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Enhancing Resilience Of Urban Ecosystems through Green Infrastructure (EnRoute)

Final Report

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Summary

EnRoute: Enhancing Resilience Of Urban Ecosystems through Green Infrastructure.

Urban Green Infrastructure (UGI) refers to the strategically managed network of urban green spaces and natural and semi-natural ecosystems situated within the boundary of an urban ecosystem. These high-quality, biodiversity-rich areas can help make cities more sustainable and contribute to solve many challenges, such as air pollution, noise, climate change impacts, heat waves, floods and public health concerns. As cities grow and develop, it is vital to improve the availability, quality and accessibility of UGI. Urban planners and decision-makers across Europe are increasingly seeking to integrate UGI, ecosystem services and nature-based solutions into their urban planning processes, but these efforts must be scaled-up further if we are to create more resilient, sustainable and 'livable' cities for future generations.

This report summarizes the main outcomes of the EnRoute project. This science-policy project, managed by the European Commission and funded by the European Parliament, involved 18 'city labs' across Europe. The project provided knowledge on how UGI can support urban policy-objectives at different stages of the planning process and at a variety of spatial scales.

EnRoute city labs: collaborations between science and policy to address urban challenges.

EnRoute demonstrated how the EU Biodiversity and Green Infrastructure policies and actions are being implemented in real-life case studies and policy-making processes at a local scale. At its core, the project is comprised of 18 'city labs' distributed across Europe: Antwerp, Dublin, Glasgow, Helsinki-Espoo-Vantaa, Karlovo, Leipzig, Limassol, Lisbon, Manchester, Oslo, Padova, Poznan, Rome, Tallinn, The Hague, Trento, Utrecht, and Valletta. The city labs have investigated how, at a local level, science and policy interact in relation to UGI development. In the city labs, particular focus has been placed on mapping UGI and the associated benefits delivered through urban ecosystem services (as part of the MAES initiative - Mapping and Assessment of Ecosystems and their Services). Next the city labs investigated how these spatial assessments can support policy- and decision-making at a city-scale.

The main policy questions were how cities can grow while maintaining UGI and its biodiversity, how cities can improve quality of life and public health through UGI, and how cities could include UGI in sustainable strategic urban planning climate adaptation.

The outcomes of applying the framework were reasonably successful. Almost all city labs achieved in mapping and assessing UGI and ecosystem services even when only limited resources were available. All city labs have been able to enter the policy process in one way or another. The city labs agreed that a detailed mapping of UGI at local level is a key product for informed decision-making. Demonstrating the benefits of urban green infrastructure requires linking ecosystem data with socio-economic statistics.

Urban green infrastructure in the EU.

EnRoute also assessed the current availability and condition of UGI and the benefits it delivers in almost 700 of Europe's functional urban areas (FUA) and core cities. The indicators used to assess UGI incorporate a variety of data and metrics: anthropogenic pressures, pollution levels, soil sealing, the amount and configuration of UGI, urban biodiversity, recreation opportunities and flood mitigation. The assessment revealed that core cities in Europe are for about 40%, on average, covered with UGI. The amount of publicly accessible green space (urban parks) is, however, much lower and estimated at 2.45%, on average. Urban dwellers in Europe have, on average, 18 m^2 publicly accessible urban green space to their availability which is double the standard recommended by the Word Health Organisation. However, the availability of public green space is unevenly distributed across Europe, with values that are much lower for southern and eastern European countries. Less than half of citizens live within a short walk (300 m) of a public park. On average, only 7 % of Europe's functional urban area consists of areas with high recreation potential (for instance green areas with trees, meadows, forest or open water) and high availability of facilities which support recreation such as playgrounds or cycling paths.46% of the FUA area, on average, has a low capacity to mitigate floods which demonstrates that flooding risk is an increasingly important concern of cities. The strategic implementation of UGI will be an essential nature-based solution to address this challenge.

The evidence reported in this study, as well as the tools developed to assess where and what share of the population has access to green infrastructure, represent an initial baseline against which the impacts of further action can be assessed. It also paves the way for future actions aimed at improving the quality and quantity of urban green infrastructure in an inclusive way.

What factors define a successful science-policy interface on urban green infrastructure?

An online survey on science policy interface (SPI) aimed at better understanding the factors that contribute to or determine whether or not an SPI on urban green infrastructure is functional and successful. The main obstacles to an operational SPI on UGI were found to be firstly, the lack of opportunities to establish professional contacts between scientists or policymakers and secondly, difficulties in communication. Addressing these challenges is possible but requires efforts from both sides. Enhancing opportunities to bring scientists and policymakers in contact was exactly an objective of EnRoute. In addition, it requires better communication: from scientists to make their science comprehensible to policymakers and from policymakers to enlighten scientists about the different steps in the policy process that requires specific scientific data, results or inputs. Once these challenges are overcome, the survey results painted a rather positive picture of science policy of urban green infrastructure: both scientists and policymakers acknowledge that scientific evidence finds its way to the policy making process and is included in policy outputs and deliverables. Moreover, contacts between scientists and policymakers, once established in the frame of a project, last also after the project. The key message to a successful SPI on UGI is therefore to seize the opportunity to establish a personal contact as soon as possible in the process and to maintain this contact throughout the entire project.

EnRoute is relevant for multiple policies.

EnRoute has first and foremost been a project about cities and for cities. It has demonstrated, through the 18 city labs, that a highly detailed map of UGI is a key piece of evidence that supports informed urban decision- and policy-making and urban planning.

As advocated by the EU Green Infrastructure Strategy, UGI should be integrated into a larger, strategically planned network linking urban and peri-urban ecosystems to the wider landscape, in order to deliver its full range of benefits. Better integration of the urban and regional planning of green infrastructure is necessary in order to strengthen the connectivity of the Natura 2000 network and take into account overlaps between functional urban areas and Natura 2000 sites. This need is recognized and addressed in the context of Action 12 of the Action Plan for Nature, People and the Economy, which aims to provide guidance to support the deployment of EU-level green infrastructure for better connectivity of Natura 2000 areas.

The co-development of knowledge and evidence on urban green infrastructure, generated through collaborative characterisation of the science-policy interface, is also highly relevant for other policies and for overarching policy ambitions. In particular, EnRoute has supported the EU Urban Agenda and can contribute to measuring progress on the urban targets under the Sustainable Development Goals (SDG 11).

More information.

More information about EnRoute and the outputs of the project are available on OPPLA: Link: https://oppla.eu/enroute

1 Introduction

The world is rapidly urbanizing. More people live in cities than ever before and this number will grow. All these citizens need an inclusive, healthy, resilient, safe and sustainable living environment. Urban Green Infrastructure (UGI) is a concept which helps address these needs. Green Infrastructure (GI) is defined as a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates (urban) green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas. On land, GI is present in rural and urban settings (European Commission 2013). UGI refers to the strategically managed network of urban, biodiversity-rich, green spaces and natural and semi-natural ecosystems situated within the boundary of an urban ecosystem (see box 1 for key terminology). UGI is multifunctional: it enhances biodiversity in cities and delivers essential ecosystem services. Through ecosystem services, UGI provides benefits to people such as clean air, protection from flooding, a cooler city during summer or spaces to recreate, pick nick or simply to enjoy nature in the city.

Cities depend on UGI and their associated ecosystem services. Cities face several kinds of environmental, social or economic problems; enhancing green infrastructure can be a key strategy for cities to become more attractive and provide healthier living environments. So how to mainstream UGI and ecosystem services in urban decision making and planning is a key question that is addressed in this report. This study is a synthesis of EnRoute, a research project funded by the European Parliament and managed by the European Commission. EnRoute is a project acronym for "Enhancing Resilience of Urban Ecosystems through Green Infrastructure". EnRoute provides knowledge on how urban green infrastructure can support urban policy objectives at different stages of planning and for various spatial scales. High-quality, biodiversity-rich, green areas can help policy-making for sustainable cities and contribute to resolving many challenges from air pollution and noise to tackling climate change, heat waves, floods and public health concerns. As cities grow, there is a need to improve the availability, quality and accessibility of urban green spaces. Urban planners across Europe are progressively integrating urban green infrastructure, ecosystem services and nature-based solutions in their urban planning process; but these efforts have to be scaled up.

Above all, EnRoute demonstrates how the EU Biodiversity Strategy to 2020 and the Green Infrastructure Strategy have been implemented in real-life case studies and policy-making processes at the local scale. The heart of the project is formed by 18 city labs distributed across Europe. The city labs represent European city administrations which have been working in partnership with scientific institutions to implement the EnRoute project. They tested at local level how science and policy interact on urban green infrastructure development.

This test is of special importance for Actions 5 and 6 under the EU Biodiversity Strategy on Mapping and Assessment of Ecosystems and their Services (MAES) and on green infrastructure. EnRoute is also considered as a test case of a pilot under MAES. The MAES initiative provides guidance to EU Member States on developing a knowledge base on ecosystems for use in different policies that impact our natural capital and natural resources.

Between March 2015 and March 2016, the working group on Mapping and Assessment of Ecosystems and their Services (MAES) carried out a pilot study on urban ecosystems. This urban pilot was a collaboration between the European Commission, the European Environment Agency, the Portuguese Directorate-General for Territory, the Dutch Presidency of the EU and 10 cities in Europe. The MAES knowledge base, as framed in the 4th MAES Report developed two main points: (1) a community of practice on enhancement of urban green infrastructure, and (2) an indicator framework on mapping green infrastructure, ecosystems and ecosystems services in urban areas.

1.1 Objectives of EnRoute

EnRoute aims at building further on the many positive experiences of the MAES urban pilot study. The objectives of EnRoute can be summarized as follows.

(1) Implementing and testing the urban MAES framework and operationalising the MAES knowledge base on urban ecosystems with a view to implementing the EU Green Infrastructure Strategy with applications and case studies at local scale and at European scale.

(2) Understanding how scientists and policymakers can successfully work together on urban green infrastructure

(3) Improving networking and flows of knowledge and information

The first objective was largely achieved by setting up 18 case studies across Europe, also called city labs, where a team of a policymaker and a scientist commonly experienced how mapping and assessment of urban green space and ecosystem services can address specific policy questions or challenges. The second objective involved the development of a questionnaire and interviews to survey policymakers and scientists of how they collaborate on urban green infrastructure. The last objective involved enhancing contacts between communities of practice at local, regional and national level in order to exchange experiences and knowledge on mapping, assessment, valuation and implementation of urban green infrastructure, urban biodiversity and urban ecosystem services. This was particularly achieved through organizing events in line with the development of the EU Urban Agenda and with the specific priorities of the EU Presidencies in 2017 and 2018.

