholders including local interest groups, NGOs, and residents responding to a PPGIS survey. For example, Löfvenhaft et al. (2002) report of a long-term collaboration-project between the City Planning Administration and the Department of Physical Geography, Stockholm University, which resulted in joint scientific publications as well as a digital biotope database produced for Stockholm City, with a scale of 1:10 000, used in the comprehensive planning to target ecologically important and environmentally sensitive areas. In **10** articles, both practitioners/decision-makers and other stakeholders were jointly involved.

The articles in our sample report different evidence concerning the effectiveness of greening interventions in the case studies. In **6** articles, the evidence provided was classified as *Measured* – either through quantitative, e.g. survey of species, or qualitative methods, e.g. interviews and PPGIS survey; in **13** articles, the evidence was *Simulated*; and in **5**, the evidence was supported by the literature or expert opinions of the authors. Six articles reported both measured and simulated evidence of the effectiveness of the implemented or existing greening interventions in the case study. An example is the publication by Andersson et al. (2007) in which surveys of local species diversity and abundance of pollinators, seed dispersers and insectivores were combined with a study of local management practices and their underlying social mechanisms – i.e. institutions, local ecological knowledge and sense of place. In this case, the measured evidence is provided by a '*higher abundance of pollinators in the informally managed allotment gardens and differences in the composition of seed dispersers and insectivores*' and by the finding that '*Allotment gardeners seem to be the most motivated managers: deeper knowledge and sense of place*'. In terms of trends, the number of articles providing simulated evidence has steadily been increasing since 2006, and in 2014, surpassed the articles providing measured evidence.

Fig. 9 illustrates how different urban greening concepts have been operationalised to support planning in Stockholm. It shows that the concepts are linked to the application of various methods, with different levels of integration into real-life planning processes, and involvement of related actors. It is evident that studies within the biodiversity category only use quantitative methods, whereas ecosystem services–related studies rely on both quantitative and qualitative methods, sometimes in combination. Both qualitative and quantitative methods supported the studies integrated in real-life planning processes, while quantitative methods were always present in articles aimed at planning support. Integrated studies also relied on the involvement of all categories of actors, or at least of decision-makers.

5. Discussion

5.1. Evolution and uptake of greening concepts in Swedish spatial planning

The 574 scientific articles show a clear temporal pattern of evolution and uptake of the different concepts; biodiversity was the earliest and most common followed by ecosystem services and green infrastructure, while NBS was the least common (if we exclude 'green belts' and 'green wedges'). This is perhaps unsurprising given that the application of greening concepts also came in response to European and international policy discourses around sustainability. In this vein, studies show that the uptake and integration of sustainability issues - including greening concepts - in local policy and research agendas has been strategically important for Sweden in general and the city and region of Stockholm in particular. By doing so, policymakers have aspired to build Swedish know-how and expertise with regard to sustainable urban development, making Sweden a frontrunner and consolidating Swedish companies (Hult, 2015; Ranhagen, 2013; UR, October 2016). Our results further show the close link between policy and science discourses and how policies inform the Swedish research agenda.

In particular, scientific publications on the concept of biodiversity began to appear following the 1992 implementation of Council Directive 92/43/EEC on the conservation of natural habitats and wild fauna and flora. The number of publications gradually grew around the year 1998, when the Directive was consolidated by the 1998 Biodiversity Strategy (e.g. Baker, 2003). Ecosystem services became a popular concept when it was linked to the policy discourse around the Millennium Ecosystem Assessment (MEA) that was launched and called for by the United Nations in 2001, and even more so after the publication of the first report of