1.2 Policy relevance

The co-development of knowledge and evidence on urban green infrastructure through collaboration on the science-policy interface is also relevant for other policies or for overarching policy ambitions. In particular we make reference to the EU Urban Agenda and the Sustainable Development Goals.

The Urban Agenda for the EU was launched in May 2016 with the Pact of Amsterdam. It represents a new multi-level working method promoting cooperation between Member States, cities, the European Commission and other stakeholders in order to stimulate growth, liveability and innovation in the cities of Europe and to identify and successfully tackle social challenges. Under the EU Urban Agenda there is a special partnership on sustainable land use and nature-based solutions. EnRoute provided input into this partnership. A final action plan of this partnership will become available during 2019. An important input to this partnership is also delivered by the Horizon 2020 program on nature-based solutions which is testing and applying a nature-based approach to urban challenges in cities across Europe.

Sustainable urbanization is also addressed by the sustainable development goals. SDG 11 includes seven specific targets aiming at making cities and communities better places to live. One important target is to provide universal access to safe, inclusive and accessible, green and public spaces by 2030. This particular target is analysed in more depth in our report.

Box 1. What are urban ecosystems and what is urban green infrastructure?

Urban Ecosystems are cities, socio-ecological systems where most people live. Just as other ecosystems, they are characterised by the interactions of energy, matter or information between and within their functional components. Urban ecosystems consist of green infrastructure and built infrastructure. In this report green infrastructure refers to both green and blue infrastructure; built infrastructure is preferred as term over grey (or other coloured) infrastructure.

Urban Built Infrastructure includes houses, buildings, roads, bridges, industrial and commercial complexes but also brown fields, dumping or construction sites. Urban built infrastructure refers to the share of built infrastructure inside cities or urban ecosystems.

Urban Green Infrastructure (UGI) is the strategically managed network of urban green spaces and natural and semi-natural ecosystems situated within the boundary of the urban ecosystem. Biodiversity is a key component of UGI. Wetlands, rivers and lakes, and marine ecosystems are sometimes referred to as blue infrastructure, but for simplicity the term green infrastructure is used for all urban green spaces as well as for those parts of other ecosystem types which are situated within the boundary of the urban ecosystem. Urban green spaces are defined as spaces that are partly or completely covered with vegetation.

The definition of UGI used in this report is well aligned with the definition adopted by the Green Infrastructure Strategy (first paragraph of the report) and with the terminology used in the 4th MAES report on urban ecosystems (Maes et al. 2016).

1.3 What is in this report?

This report is a synthesis of all the knowledge and material that has been produced under the project so far and provides already some key outcomes that still need to be reported in more depth.

Chapter 2 is a synthesis of the work delivered by the 18 city labs of EnRoute and it constitutes an essential outcome of the project. Every city lab has adopted a similar approach to addressing a policy questions or challenge. This approach and the outcomes are well documented in city lab reports and they will be published on Oppla, a collaborative platform on ecosystem services and nature-based solutions.

Chapter 3 reports the EU wide assessment of urban ecosystems and their services and is an application of the MAES approach at EU scale. Again, chapter 3 is a synthesis of the most important outcomes so far but it also contains results which need further elaboration under the planned EU wide ecosystem assessment that will support the final evaluation of the EU Biodiversity Strategy and that will deliver during 2019 and 2020.

Chapter 4 summarizes the outcomes of an on-line survey on science policy interface on urban green infrastructure.

Chapter 5 describes the options for networking and developing a community of practise.

Chapter 6 contains the essential conclusions and messages of EnRoute.

During its 2-year term, EnRoute produced a lot of other materials and reports that can be consulted as well. All this information is available on the EnRoute site of Oppla: https://oppla.eu/enroute. Oppla served as a working and communication platform for EnRoute. It contains an EnRoute Inception Report and a Progress Report as well as the reports of three meetings that were held under the rotating presidencies of the EU in Malta, Latvia and Bulgaria.

2 EnRoute city labs: Mapping and assessment of urban green infrastructure and ecosystem services in cities to support urban policy and planning

2.1 Introduction

EnRoute has been testing in 18 case studies or city labs how the MAES framework on Mapping and Assessment of Ecosystems and their Services can be used in urban areas and cities in order to support urban policy and planning. Particular focus went to mapping urban green infrastructure and the associated benefits delivered through urban ecosystem services.

This chapter synthesizes the most important outcomes from the case studies by describing the working approach, summarizing the key results per city lab and presenting a set of conclusions and lessons learned.

2.2 The city labs: the core of the EnRoute project

Eighteen city labs (Figure 2.1) were created to test the applicability of the MAES indicator framework for urban ecosystems (Maes et al. 2016). City labs consisted of a researcher and a policymaker or city stakeholder. The EnRoute researchers had thematic expertise in environment, biodiversity, ecosystems and ecosystem services whereas the city stakeholder was typically a policy officer or civil servant in the city's administration responsible for green infrastructure, biodiversity, or sustainable development.

All city labs were asked to follow a similar approach to test the usefulness of the MAES indicator framework for local policy applications:

1. Formulate one or more specific policy questions or challenges related to the use, functions, or impacts of urban green infrastructure;
2. Make an analysis of the kind of ecosystem condition or ecosystem service indicators necessary to address these questions; which key knowledge systems, indicators, and data are available for addressing this question;
3. Map and assess the indicators; what are the key results;
4. Analyse the outcomes, the policy relevance and the limitations of the approach; how can mapping and assessment outcomes be used in policymaking or implementation?

During the first year of the project the city labs, together with the JRC, established the relevant local needs or policy goals and the type of indicators useful for local authorities that will be mapped during the second year.

The city labs presented their policy context and how they will contribute to EnRoute during two poster sessions, held in Rome (6-7-8 March 2017) and Tallinn (24-25 October 2017). In between there was an opportunity to discuss the progress of the work in the context of an EnRoute conference in Malta (13 -14 June 2017). During a special EnRoute workshop in Sofia on 25 April 2018, linked to a conference on urban biodiversity the day before, all city labs presented their progress, contributed to a synthesis of the results, and discussed what works and what not when using the MAES framework in a local context. At this meeting, the city labs agreed on common reporting structure to report the final outcomes.

The city labs were mutually supporting each other. The JRC was actively collaborating with several city labs on cultural ecosystem services and on pollination but city labs also shared methodologies to calculate certain indicators.

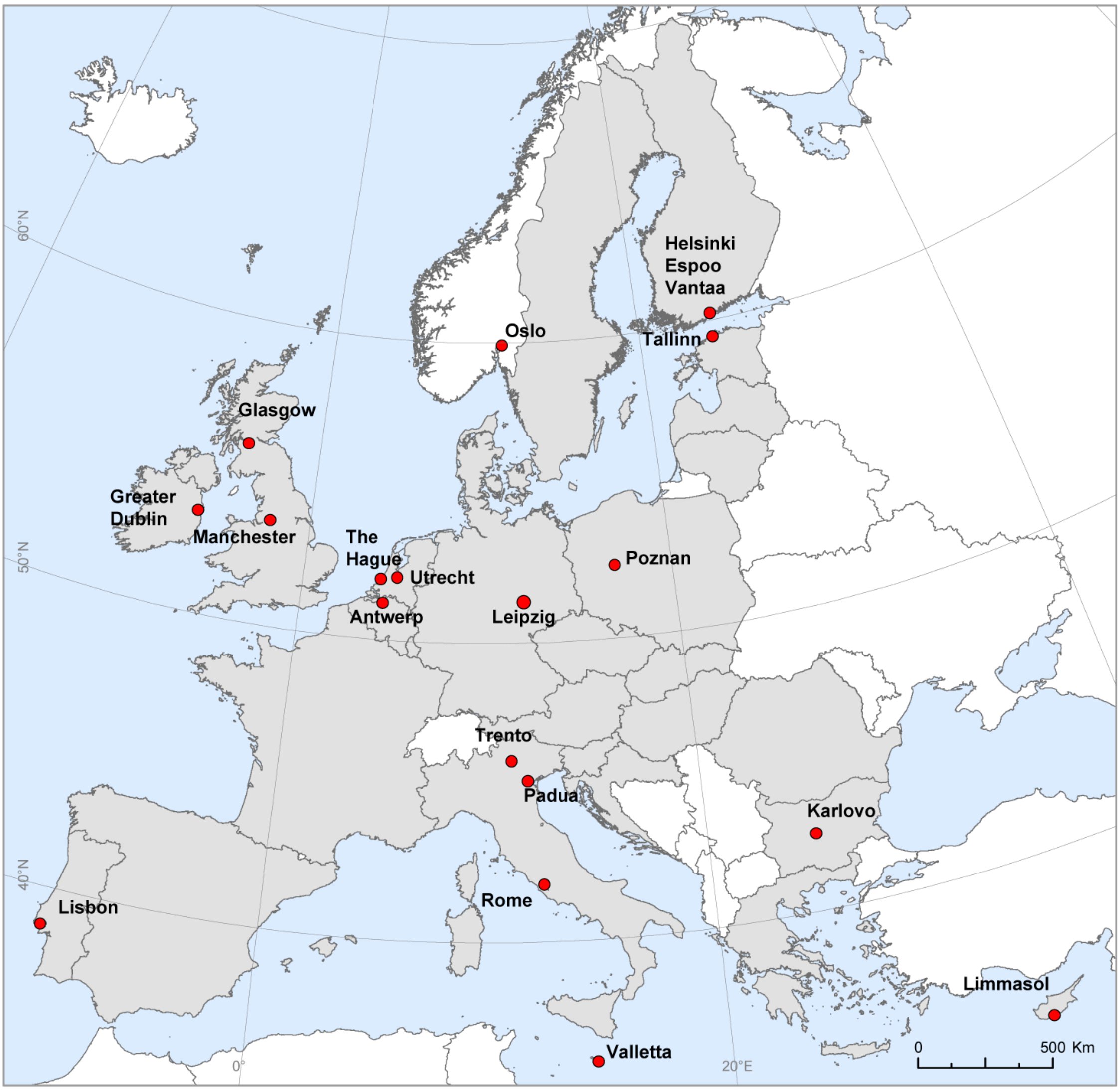


Figure 2.1. The EnRoute city labs

2.3 Results

2.3.1 Synthesis of city labs

This section contains a short summary per city lab. It describes the key policy challenge, the knowledge systems and tools used to address the challenge, the policy relevance of the work and possible limitations of the EnRoute approach. Key policy questions are printed in bold. All city lab reports are published on oppla.eu/enroute.

Antwerp

The city of Antwerp is a mix of a highly urbanized central area, with a clear shortage of available green space, some larger important conservation areas at the borders of the city, and an industrial harbour area. It has important environmental challenges such as flood risk, air pollution and heat stress. **A key question is how to develop a city master plan green and blue infrastructure based on multi-functional ambition levels, supported by related maps and indicators**. To this end, the city has commissioned the development of Greentool which maps at high resolution (10 m) urban green space and key ecosystem services. The tool is used to raise awareness among citizens about the role of the environment for human-wellbeing and in the preparation of plans. Yet, it is still challenging to integrate the knowledge present in the Greentool during the implementation phase of urban plans. Importantly, very high resolution of UGI and ecosystem service maps is needed to be relevant at city level.

Dublin

How a Green Infrastructure Strategy can inform a Regional Spatial and Economic Strategy for the Dublin City Region of Ireland. Mapping water ecosystem services was informative for policy design as it shows the potential of upstream wetlands and ecosystems. An ecosystem services approach can be an opportunity to enhance contacts among stakeholders. However, it remains difficult to integrate ES and concepts of urban green space in the implementation of policy and planning.

Glasgow

Climate change is expected to hit Glasgow with increased flooding during winter and more heat waves during summer. **So the question is how to integrate Green Infrastructure into the city's climate change adaptation plan ensuring a just transition?** This has been done by mapping urban green infrastructure, scoring ecosystem services in cooling and flood mitigation and by combining this with information about deprivation. Different layers of science-underpinned-evidence can be used by the city and by planners to ensure equal access to the services delivered by urban green infrastructure. Limitations are the data quality and uncertainty about the assessment resulting from assumptions made on the data.

Helsinki, Espoo and Vantaa

How to preserve biodiverse cities under the pressure of infill development? The Helsinki Metropolitan Area, comprising the cities of Helsinki, Espoo, Vantaa and Kauniainen, has about 19 % of Finland’s population in just 0.2 % of its surface area, thus the housing density of the area is high by Finnish standards. The current urban development policy in the area is to avoid urban sprawl and place new construction inside the dense urban structure. This infill development often takes place in green space and thus the challenge is how to place it in a way that does not critically harm biodiversity, the condition of ecosystems, ecosystem functioning and provision of ecosystem services. We tackled this challenge by investigating whether pollination maps could be used to prioritize small urban green areas and to safeguard the most important ones from the point of view of biodiversity and pollination service provision. Benefiting from pollinator researchers' expertise coupled with the city lab's local knowledge and data, a fine-scale pollination potential map was produced. Ground truthing of the map should be conducted by monitoring extensively both the abundance and composition of wild pollinators. In the face of diminishing resources, new ways of cost-efficient monitoring should be developed. In addition, more attention should be paid to planning and managing continuous flowering in urban areas using species favoured by different wild pollinators.

Karlovo

Growing cities depend on ecosystem services but to which extent? **Is the green infrastructure in Karlovo and in the region healthy enough to continue supplying ecosystem services so as to sustain agriculture, to mitigate impacts of climate change or to reduce disaster risks? What kind of knowledge is still needed for local authorities to anticipate and benefit from the concept of ecosystem services?** This case study mapped and assessed the condition of urban ecosystems and the multiple ecosystem services they provide at the local and regional scale and concluded that such knowledge acts as a basis to promote adaptive forms of evidence based management and governance of urban green space. Further increasing the thematic and spatial resolution of data is needed to enhance confidence in mapping approach.

Leipzig

Leipzig is one of Germany's greenest cities with an average of 254 m2 green space per inhabitant. Leipzig is also a fast growing city so **how can the city maintain or even enhance ecosystem services of green and blue infrastructure under the conditions of dynamic urban growth, land use pressure and recompaction?** To better understand where urban green infrastructure is under pressure, the Leipzig EnRoute city lab mapped at high resolution the presence of urban green space and combined it with detailed population statistics. The mapping exercise provided an indispensable building block for the Green Master Plan, which is currently being prepared. An important lesson is that mapping should be combined with in situ green space monitoring of, for example, vegetation biomass. This would add value to remote sensing data and improve the capacity to assess ecosystem services provided by urban green space such as carbon dioxide removal. In addition, data were only available for 2012. An account based on time series of land cover and land use would help city planners to better understand where urban green infrastructure is under pressure.

Limassol

Limassol is the second largest of Cyprus locates on its southern coast. The city is a mix of a highly urbanized central area, with a clear shortage of green spaces. The city has the ambition to increase the green spaces. To achieve this purpose, **a masterplan on greenways infrastructure was developed, focusing on the parks, squares, protected areas, walkways and roads.** The master plan includes large-scale protected areas and urban parks and small-scale urban parks, squares, walkways, bikeways such as green areas along the streets, walkways, and bikeways. Following this strategic plan, several local green plans at district level have been constructed and two linear parks are developed: one along the harbour area and one linear park along the River Garilis. Such a plan needs a detailed mapping approach of the different functions of urban green infrastructure. The city lab prepared a new land use map at 1m resolution as a combination of different layers. The next step is to integrate this information in local planning at district level.

Lisbon

In Europe, **Lisbon has positioned itself as city with a deep sense of responsibility to preserve and protect its biodiversity.** This is evident through the local biodiversity action plan which aims to increase biodiversity with 20% by 2020. The underpinning rationale is that a city with high levels of biodiversity has a good quality of the environment which in turn increases the quality of life for people. The EnRoute city lab has created the opportunity to establish a relation between biodiversity and ecosystem services and it allowed updating the Lisbon's Master Plan with specific information about the ecosystem services provided by green infrastructure. More and better data is expected to increase the acceptance of environmental challenges in the urban planning process.

Manchester

The Manchester city lab developed **a unique and inspiring, collaborative natural capital-approach designed to work with local communities and practitioners to enhance the value of nature in their local landscape, build community resilience, improve people's quality of life, enhance the local environment and increase local economic prosperity.** The ecosystem services mapping framework co-created, refined and tailored through consultation with local stakeholders and with locally-specific data and evidence - made a strong and compelling case in an accessible way that UGI is the life support system for the modern city. This evidence is now being used to inform a current review of the Manchester UGI Strategy and to target the delivery of new projects focused on protecting and enhancing UGI, natural capital and ecosystem services provision in Manchester. Limiting factors are the availability and quality of the spatial data required for the assessment of key indicators and for the assessment of the condition of urban ecosystems. The Manchester city lab contains an inspiring narrative of how to green a city so that people benefit from it. It also shows how to engage stakeholders and citizens and make science and data accessible and understandable to them. It is a guide for scientists to help them bring their results and messages to policymakers.

Oslo

As one of the fastest growing metropolitan areas is Europe, **how can Oslo maintain and strengthen its blue-green structure so that urban open space is preserved for recreation and public health, but also for biodiversity, mobility and climate change adaptation?** Building on multiple research projects that studied natural capital in and around Oslo, the city lab used ESTIMAP to analyse pollination and recreation services supplied by urban green space. The assessments were expected to address specific questions from the municipality with respect to spatial zoning and capacity for honey bee keeping and recreation. The GIS and remote sensing based modelling approach could not entirely match these expectations. While the resulting maps of potential pollination and potential recreation helped raise awareness and conceptual understanding about the functions of urban green space, they fell short in providing quantitative policy support required for zoning recommendations. In cities, more detail in terms of thematic and spatial resolution is needed, including validation using spatially representative monitoring data.

Padova

A common limitation encountered in the EnRoute city labs is the lack of very detailed data of green infrastructure. Not so in Padova where the city manages a database with the location and the specifics of public trees. The city lab in Padova extended the possible uses of this database by adding information about ecosystem services delivered by single tree species. Different trees provide different services so the mix of tree species is important to understand the spatial distribution of services such as air quality regulation or nectar provision but also to detect where possible disservices arise or where particular management needs are required. This knowledge is useful to identify and prioritize management interventions on the existing trees, but also, in a longer-term perspective, to plan for the future development of Padova urban green infrastructure so that citizens can profit equally from the benefits provided by urban trees.

Poznań

How can previously neglected areas be revived through the development of new green infrastructure while strengthening urban resilience and ensuring a more equally distributed access to urban green space? This was the challenge of the citylab of Poznań. Creating new green infrastructure is particularly challenging in densely built-up areas. Poznań analysed the present distribution of its urban green and blue infrastructure and mapped the recreation opportunities offered by UGI adapting ESTIMAP-recreation to fit the local needs. Based on this knowledge a scenario proposed the creation of urban green space in a deprived part of the city, targeted for urban regeneration. The scenario showed the number of beneficiaries calculated as citizens who would profit from increased availability to areas of high recreation potential. The EnRoute study was well aligned with ongoing urban development planning which aims to mitigate depopulation in the city centre by developing of sports and recreation infrastructure and by revalorizing public green spaces. This is seen as a solution to increase the attractiveness of residential areas improving health and strengthening social ties. Also in this city lab, data accessibility and availability is a barrier to provide up to date policy support.

Rome

Rather than addressing an initial, specific policy question, the Rome city lab showed **how the MAES approach can be implemented at different spatial scales but with the aim to inform policy on the management and benefits of urban green infrastructure.**

The study adopted a multi-scale mapping approach to deliver empirical evidence on the importance of enhancing ecosystem condition and preserving ecosystem functions for sustaining the provision of multiple ES including the regulation of air quality. Special focus went to effective knowledge transfer to local policymakers: how raise awareness of the public administration about the importance and effectiveness of nature-based solutions and regulating and cultural ES in the city. Successful knowledge transfer requires a deep understanding of the role of different vegetation types (biodiversity) to improve environmental conditions in the city as well as quality of life; delivering multiple argument for conserving urban biodiversity; convincing policymakers about the need to restore abandoned urban sites and maintain local biodiversity; and promote better coordination of different policy initiatives.

Tallinn

Extreme weather events linked to climate change, particularly heavy rain and snowfall, can cause flooding in Tallinn. The Tallinn city lab investigated **how the full implementation of the comprehensive spatial plans of eight Tallinn districts affect the current and future provision of water regulating ecosystem services delivered by urban green space.** The city lab mapped in detail the current surface permeability, the canopy cover and the access for citizens to green space and compared the results with a scenario for the future based on greenery rates, (+definition). An important conclusion of the assessment was that permeability is, on average, expected to decrease which, in turn, will increase flood risk. Maintaining a climate resilient city would require a critical review of the district comprehensive plans so as to help adapt the city to climate change.