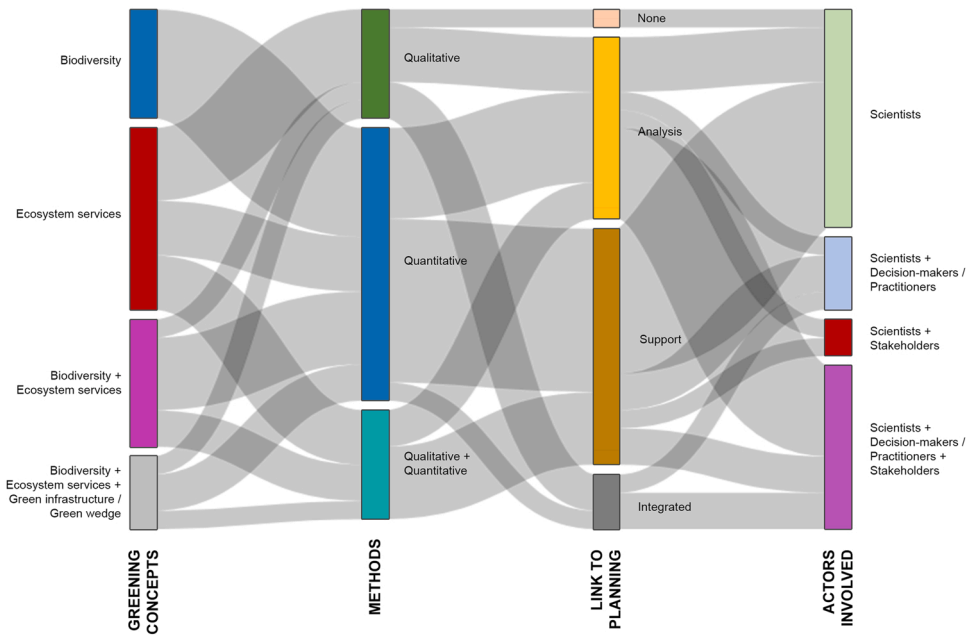

Fig. 9. Frequency of the combinations of applied methods, levels of integration in planning, and types of actors involved with respect to different urban greening concepts, among the reviewed empirical applications in Stockholm.

'The Economics of Ecosystems and Biodiversity' (TEEB, 2010). Our results also reveal that scientific work on ecosystem services has intensified since the publication of the MEA in 2005. Similarly, scientific publications on green infrastructure emerged around 2003 but grew rapidly around 2012, a trend that can be linked to the Commission's adoption of a Europe-wide strategy promoting green infrastructure investments in May 2013 (European Commission, 2013).

Regarding NBS, its uptake in the analysed scientific works only became visible around 2015 (Figs. 2 and 3). In fact, the concept of NBS was first introduced in the late 2000 s in the context of addressing the impacts of climate change, yet the application of the concept lacked consistent policy support (Davis et al., 2017, p. 42). The use of the concept, particularly in scientific research, has gained momentum since 2015 when it was adopted and strengthened by the European Commission as a tool to support the green economy (Davis et al., 2017). Overall, these linkages show how the research agenda is informed by policy initiatives. However, even if the term NBS was not used earlier, the general idea of working with nature rather than against it might still be reflected in some of the planning recommendations and actions undertaken before. The Office of Regional Planning and Urban Transportation (ORPUT) offers early examples of holistic planning of green areas in the Metropolitan Region of Stockholm in 1985, 1989, 1992 and 1996 with the shaping of the Stockholm green belt, green wedges and green structure, as well as their integration into main planning contexts. They addressed biodiversity and what is today called regulating and cultural ecosystem services, including the attractiveness of the urban landscapes (ORPUT, 2008).

The pattern of uptake of different greening concepts in Sweden (see Figs. 2 and 3) illustrates how greening interventions in spatial planning have developed, contributing to a growing scientific understanding of the impact – and dependence – of cities on ecological systems. There has been a shift from focusing solely on biodiversity, to recognising and mapping different components for assessing ecosystem services (Andersson, 2021), to undertaking a broader systematic approach that links green infrastructure with ecosystem services, including biodiversity, nature connectedness and multiple societal ancillaries (European Commission, 2013). The latest concept of NBS was conceived as a more comprehensive term than previously used greening terms and an umbrella concept of ecosystem-based approaches to address most, if not all, current societal challenges (Davis et al., 2017; Ramírez-Agudelo et al., 2020).

However, the evolution of concepts that enhance our holistic understanding of urban socio-ecological systems does not necessarily mean that integrating these concepts into sustainable urban development planning has become more feasible. As noted by Andersson (2021), diverse preconditions and processes are needed to integrate these concepts that have to be supported by appropriate policies that define clear measures and tools, among others. Also highlighted by Davis et al. (2017), the introduction of newer and often more complex concepts of urban greening can be practically distracting and confusing. Citing Swedish practitioners, Davis et al. (2017) described this issue with regard to NBS. Although Swedish national agencies have already widely adopted the concept of NBS implicitly, the term NBS is not used by Swedish practitioners as such. Instead, green infrastructure and ecosystem services are more commonly applied, particularly since 2014. This is to avoid the introduction of NBS as yet another new concept that could lead to additional burden, stress and confusion for municipalities (Davis et al., 2017, p. 29).