The Hague

The Hague is a relatively green city in which green spaces make up to 17 % of the city's surface area. At the same time the city faces serious challenges with respect to public health and quality of life. So The Hague raised the question as **to which extent public health is related to presence of urban green infrastructure**. To this end, the city used LIDAR data to map at high resolution the tree volume and collected a set of health statistics available at neighborhood level such as the prevalence of obesity or the percentage of suffering from depression, chronic diseases, and fitness statistics (percentage of people meeting the exercise and fitness standard). Tree volume was negatively related to the prevalence of obesity in the population whereas people were in general fitter in neighborhoods with a higher tree volume. Linking the presence of urban green infrastructure to public health statistics is still challenging. The availability and accessibility of data – especially on public health – is a critical factor. Due to privacy legislation health data are provided on a high level of aggregation, which may level out correlations, in particular within a single city. Yet, this first assessment is a first step to raise awareness about the role of urban green infrastructure for human health.

Trento

Increasing the area of public green space to enhance recreation opportunities for citizens and to increase cooling capacity during summer, particularly in deprived neighbourhoods, has been a chief objective of Trento. The Trento city lab tackled this objective by introducing an ecosystem services approach in the current Urban Plan, and this in close collaboration with key staff from city administration and based on experiences and results from other projects. Using maps of ecosystem services, the city lab identified ecosystem service hotspots, which can be included as strategic structural elements in the Urban Plan. This inclusion ensures that urban green and blue infrastructures are considered as a primary component of the urban system which need preservation from urbanization. Moreover, different actions are under consideration to improve the current network of green and blue spaces, thus increasing both connectivity and the provision of ecosystem services. More spatial and thematic detail in the ES mapping approach would enhance policy support.

Utrecht

Utrecht is the fastest growing city in The Netherlands with an expected population increase of 30% by 2040 relative to today. This growth has to be accommodated within the city boundaries so as to spare nature and recreational areas around the city. This will put additional pressure on the existing green space. **So how to maintain the present level of accessible green space per person under this growth scenario?** Hereto Utrecht has developed an Urban Green Structure plan with a focus on Healthy Urban Living for Everyone. Using spatial data sets and indicators of human well-being and ecosystem services, the city seeks for win-win situations where the conservation of green space serves multiple goals: a better health, adaptation to climate change, access to urban green for recreation, and cleaner air. Investing in high quality and high resolution data is a prerequisite to deliver tailored policy support. The EnRoute city lab created an opportunity to better communicate the benefits from urban green space for recreation and other ecosystem services but more efforts and success stories are needed to convince the planning department and other stakeholders from the added value of a natural capital approach.

Valletta

The Valetta city lab is an excellent case study **of implementing the MAES approach at local scale with well-established links to policy objectives with respect to biodiversity, regional development and transport**. The city lab used data and methods which are scalable and which can be used by any city in Europe to assess the composition, structure and functions of urban green infrastructure: COPERNICUS based images, ortho-photos and published methods to quantify key urban ecosystem services such as air quality regulation, carbon storage, local climate regulation and noise reduction. This allowed the city lab to deliver high resolution maps, but mapping ecosystem services requires additional data, which are not always available at the same spatial resolution. Given the densely populated nature of the city, the development of a comprehensive understanding of the location, condition and type of urban green infrastructure is particularly important for urban planning. This may be considered as the first step towards an analysis of the contribution of green infrastructure to the well-being of local communities through the delivery of ecosystem services such as air quality regulation, space for recreation and climate mitigation and adaptation.

2.3.2 Which key policy issues emerged from the city labs?

The eighteen city labs were asked to organize their work starting from a specific policy challenge which possibly needs an intervention on urban green space or infrastructure. Six general policy challenges or themes emerged which can be addressed using a natural capital approach based on maintaining or enhancing urban green infrastructure (Figure. 2.2).

An important question that cities have is how to reconcile the growth of cities resulting from increasing urbanization with a sufficient availability and access of green space for citizens. This requires indeed a careful urban planning process which needs to consider the different functions, services and benefits delivered by urban green infrastructure. Utrecht is an example among other cities.

Several cities focused on maintaining or enhancing urban biodiversity as a policy goal on its own. Evidently, this requires knowledge about the presence, distribution and configuration of urban green spaces within the city boundaries. Lisbon is a good example for setting an urban biodiversity policy. An ecosystem services approach could be helpful to justify the means needed to manage urban green infrastructure. This policy challenge relates also to efforts of some cities to enhance the status of pollinators in cities. Oslo and Helsinki-Espoo-Vantaa are illustrative examples.

Improving the quality of life through the management of urban green infrastructure is a third important policy challenge. Framing urban green infrastructure in this specific context enables an inclusive approach with stakeholders and citizens. This is well exemplified by the Manchester city lab which uses on a community based approach to mainstream natural capital in policy making. Recreation in green space is an important determinant of quality of life and several city labs, for instance Poznan, have made special efforts to map and assess recreation in cities to inform policy.

Linked to quality of life is human or public health. Green infrastructure is linked to mental and physical health benefits for people arising from cleaner air or the proximity of green infrastructure of achieving lower stress levels.

Growing with green ambitions Growing cities with sufficient green space for everyone **Leipzig**, **Utrecht**, **Karlovo**	***BiodiverCities*** A focus on maintaining urban trees and biodiversity; embedding the city in a regional ecological network, and urban bee keeping **Lisbon**, **Limassol**, **Oslo**, **Helsinki-Espoo-Vantaa**, **Padova, Rome**	***Improving the quality of life*** Community based approaches for investing in natural capital and urban green space for recreation **Manchester, Poznan, Trento**
Green cities, healthy cities Different examples of proper planning of how urban green space delivers benefits for physical and mental health. **The Hague**, **Rome**	***Sustainable strategic urban planning*** Development of multi-functional urban green and blue infrastructure and integration in regional planning. **Antwerp**, **Valletta**, **Dublin, Trento**	***Climate-proof cities*** Urban nature to support climate transition **Glasgow**, **Tallinn**, **Utrecht**

Figure 2.2. Emerging policy challenges in the EnRoute cities based on specific policy questions of the city labs

Some city labs have used the EnRoute opportunity to call for the inclusion of data and information of urban ecosystem services in the city's or even the region's strategic planning processes (for instance Antwerp and Dublin). Introducing additional layers of environmental information for the purpose of strategic planning is seen as an approach to mainstream urban green infrastructure in other policy domains.

Adaptation to climate change in cities is almost unthinkable without considering green infrastructure. Urban green infrastructure is particularly needed to mitigate flood risk stemming from an increasing number of extreme weather events. Also several EnRoute cities coupled therefore the climate agenda to biodiversity policy, e.g. Tallinn and Glasgow.

The boundaries between these policy challenges are not so strict; urban green infrastructure is indeed a cross cutting theme which can deliver on several policy challenges at the same time.

2.3.3 Which indicators are used by cities to map and assess urban green infrastructure and urban ecosystem services?

All together the city labs used 125 indicators to map and assess the condition and functions of urban green space (Table 2.1). This number is broken over 52 condition indicators, 13 biodiversity indicators, 47 indicators for ecosystem services, 7 socio-economic indicators and 6 human health indicators. City labs used on average a set of 7 indicators but there are strong differences. City labs which focused on sustainable strategic planning (e.g., Antwerp) or quality of life (e.g., Manchester) used a more varied set of indicators to make their case than city labs with specific policy questions of for instance pollination (e.g., Oslo, Helsinki-Espoo-Vantaa) or recreation (e.g., Poznan).

Table 2.1 provides an interesting reflection of the indicators which are effectively used by cities to address policy challenges in relation to urban green space. Unsurprisingly, the share of urban green infrastructure is the most popular condition indicator. Sometimes the indicator is refined to address a specific question. The Rome city lab for instance used the share of urban green infrastructure which is suitable for pollination; also other city labs combined this indicator with a certain function. Also other land use types are assessed as proportions and are frequently used as indicator. Next, air quality is an important indicator as well.

The biodiversity indicators mainly come from the Lisbon city lab, which had a strong focus on its local biodiversity action plan. The surface area of protected area is a key biodiversity indicator, together with the presence of distribution of selected species.

The list of ecosystem service indicators mapped by the city labs gives a clear impression of the issues at stake in the eighteen cities that participated to EnRoute. Recreation opportunities were assessed most often, followed by flood control, access to green space and carbon storage.

Population density is a key indicator for cities. In addition, more detail about the spatial distribution of specific cohorts, is used in combination with green infrastructure to assess the amount of green space per inhabitant, the impact of certain pressures, or the benefits of ecosystem services for people.

Some city labs linked urban green space to social-economic indicators. Glasgow for instance assessed the distribution of regulating ecosystem services related to flood and temperature risks using socio-economic statistics. Helsinki-Espoo-Vantaa examined easy accessibility to forests and parks from kindergartens and the distribution of different land cover types in the vicinity of kindergartens.

Finally, the two Dutch city labs related urban green space to metrics about human health, mostly using correlation graphs.

Table 2.1. Indicators used by the city labs to map and assess urban green infrastructure. Indicators are assorted per group and ranked by increasing use by the city labs.

Group	Indicator	Frequency of use by the city labs
Ecosystem condition indicators	Share of green infrastructure (use, demand, green space with certain suitability	7
	Share of different land covers or land uses	7
	Air pollutant emissions / air quality	5
	Permeability/imperviousness	3
	Temperature and urban heat island	3
	Water quality	3
	Flood risk	2
	Leaf Area Index /NDVI	2
	Naturalness / nature value	2
	Vegetation cover	2
	Anthropic connectivity	1
	Carbon stock	1
	Connectivity at canopy level	1
	Connectivity at ground level	1
	Fragmentation	1
	Geological hazard risks	1
	Health status of tree vegetation in GI	1
	Integrated index of spatial structure	1
	Noise	1
	Organic matter in soil	1
	Organic matter in vegetation	1
	Privately owned green space	1
	Proximity to roads	1
	Shortage urban green	1
	Soil sealing	1
	Soil types	1
Biodiversity indicators	Protected and classified areas	4
	Presence and distribution of specific species (pollinators, plants, trees)	3
	Habitats to fauna	2
	Conservation status	1
	Ecological traits of tree species	1
	Ecotopes naturalness degree	1
	Main ecotopes	1
Ecosystem service indicators	Recreation opportunities / cultural facilities	9
	Water retention / flood control /flood damage costs	7
	Accessibility to green space	5

	Carbon sequestration/climate regulation	5
	Air quality regulation/ removal of pollutants	4
	Cooling capacity / microclimate regulation	4
	Amenity value /aesthetic values	3
	Noise reduction	3
	Pollination potential	3
	Food production	2
	Land promoting good water quality	1
	Protective function of forests	1
Social indicators	Population density / number of people benefiting from UGI	3
	Consumer satisfaction with public green	1
	Deprivation	1
	Perceived quality of the environment	1
	Property value	1
Human health indicators	Life expectancy	1
	Percentage of population that suffers from obesity	1
	Percentage of population that suffers from moderate to severe anxiety disorder or depression	1
	Percentage of population that suffers from one or more chronic diseases	1
	Percentage of population that experiences a good health	1
	Percentage of population that meets the exercise standard	1
	Percentage of population that meets the fitness standard	1

The key knowledge sources to quantity these indicators are remote sensing and local data (for the share of urban green infrastructure, other condition indicators, and socio-economic indicators) and models for the assessment of ecosystem services. Land cover and land use information primarily comes from remote sensing such as Copernicus but also LIDAR data. European data sets such as Corine or Urban Atlas were rarely used to map urban green space. Only Helsinki-Espoo-Vanta used Urban Atlas in the local assessment but together with more detailed local datasets. The availability of high resolution spatial data to map urban green space remains an important challenge (see further).

2.3.4 What is the policy relevance of the EnRoute city lab results?

The city labs also self-assessed the policy relevance of their work. These results are summarized in Figure 2.3. Following the lecture of each report, we checked for every city lab if they achieved in delivering on one of the following options of policy relevance with reference to mapping and assessment of urban green infrastructure and ecosystem services:

- could not address the policy question raised by the city stakeholder;
- was mainly used for awareness raising of the role and functions of urban green infrastructure;

- was informative and therefore used by the city in current policy actions as a source of additional information;
- has contributed to current strategic urban planning or will be included in future strategic urban planning;
- was a cause for a policy intervention.

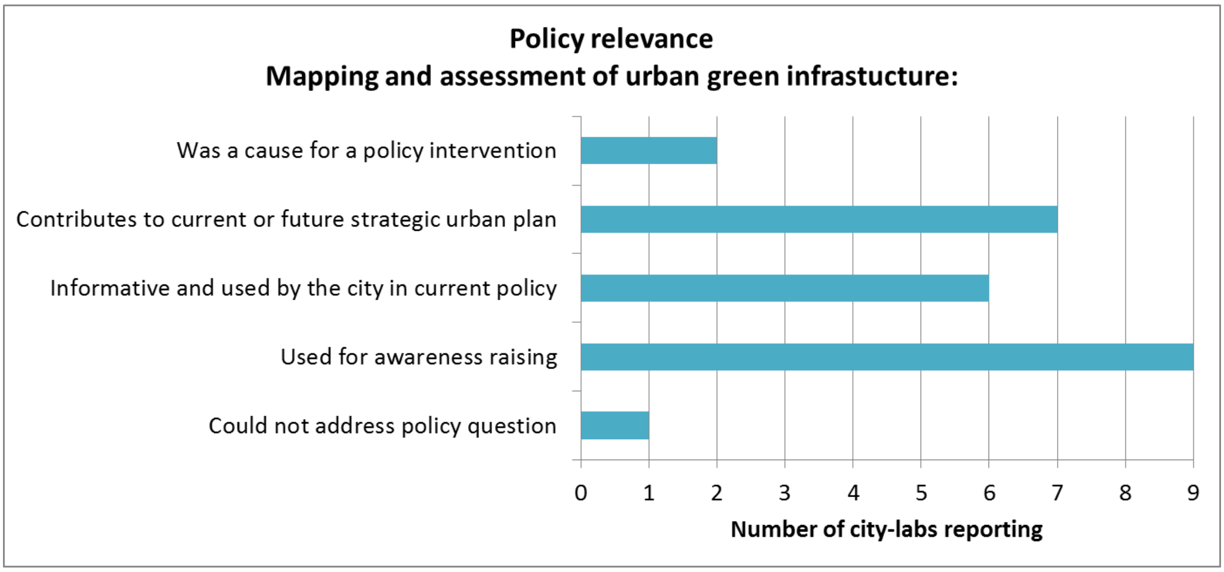


Figure 2.3. Policy relevance of mapping and assessment of urban green infrastructure based on the experience of the city labs (expressed as the number of city labs reporting).

Figure 2.3. reports the different types of policy relevance in order of increasing importance. One city lab, Oslo, was critical in its self-assessment and acknowledged that at least a part of the assessment could not address the policy question which was raised at the start of the project. At the other end of the spectrum, two city labs reported examples that the findings of mapping urban green infrastructure, its natural capital and its biodiversity have been used to justify policy interventions: the 'Nature of Hulme' project in Manchester and the definition of areas of future green spaces in Lisbon.

The other types of policy relevance were each reported by between one third and halve of the city labs (Figure 2.3). Maps of urban green space in relation to statistics about the condition of urban ecosystems, ecosystem services or socio-economic and public health data have been used mainly to raise awareness about the role of UGI and but also to inform current policy actions. More and more, UGI and ecosystem services find their way in the current and future strategic urban planning. Trento, among several other city labs is a useful example in this context.

2.3.5 What are the challenges of mapping and assessment of urban green infrastructure?

The city labs had also the opportunity to report specific challenges and limitations in their report. The most frequently mentioned limitations are related to data quality and accuracy (Figure 2.4). Almost all city labs reported that data quality was often not sufficient to address the policy questions. Cities need high resolution data about the occurrence of urban green infrastructure within the city boundaries. Related to this challenge is the difficulty to acquire information or data about the presence and the management of urban green space in privately owned land. Mapping also ignores the third dimension (height) which is important to address the functional role of trees and urban forests. This information is lacking if maps of urban green infrastructure are based on earth observation from satellites. The use of LIDAR, as in the The Hague city lab and Helsinki-Espoo-Vantaa city lab, is a tool to overcome this challenge.

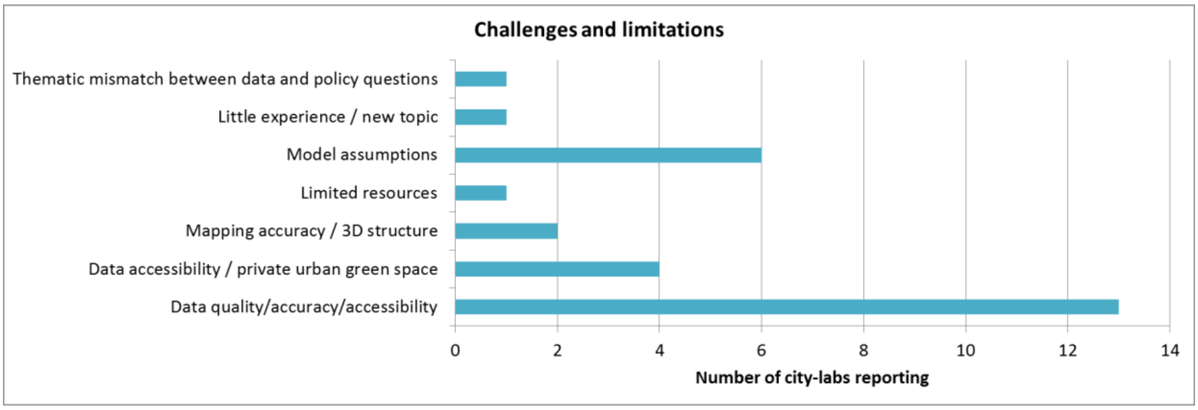


Figure 2.4. Challenges and limitations of mapping and assessment of urban green infrastructure based on the experience of the city labs (expressed as the number of city labs reporting).

The Oslo city lab report included an important risk about mapping. Their resulting ecosystem service maps gave the impression of spatially resolved information on services when this is often not the case. This is not apparent at the aggregate European or national scales, yet becomes apparent at local/municipal scales when local inhabitants and experts easily can validate the relative values in the map based on personal experiences. Often, it is sufficient for one stakeholder participant to find one local deviation in a polygon or raster pixel during a consultation for the whole product to be invalidated in front of an audience.

2.3.6 What is the applicability of the MAES framework at local scale

A dedicated session of the EnRoute workshop in Sofia surveyed the applicability of the MAES framework at local scale among the EnRoute city labs. The MAES framework mainly gives guidance to member states on how to map and assess ecosystems and their services on their territories but the framework has been used to give guidance in other contexts as well (e.g., for LIFE project assessments). The framework essentially consists of typologies for ecosystems and ecosystem services and indicators to assess ecosystem condition and ecosystem services. EnRoute was set up as a test case for operationalizing MAES at the local scale. The results of the workshop are presented in Table 2.2, which addresses the usefulness of the MAES framework and approach, the requirements for application and pitfalls, and the lessons learned by the city labs.

Table 2.2. Applicability of the MAES framework at local level. Outcomes of a discussion session at the EnRoute workshop in Sofia.

The MAES framework is useful for:	**Requirements for application and pitfalls:**	**Lessons learned**
• Making a case at local level • Getting the best output from data • Compare the performance of cities • Raising awareness about the multiple functionality of ecosystems • Providing examples of best practices • Enhancing cross-sector cooperation or cooperation across different political levels • Connecting different levels of governance • Delivering the tools for monitoring cities and for improvement • MAES guidance is easily adaptable and not prescriptive • MAES is mind changing and a good starting point • Giving directions	• Do not duplicate what has been done already using other frameworks • Use the right language and terms • Be open and transparent: share knowledge and actions • Don't be overambitious • Avoid top down approaches in cities; solutions to urban challenges often require a participative approach • Involve people across sectors and learn from each other	• Don’t be overambitious in collecting data • Use an iterative approach (adaptive management) • MAES provides inspiration at national and local level • MAES provides a framework that can be adapted to fit local needs • Helps build communities of practice across sectors • A diverse set of examples/city labs gives inspiration

2.4 Key conclusions of the city labs

1. **The MAES approach works and can deliver, also at local scale:** The real challenge of MAES and of EnRoute in particular, is to integrate and mainstream urban green infrastructure (UGI) and ecosystem services in urban policymaking and implementation. The outcomes of applying the framework developed by MAES in 18 cities across Europe were reasonably successful. Almost all city labs achieved in mapping and assessing UGI and ecosystem services even when only limited resources were available. All city labs have been able to enter the policy process in one way or another.