Our smaller sample of selected articles applying greening concepts in Stockholm also reflects that ecosystem services and biodiversity are the dominant concepts, while green infrastructure is used in only three articles and NBS in one article. This finding could partly be affected by our selection of search keywords, which did not include other concepts potentially related to greening interventions, for example in the context of sustainable urban drainage systems such as Best Management Practices (Stahre, 2002) and locally managed stormwater (Stormwater strategy 2015 as cited in (Suleiman et al., 2020a). It is thus likely that we missed important insights into greening interventions in Sweden and Stockholm (e.g. Suleiman et al., 2020a, 2020b). In addition, by several national and regional plans explicitly promote ecosystem services and green infrastructure, which may not be necessarily evident from the scientific literature (see Box 1 in the SM). More in general, the key findings of this paper could be further expanded by analysing the extent to which planning regulations motivate and support the uptake and integration of a broader set of greening concepts and interventions in planning practices. In this sense, a grey literature review, interviews with relevant practitioners and analyses of planning regulations constitute an untapped resource. Combining the two methods would

plausibly provide coherent scientific evidence, but this goes beyond the scope of this paper.

5.2. Relations between societal challenges and greening interventions in Stockholm

In Stockholm, the adoption of greening concepts has taken place primarily to address the socio-environmental challenges and constraints of increasing urbanisation and population growth, or to counteract the already negative impacts of urbanisation. Green space management interventions in the latter group are generally driven by the goals of improving the connectivity of fragmented areas, promoting biodiversity and restoring or maintaining the provision of ecosystem services, and regenerating urban areas and the built environment to improve their environmental conditions. The general emphasis on concepts relating to biodiversity, and ecosystems connectivity can be explained by a long tradition of nature-conservation in Sweden, with increasing focus on species and habitats (Borgström et al., 2013). While outdoor recreation was targeted early in nature conservation, especially in urban regions (Borgström et al., 2013), only more recently a wider range of societal challenges has gained increased attention in the nature conservation discourse. The uptake of biodiversity can also be related to the fact that both the largest universities in the region have long-term strategic partnerships with Stockholm City and Region Stockholm, including policy support, trans-disciplinary research and staff mobility. Such policy support has driven several of the co-creation projects mentioned earlier (e.g. Bergsten and Zetterberg, 2013; Högström et al., 2021; Karlsson and Bodin, 2022; Löfvenhaft et al., 2002; Mörtberg et al., 2012). Strategic partnerships are also in place in other metropolitan regions of Sweden, such as Göteborg and Malmö. Similar policy support may also explain the later broad but disparate uptake of ecosystem services in planning, not least in metropolitan regions (e.g. Khoshkar et al., 2020b; Sang et al., 2021).

Many articles also deal with participatory planning and governance, but it is unclear whether this is considered a societal challenge that drives the greening projects or a challenge that is addressed by the planning and implementation of these projects. Greening projects to address climate change are of lesser importance in the reviewed studies. It has also been noted that urban greening projects are rarely driven by improving social justice and cohesion, but are more often driven by economic objectives such as improving economic opportunities and creating jobs, for example in the forestry sector. Perhaps, the low relevance of climate change can partly be attributed to our search keywords, which missed articles related to NBS that deal with climate change and sustainable urban water management, among other topics. In this regard, it is worth mentioning how the regional plan for Stockholm, RUFS 2050, highlights the importance of innovations, green and blue infrastructure and circular and blue-green cycles (Region Stockholm, 2018).

In general, articles on ecosystem services seem to be linked to a wider range of societal challenges, while articles referring to the concept of biodiversity link less often, if ever, to challenges related to urbanisation impacts and the built environment (e.g. urban regeneration, climate change mitigation and adaptation, water management, and air quality). In addition, allotment gardens, private gardens, and external building greens are types of green elements never mentioned by articles adopting exclusively the concept of biodiversity. Most of the articles that address blue areas, including wetlands, and infrastructure with green features link them to ecosystem services rather than biodiversity. Overall, this suggests a progressive widening of the range of greening intervention considered, in parallel to an expansion of the societal challenges addressed.