2. **A standard approach is a useful starting point but local knowledge is important**: As the city lab of Dublin recognized in its report, cities can benefit of using a standardized approach to Urban Green Infrastructure assessment and the framework and indicators from EnRoute were useful for local authorities in particular. But clearly, standardized approaches have to be locally adapted and complemented with local knowledge.

3. **A detailed map of urban green infrastructure is a key product for informed decision-making**. Few cities make use of European wide or even national datasets for supporting local decision making. EnRoute learns that detailed and locally collected spatial data are needed to integrate urban green infrastructure in policy. So sufficient time, efforts and resources should be considered in developing a detailed, spatially resolved map of urban green space as this will substantially increase the success of policy integration.

4. **Demonstrating the benefits of urban green infrastructure requires linking ecosystem data with socio-economic statistics**. Clearly, a detailed knowledge of the distribution of the population in cities in combination with statistical information about age, deprivation, and public health is key to understand the distributional benefits of urban green infrastructure. Several city labs including Leipzig, Glasgow, The Hague, Helsinki-Espoo-Vantaa and Utrecht made the relation between urban nature and people explicit to raise awareness so as to enter the policy action cycle.

5. **Front-runner cities have multiple research projects situated on the science-policy interface.** Several city labs profited from synergies with other initiatives and projects which involved the city as stakeholder. Surrounding the science-policy interface on urban green infrastructure with multiple research projects makes a natural capital approach more visible and prominent within the administration, and for the officers involved in green area management and urban planning. Multiple initiatives can provide a clear contribution to the emergence of ecosystem services in the policy agenda and enhance the success of mainstreaming natural capital.

3 Mapping and assessment of urban ecosystems and their services at European scale.

3.1 Introduction: Challenges of large-scale mapping of urban green infrastructure for urban policy and planning.

An important challenge of EnRoute was to test the MAES approach on mapping and assessment of ecosystems and their services at urban level and at European scale. The challenge lies in the fact that, as demonstrated in Chapter 2, urban policies require high resolution data. However, this contrasts with the observation that European-scaled mapping is to a large extent limited by spatial resolution. Even in times when high resolution datasets become more and more available, e.g., through Copernicus, many policy-relevant indicators still lack the spatial resolution that is needed to deliver evidence-based information for urban policy and planning. Mapping and assessment of urban green infrastructure, the condition of urban ecosystems and the ecosystem services provided by urban green infrastructure are not solely reliant on environmental datasets observed through remote sensing which provide full spatial coverage at high resolution (sometimes < 1m). It also requires the use of many other datasets that are collected in various ways and with many data gaps. Examples are data on pollution, socio-economic variables or statistics on public health. These data are equally important to map ecosystem services and to understand how urban green infrastructure is relevant for human well-being.

This chapter provides a first test of mapping urban ecosystems and their services at European scale. The objectives of this chapter are (1) to develop and provide consistent overview of European cities for what concerns the condition of urban ecosystems and the capacity to provide ecosystem services; and (2) to offer examples of methodologies that can be replicated at various scales or in different territorial contexts (Endlicher et al. 2007) and thus provide the tools for mapping urban ecosystems and their services; and (3) to make these data available for future analysis, e.g. in the framework of the EU wide ecosystem assessment currently planned for 2019 and 2020.

Urban ecosystems are very peculiar ecosystem types with respect to land structure and the incisive presence of people and human activities. Although core urban areas of cities are often almost completely artificial, urban and peri-urban zones can include, in different proportions, forest, lakes and rivers, agricultural areas and coastal zones (Endlicher et al. 2007). The combination of land use structure and population density helps the understanding of the kind and extent of pressures on ecosystems and their services. For this reason we used the concept of land configuration to offer a more articulated overview of the situation of European cities and their surroundings.

The remainder of this chapter is structured as follows. Firstly, a short introduction is provided to the concept of Functional Urban Areas (FUAs), the system for spatial extent and reporting units that is used here. Next, this chapter makes a proposal for reporting based on the spatial configuration of cities in Europe. Then the chapter follows the same outline as the city lab reports: what are the key indicators available for describing the condition and services of urban green infrastructure, a short summary of the key results, an analysis of the main limitations, a proposal for policy relevance and final conclusions of the work. Importantly, this chapter provides a summary of a larger study on EU wide mapping and assessment of urban green infrastructure, which will be presented later in a technical JRC report.

3.2 Functional Urban Areas as spatial unit for the mapping and assessment of urban ecosystem and their services

This study covers about 696 European cities and their surroundings. As basic mapping boundaries and spatial reporting units we used the Spatial system for city statistics[1],version 2011-2014, as recommended by EUROSTAT (EuroStat 2016; Statistics 2017). This system is structured as follows

- **Functional Urban Areas**, defined as the core city (with at least 50,000 inhabitants) and the commuting zone. It is based on commuters, employed persons living in one city that work in another city. It represents an 'operational urban spatial extent' that allows to map and evaluate the city and its surroundings. The commuting area is an area of transition, from agricultural or semi-natural land uses to urban land use and is very important when considering ecosystem services. There are cities that never had a commuting zone or that lost its commuting zone.
- **Core cities** are cities with at least 50,000 inhabitants. One FUA includes one or more core cities. As reporting unit for core cities, we aggregated all core cities within the same FUA.
- **Commuting zone (or sub city districts),** it represents the commuting zone around the core city; occasionally FUAs do not include a hinterland (15% of the cases).
- **'Greater city',** are urbanized areas that stretch far beyond their boundaries. The greater city can overlap completely the FUA and includes one or more urban centres (Table 3.1) Figure 3.1 presents a map of FUAs in Europe.

For reasons of consistency, *Greater cities* have been considered as core city for the respective FUAs (e.g., Naples, Paris, London, Athens, see Table 3.2).

[1] https://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/administrative-units-statistical-units/urban-audit

In the EU there are 696 Functional Urban Areas and 917 core cities. The total area of all FUA covers 20.6% of the European territory. In Cyprus, Denmark, Germany, Malta, and Netherlands FUA represent over 40% of the territory. Luxembourg is a special case where simply the whole country was assigned as a functional urban area. Low percentages (<10%) are observed in Greece, Switzerland, and Romania (Table 3.1). In contrast, the total area of core cities covers 3.48 % of the European territory, a percentage which is notably smaller than the total area occupied by FUAs.

In addition, Europe has 31 greater cities which entail all together 121 core cities under the FUA classification (Table 3.2).

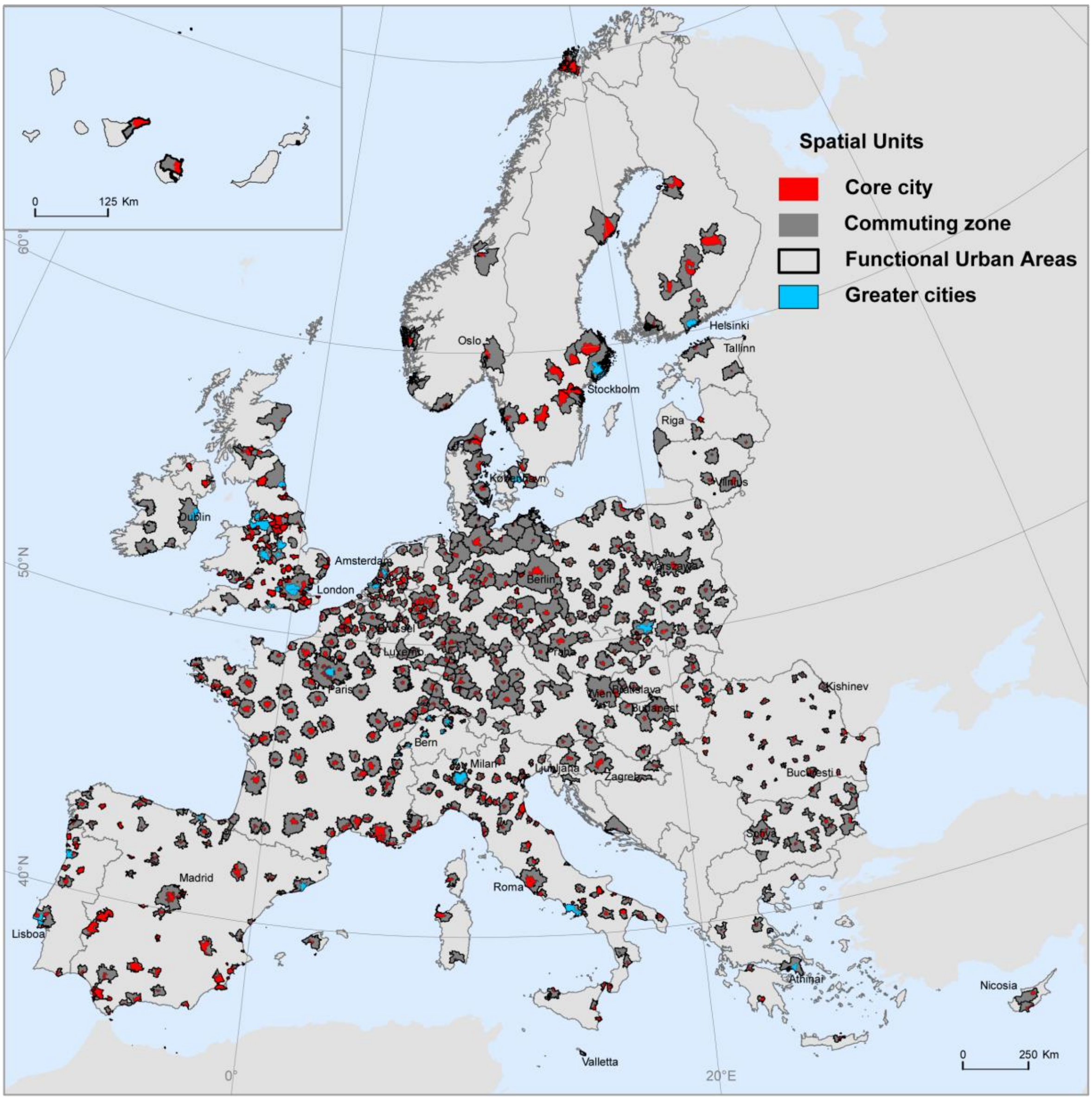


Figure 3.1. Distribution of Functional Urban Areas, Commuting zones, Core cities and Greater cities in Europe (EU28, Norway and Switzerland).

Table 3.1. Spatial system for city statistics, number and share of FUAs per country. 15% of the cities do not have a commuting zone or lost its commuting zone.

Country code	Number of FUA and aggregated core cities	Number of core cities	Share of surface area of FUA of the territory (%)
AT	6	6	25.61
BE	11	11	34.78
BG	17	18	25.14
CH	10	10	8.99
CY	2	2	44.37
CZ	15	18	37.67
DE	94	125	53.95
DK	4	4	46.72
EE	3	3	16.33
EL	9	9	7.24
ES	70	109	11.68
FI	7	9	10.5
FR	84	114	27.71
HR	5	5	21.53
HU	10	10	25.19
IE	5	5	21.46
IT	74	76	17.97
LT	6	6	12.8
LU	1	1	100
LV	4	4	12.72
MT	1	1	78.07
NL	34	51	46.07
NO	6	6	8.35
PL	58	68	26.28
PT	13	25	11
RO	35	35	5.57
SE	12	13	10.97
SI	2	2	23.31
SK	8	8	17.69
UK	90	163	27.98
EU	696*	917	20.64

Table 3.2. Spatial system for greater cities in the EU28, Switzerland and Norway.

Country code	Number of greater cities	City name	Number of core cities
CH	6	Genève; Basel; Bern; Lausanne; Luzern; Lugano	6
DK	1	Copenhagen	1
EL	1	Athens	1
ES	2	Barcelona, Bilbao	13
FI	1	Helsinki; Espoo; Vantaa	3
FR	1	Paris	1
IE	1	Dublin	1
IT	2	Naples; Milan	4
NL	2	Amsterdam; Rotterdam	8
PL	1	Katowice	8
PT	2	Lisbon, Porto	11
SE	1	Stockholm	1
UK	10	London; West Midlands urban area; Liverpool; Greater Manchester; Tyneside conurbation; Leicester; Portsmouth; Greater Nottingham; Southend-on-Sea; Reading; Preston	63

3.3 Key indicators for mapping and assessment of urban ecosystems and their services

This study presents a first test of the MAES indicator framework for ecosystem condition and ecosystem services at EU scale for urban ecosystems. Table 3.3 is a summary of the state of the art which is currently available at EU scale. It presents the indicators that can be used to map the pressures on urban ecosystems, the condition of urban ecosystems as well as the urban ecosystem services delivered by urban green spaces, all at the level of FUAs. All the indicators are spatially explicit (50m resolution), only few indicators were compiled using aggregated data (see Table 3.3). In addition a collection of maps which can be used for urban assessments is presented.

This chapter presents a summary of the EU wide assessment. A more in depth analysis will be made available in a forthcoming JRC technical report which explains in full detail the methodology and the data sources used.

Table 3.3. Summary statistics of the indicators used to assess pressures, condition and services of urban ecosystems in Europe. **indicators based on aggregated data.

Indicator (unit of measure)	Reporting Unit	Mean	Minimum	Maximum
Pressures **				
Emissions of NOx (tonne/year)	FUA	5761.3	35.7	99806.54
Invasive alien species: Potential negative impact within FUAs(dimensionless)	FUA	0.7	0	2.7
Invasive alien species: Potential negative impact around FUAs (dimensionless)	FUA	0.7	0	2.3
Population				
Population density (inhabitants/km2)	Core city	1521	27	17380
Population density (inhabitants/km2)	FUA	549.4	14.96	5751.5
Soil sealing				
Sealed soil per surface (%)	Core city	22.15	0.42	86.98
Sealed surface (m2) per inhabitant	Core city	174.72	47.25	823.43
Inhabitants per sealed surface (m2)	Core city	0.65	0.12	2.11
Sealed soil per surface types				
Sealed soil in artificial areas (%)	Core city	58	22.47	88
Sealed soil in areas of transition to highly heterogenic (%)	Core city	14.62	1.64	42
Soil in areas of transition with prevalence of agriculture (%)	Core city	3.9	0.06	21.9
Pollution levels **				
PM10 concentration Yearly average (µg/m3)	FUA	18.06	3.97	36.51
PM10 36th highest daily mean PM10 concentration (µg/m3)	FUA	31.27	5.89	76.98
O3 26th highest daily maximum 8-hour value in µg/m3	FUA	111.87	59.01	196.74
NO2 Yearly average (µg/m3)	FUA	17.39	2.64	36.51
Green space in core cities				
Proportion of the surface area of green infrastructure (%)	Core city	39.72	0.04	86.88
Proportion of the surface area of public green space (%)	Core city	2.45	0.02	20.86
Urban protected areas				
Share of Natura 2000 sites (%)	FUA	11.7	0	70.74
Share of Natura 2000 sites (%)	Core city	8.5	0	73.12
Cultural ecosystem services				
Surface area of publicly accessible green space (m2)/inhabitant	Core city	18.2	0.82	253.88
Share of the population within 300 m from a public park	Core city	44.22	1.92	90.18
Surface area with high recreation potential and high availability of facilities to reach and enjoy recreational sites (%)	FUA	6.94	0.05	37.9
Surface area with high recreation	FUA	35.33	1.3	89.81

potential (%)				
Regulating ecosystem services				
Pollination potential (suitability of land to support pollinators) (dimensionless)	Core city	0.34	0.04	0.73
Share of the surface area with low capacity to control flooding (%)	Core city	46	3.3	97.9
Share of the surface area with medium capacity to control flooding (%)	Core city	31.8	0.4	78.7
Share of the surface area with high capacity to control flooding (%)	Core city	22	0	90.8

3.3.1 Pressures on urban ecosystems

Two pressures have been quantified: the emissions of NOx, a pollutant which is mainly released by traffic and combustion of fuels and the presence of invasive alien species (IAS).

The emissions of NOx amount to an average of almost 6000 tonne annually with large variations across cities (Map 1).

The IAS indicator is based on a new development making use of the data from EASIN. The indicator was developed for EnRoute but will also be used for the assessment of the impacts of IAS in other ecosystem types. Alien species are animals and plants introduced accidentally or deliberately into a natural environment where they are not normally found. Such species can become invasive in their new environment if they start spreading and causing serious damage to native species and ecosystems. Target 5 of the EU Biodiversity Strategy requires that by 2020, invasive alien species are identified, priority species controlled or eradicated, and pathways managed to prevent new invasive species from disrupting European biodiversity. Here we mapped the potential negative impact of terrestrial invasive alien species within and around functional urban areas.

The indicator is based on data collected in the EASIN, the JRC knowledge hub on IAS. Of the 37 species considered within the 'Baseline distribution of Invasive Alien Species' (Tsiamis et al. 2017), we only considered those reported to have negative impacts on at least one terrestrial land cover type (28 species), and for which occurrence data are available. Negative impacts were grouped in three general categories: social, economic, and environmental (Tsiamis et al., 2017). Information was aggregated to obtain a cumulative impact for grid cells, and this information was again aggregated to deliver an average value per FUA. The impact is better visible on the map (Map 2). The impact is particularly high in cities in the UK, Belgium, the Netherlands, Germany and Italy. Lower impacts are observed in other countries whereas low to no impact are visible in central and Eastern Europe. This suggests an introduction pathway mainly through port areas situated along the English Channel and the North Sea and extending from there to land inwards.

3.3.2 Population

Population is a key variable to characterize cities and it is an important determinant for the use of urban green space and ecosystem services. The average European city has a population density of 1521 inhabitants per square km. This number decreases to 549 if the whole FUA is considered. Map 3 plots population density inside core cities in Europe.

3.3.3 Soil sealing

Soil sealing is the covering of the soil surface with materials like concrete and stone, as a result of new buildings, roads, parking places but also other public and private space. Depending on its degree, soil sealing reduces or most likely completely prevents natural soil functions and ecosystem services on the area concerned (EEA 2011). The provision of ecosystem services is a function of the degree of surface imperviousness; all of the land use classes that show a potential to provide ecosystem services are either not or only minimally sealed (Larondelle et al. 2014). This is particularly important for flood risk and flood control.

Different indicators can be used to assess soil sealing in cities which all express slightly different aspects of soil sealing: the surface area of sealed soil per inhabitant in core cities and commuting zones, an inversion of this indicator so the number of inhabitants per sealed surface, and the surface area of sealed soil as a proportion of the total surface area or specific per land type (Table 3.3). Considering this last indicator, European cities have sealed, on average, 22% of their soil but this increases to 58% if only soil sealing in artificial areas is considered. Soil sealing is lower in the peri-urban areas where other land types such as forest and agriculture occur. Map 4 plots the share of sealed soil in core cities.

3.3.4 Air pollution

Air pollution is a key indicator for the quality of life in cities as well as for the condition of urban ecosystems. Humans can be adversely affected by exposure to air pollutants in ambient air. In response, the EU has developed an extensive body of legislation which establishes health-based standards and objectives for a number of pollutants present in the air. These standards and objectives (for pollutants reported here) are summarised in Table 3.4.

Table 3.4. Air quality standards and objectives established under EU Directive 2008/50/EU.

Pollutant	Concentration	Averaging period	Legal nature

Nitrogen dioxide (NO_2)	40µg/m3	1year	Limit value to be met as of 1.1.2010 *
Particles (PM10)	50 µg/m3	24 hours	Limit value to be met as of 1.1.2005 **
Particles (PM10)	40µg/m3	1 year	
Ozone (O_3)	120 µg/m3	Maximum daily 8 hour mean	Target value to be met as of 1.1.2010

**Under Directive 2008/50/EU, the Member State could apply for an extension of up to five years (i.e. maximum up to 2015) in a specific zone.*

***Under Directive 2008/50/EU, the Member State was able to apply for an extension until three years after the date of entry into force of the new Directive (i.e. May 2011) in a specific zone.*

This assessment is based on the interpolated air quality maps provided by the European Environment Agency to extract the average values per city.

On average, the air quality in European cities is respecting the threshold values reported in Table 3.4. However, this assessment is based on already interpolated and averaged maps. It follows that day to day variation is not included and that peak events for example in ozone or PM concentrations are averaged out. The maximum values for ozone and PM10 are, however, exceeding the limit imposed by EU legislation. For PM10 values for the 90.4th percentile are used. This corresponds to the 36th highest value of the data series since the legislation allows 35 exceedances of the 50 µg/m3 threshold over a 1-year period. A similar observation applies for ozone.

Map 5 plots the indicator values for air pollution across Europe. A clear gradient with increasing values is visible from north-west to south-east with higher than average values in central and Eastern Europe as well as in the Mediterranean area. Cities situated in the Po plain score worst for this indicator.