5.3. Methods to operationalise greening concepts and evidence to support planning

The prevailing focus on the municipal level reflects the key role that municipalities have in the Swedish planning system. On the other hand, almost as many articles addressed the regional scale, which can be linked to the different initiatives for regional green infrastructure integrated in the Regional Development Plan – RUFS 2050. This is consistent with a view of the regional scale as the most appropriate to integrate ecosystem services knowledge in spatial planning (Longato et al., 2021), as well as with a traditional aspiration of connectivity and fragmentation analyses to overcome local administrative boundaries. In our sample, studies that focus on the regional scale have primarily used biodiversity as a greening concept. As discussed above, significant greening interventions in Stockholm have aimed to address environmental challenges concerning urbanisation and improve the connectivity of fragmented areas, restore or/and maintain ecosystem services and enhance biodiversity. The limited coverage of local or neighbourhood-scale case study applications can partly be attributed to the lack of scientific articles in our sample that deal with greening interventions aimed at naturally managing stormwater, reducing the risk of floods and improving water quality (Adem Esmail and Suleiman, 2020; Allen, 2012). However, it also reflects the progressive inclusion of different types of green and blue elements as the focus of the studies. Small-scale green and blue elements such as those connected to grey infrastructures and building greens only started to be considered in the most recent years, when the concept of ecosystem services contributed to reveal their role for human wellbeing. Planning tools such as the Green Area Factor, applied in the City of Stockholm and the two other biggest cities in Sweden, already address this scale. The Green Area Factor is adopted for development districts and is used during land allocation within the municipality, to set a threshold of green areas over the total area of the property (Wikström, 2020). Its application targets and combines biodiversity, cultural ecosystem services, local climate regulation and stormwater management, using both green and blue areas (City of Stockholm, 2021; Wikström, 2020).

Articles that simultaneously address three spatial scales are few, but the studies that focus on two or three spatial scales of analysis have notably increased since 2013. This may be explained by the growing understanding of greening concepts and their operationalisation in urban planning. As highlighted by Allen (2012), among others, best practices in green infrastructure planning attempt to link and coordinate planning and implementation across various spatial scales that make sense in terms of both their benefits and economics. This progressive broadening of the scales and types of green and blue elements included in the study coincides with a widening of the methods applied. All articles focusing only on biodiversity applied only quantitative methods, while articles that (also) consider ecosystem services and other concepts used both qualitative or quantitative methods. This could imply that they refer to a wider spectrum of benefits, some of which are perhaps more challenging to quantify. For example, topics such as mental restoration or social cohesion may allow for quantitative indicators to be developed, but the issues are inherently qualitative.

Taken together, the results suggest that - despite decades of advocating for greening concepts in planning in Stockholm - the spatial planning literature is contributing to their integration only to some extent, and mostly indirectly. This aligns with previous research concluding that forms of integrated planning towards the uptake of greening interventions have been rather slow and characterised by institutional lock-ins (Andersson, 2021; Cettner et al., 2014; Suleiman, 2021). In our sample, only a few articles link these concepts to actual planning processes. Most of the articles focus on greening concepts to either support or inform hypothetical planning processes. By relating these findings with our discussion on greening concepts used in planning, we can argue that there is a discrepancy between the one-time effort to produce research outcomes and the more long-term process of their uptake in real-life planning (e.g. Ruckelshaus et al., 2015). In addition, as discussed above, EU and international policy discourses inform and influence the Swedish research agenda, but, as shown in our sample, research outcomes do not seem to influence the integration of

greening interventions in actual planning processes. This finding is not specific to this study; Longato et al. (2021) found that conceptual and methodological studies made up the majority of articles applying ecosystem services to spatial planning issues, while only a small number of publications addressed the actual integration of ecosystem services in spatial planning processes. In a similar vein, Andersson (2021) warned against a 'superficial' mainstreaming of greening concepts in policy, highlighting diverse preconditions and processes needed for fully integrating urban ecosystems into (sustainable) urban development planning and practice. In this regard, our study reemphasises the non-linear relationships between scientific research, policy and decision-making, whereby scholarly insights are and necessarily need to be an important, but not the only, source of reasoning in democratic societies. Moreover, revealing the difficulties of tracking the influence of scientific research results on actual decision-making, further research calls to examine the uptake of greening concepts in other leading metropolitan regions in Europe and beyond, to assess the extent to which the results for Stockholm are transferable. A comparative investigation could shed light on how new concepts (often promoted by supranational political discourses) and methods migrate into planning practice and vice versa.

With regard to NBS as the latest greening concept discussed, it seems too early to gather evidence of its use in applied research in the Stockholm region. However, some opportunities emerge when considering the overall development of greening concepts. First, NBS can continue the trend initiated by the ecosystem services framework and contribute to raising awareness of the benefits of greening interventions, especially considering socioeconomic issues such as social justice, social cohesion, economic opportunities and green jobs (Babí Almenar et al., 2021; Raymond et al., 2017). This should reflect a wider range of societal challenges linked to greening interventions and be accompanied by a parallel broadening of the methods adopted to analyse their impacts (including both quantitative and qualitative methods) while helping to include a plurality of perspectives (Jacobs et al., 2016). Again, the concept of NBS can embrace a wider range of greening interventions at multiple scales, a goal that the concept of green infrastructure has never achieved as it has mainly been considered, at least in practice, at a regional scale. The ecosystem services lens has revealed that also small-scale green and blue elements provide important benefits and can contribute to address multiple societal challenges. This constitutes an important ground for defining and identifying NBS. At the same time, there are challenges in seizing these opportunities in the transition to NBS. The risks include, among others, losing focus on biodiversity and ecological functionality (including connectivity) and eventually disregarding valuable practical experience previously gained by applying planning-related concepts such as green belts and green wedges. Science plays a key role in ensuring that the uptake of the new concepts, so strongly promoted by international policies, builds upon and expands existing experiences with previously used concepts to enable continuous learning towards sustainable transformations in city regions.

6. Conclusion

In this paper, we performed a systematic review of case studies published in the scientific literature. We identified 574 articles that reflect substantial research on greening concepts in the Swedish planning context, with initial attention on biodiversity-related issues, later with a stronger focus also on ecosystem services and more recently NBS. From a detailed analysis of studies focused on applications in the Metropolitan Region of Stockholm, *Population growth/densification*, *Greenspace management*, and *Biodiversity conservation* emerged as the societal challenges most commonly addressed. The most common type of green and blue elements is *Parks and (semi)natural urban green areas, including urban forest*, followed by *Blue areas,* and *Urban green areas connected to grey infrastructure*. Most of the considered articles applied quantitative methods, almost half used qualitative methods, and one in three combined qualitative and quantitative methods. Evidence regarding the effectiveness of greening interventions in the case studies is often measured, but most frequently simulated. Overall, this study underlines the interdependencies and temporal links in the evolution of greening concepts in policy discourse and their adoption in scientific publications focusing on spatial planning practices.

Some recommendations for practice emerge. First, planners in Stockholm should draw on both the wide range of insights already available and the established community of research and practice around greening concepts. Making this scientific knowledge useful will still require translation and boundary management - a task in which scientific communities can play a decisive role. Second, the currently emerging narratives that frame the conservation and sustainable use of biodiversity and ecosystem services as contributions to human well-being and as "solutions" to societal challenges provide many opportunities for mainstreaming and upscaling of ideas and actions. For example, the concepts allow for communicating restoration projects not simply as actions to preserve a few species, but rather emphasising the substantial co-benefits such actions can produce for climate change adaptation, flood risk reduction, and improved recreational opportunities. These multiple benefits of urban green and blues spaces will be increasingly important to support and communicate, considering the constant pressure for urban densification and expansion in the Metropolitan Region of Stockholm. Third, our analysis showed the wide variety of methods and data already available to operationalise different greening concepts, including to monitor changes in biodiversity and ecosystem services. There are great opportunities for adapting these methods for planning applications and integrating them into decision support systems to better understand the status and trends of ecosystems and their services in Stockholm, and to inform studies of future development pathways and their likely impacts on people and nature.

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CRediT authorship contribution statement

Blal Adem Esmail: Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing, Visualization. **Chiara Cortinovis:** Conceptualization, Methodology, Investigation, Writing – review & editing, Visualization. **Lina Suleiman**: Conceptualization, Methodology, Investigation, Writing – review & editing. **Christian Albert**: Conceptualization, Writing – review & editing. **Davide Geneletti**: Conceptualization, Writing – review & editing. **Ulla Mörtberg**: Conceptualization, Writing – review & editing.

Declaration of Competing Interest

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

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ufug.2022.127584.

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