3.3.5 The amount of green infrastructure in European cities

Already identified in Chapter 2, the area of urban green space available for citizens is the most important indicator used by cities to assess urban green infrastructure. Urban and peri-urban green plays a fundamental role in urban ecosystems. It is a key structural and morphological component, supports biodiversity (Whitford et al. 2001; Hostetler et al. 2011; Capotorti et al. 2017) and provides key ecosystem services (Derkzen et al. 2017, Whitford et al. 2001).

Different classifications of urban green space are available and generally they are used for management purposes, such as urban parks, playgrounds, road sides or tree lines (see Maes et al. 2016; 4th MAES report). At EU scale we do not have enough information to implement a detailed classification of urban green space. In this study we could only distinguish between public and private green spaces, urban forest and semi-natural vegetation using information derived from Urban Atlas and the European Settlement Map (Copernicus Land Monitoring Service 2016; Ferri et al. 2017).

Traditionally urban green is measured using standards. There are five types of standard approaches that are commonly used (Maryanti et al. 2016):

- Area percentage standards: A specified percentage of land to be allocated for open space (e.g. 10% from the total development area is allocated for open space).

- Population /ratio (fixed) standards: A prescribed level of provision of open space related ratio/fixed to the level of population – typically per 1000
- Catchment area based standards: Distances, which residents should have to travel to gain access (e.g. 300 meters walking distance from users' neighbourhood).
- Facility standards: Specifications (size, markings and equipment for a sports field).
- Local standards: Standards of provision specific to a local area based on local conditions and data, locally determined or expressed in any of the above formats

This synthesis reports the area based percentage but information on the amount of urban green space per person and the distance to urban green space is given further.

The total area of urban green space in Europe's core cities takes almost 40% of the total surface area. This statistic should be interpreted as the amount of open urban green space in cities. It includes forests, grasslands, and other urban green spaces. It is a bulk statistic of all open green space. This is in agreement with the statistics reported for soil sealing. This indicator varies spatially across Europe (Map 6). High values with percentages >50% are observed in Scandinavian cities but also in cities bordering the Mediterranean sea, which are compact with a large area of urban forest.

However, this statistic should receive some nuance. If only publicly accessible green space (public parks in cities) is considered this share decreases to 2.45%. Also the spatial pattern, presented in Map 7, differs considerably from Map 6. Higher proportions of publicly accessible urban green space are not limited to compact cities with large urban forests but are evident for cities across Europe with a high incidence in the UK, Netherlands, Belgium, Germany and Poland as well as in capital cities.

These two statistics highlight a specific reality which will be further illustrated in the section of cultural ecosystem services. Cities can include substantial areas of open space within their boundaries which are important for delivering key regulating ecosystem services but much of this open space is not directly available for use by citizens for recreation purposes.

3.3.6 The importance of the Natura 2000 network

Natura 2000 is a network of core breeding and resting sites for rare and threatened species, and some rare natural habitat types. It stretches across all 28 EU countries, both on land and at sea. EU member states have to introduce appropriate conservation measures to guarantee the conservation of habitats and avoid their deterioration and any disturbance to species. Natura 2000 is therefore a key element for the protection of European biodiversity.

Nevertheless, Europe is one of the most urbanized continents in the world and the possibility that Natura 2000 sites fall close or within a metropolitan area is therefore high. This is evidenced by the data: 15.2% of the network falls within the boundaries of the FUAs. This becomes 1.95% if only core cities are considered.

As it could be expected, more urbanized countries, like Malta or Belgium, have a larger share of Natura 2000 sites inside FUAs than countries like Finland or Sweden (Figure 3.2). But the configuration of the network also matters, for example, Germany has created a dense network of relatively small protected sites which often overlap with urban areas.

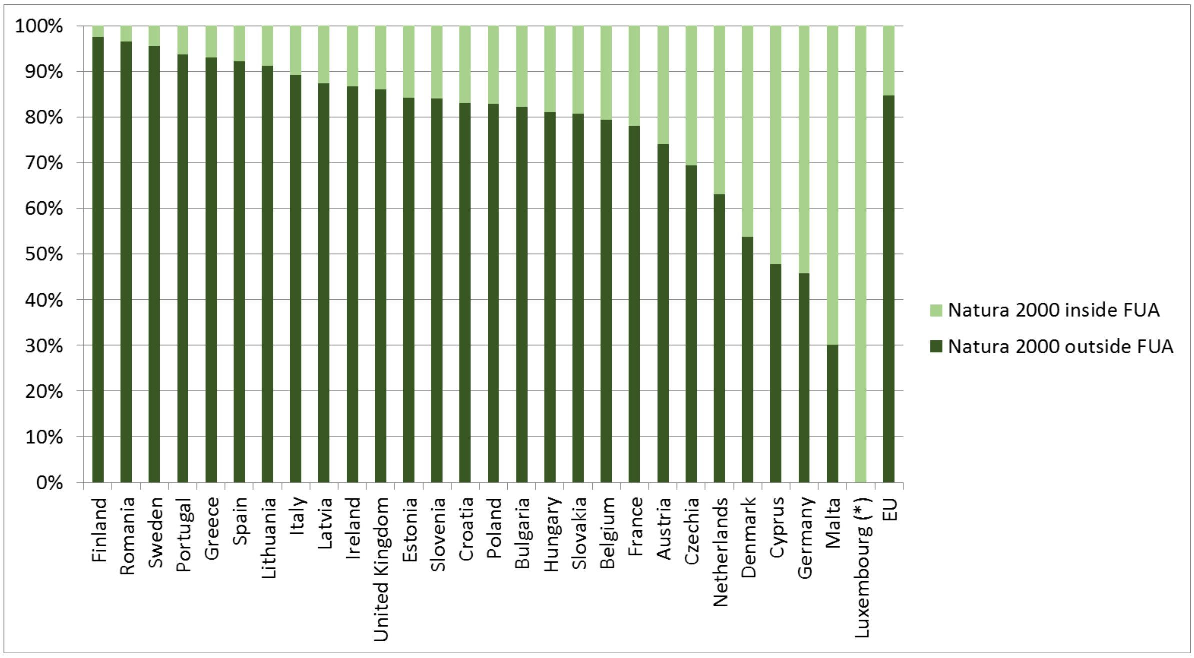


Figure 3.2. The percentage of the Natura 2000 network inside and outside Functional Urban Areas (FUA) in the countries of the EU-28. * The FUA system assigns the whole territory of Luxembourg as a single FUA unit.

3.8. Cultural ecosystem services: access to urban green space for recreational purposes

Cultural ecosystem services and recreation in particular, play a central role in cities (Kienast et al. 2012). They provide the opportunity to be in contact with "nature" and practice different kinds of open-air activities (Van Herzele and Wiedemann 2003; Kienast et al. 2012; Dickinson and Hobbs 2017; Oh et al. 2017; Fischer et al. 2018).

We used two approaches to map cultural ecosystem services in cities. The first is a standard approach to map the total available area of public urban green space per person and the proximity to public urban green space in core cities. The second, based on an application of ESTIMAP, is a more articulated method that allows considering the potential capacity of nature to provide opportunities to recreate as well as the presence of infrastructures to reach and enjoy nature (Zulian et al. 2017).

The standard based approach assumes that urban dwellers need an public urban green space close to home to enjoy being outside. Therefore we mapped the percentage of people which lives within 300 m from the nearest public green space (Niemelä et al. 2010; Söderman et al. 2012; Egorov et al. 2016). Considering the resolution accepted for this study (50 m) we based the analysis on the Euclidian distance (Apparicio et al. 2008). The method is relatively easy to be computed and to be compared (allows benchmarking and comparisons of cities). The parameters were derived from international targets (Breuste and Rahimi 2015) and applied in previous studies at European scale (Poelman 2016). However, it does not take into account the internal structure of public parks (in terms of size and type of facilities) neither the territorial context. Moreover this indicator is very sensitive to population density and could deliver misleading conclusions when a high proportion of people live very close to a small public park. Therefore, an additional indicator showing the number of people living in the distance of 300 m from the public parks (or other areas available for public use) would complement the picture (Söderman et al. 2012).

On average, European citizens have access to about 18 m^2 public green space within the boundary of their city; this is double the amount suggested by the World Health Organisation of 9 m^2 (World Health Organization, 2010), with a benchmarking of 20 m^2 per person. However, this average hides the fact that, on average, most urban dwellers have to travel over 300 m to reach a publicly accessible park. Only 44% of citizens, on average, lives within this threshold distance and has thus easy access to a public green space. Put another way, more than one out of two urban dwellers needs to travel further than 300 m to reach a public park. The indicator takes almost all values between 0 and 91% showing the large variability around this average.

Both indicators vary spatially but in particular the total area of accessible urban green space follows a north-south gradient with higher than average values in the north of Europe and lower than average values in the south (Map 8). This confirms previous studies where a below average availability of public urban green space was reported for southern EU cities (Kabisch et al. 2016). Spatial variation in the share of people living within 300 m from urban parks is less pronounced (Map 9). The above average availability of urban green in northern cities is a result not only of their socio-economic, biophysical and geographical condition but also of the cultural attitude toward having nature and forest close to home (Kabish et al. 2016).

Both the amount of public urban green space as well as the share of people living within a certain distance from it are essentially measures of quantity. They don't express the quality of the recreation opportunities that publicly accessible green areas offer to urban dwellers. Here we present a synthesis of an in-depth analysis of the recreation opportunities delivered by urban green infrastructure. This approach is based on the JRC's model ESTIMAP –recreation. This model can be described as an "advanced multiple layer look up table" approach that measures the capacity of ecosystems to provide nature-based outdoor recreational and leisure opportunities. It consists of two basic components: (1) the Recreation Potential (RP), which maps the potential capacity of ecosystems to support nature-based recreation activities based on land suitability for recreation; (2) the Recreation Opportunity Spectrum map (ROS), which combines a proximity-remoteness concept with the potential supply (RP) (Zulian et al. 2017). We adapted the approach, originally developed and applied to fit the European scale (Zulian et al. 2013b; Paracchini et al. 2014; Liquete et al. 2016; Vallecillo S, La Notte A, Polce C, Zulian G, Alexandris N, Ferrini S 2018; Vallecillo et al. 2019) for urban settings. Urban dwellers in fact need areas to enjoy the nature and practice recreation activities relatively close to the city. Recreation areas have to be accessible and should provide specific facilities in order to reach and enjoy nature. The model measures the availability of locations with high potential to provide recreation opportunities, close to infrastructures to reach them and facilities to enjoy. In 2017-2018, within the EnRoute project, the urban EU-ESTIMAP recreation model was tested with the collaboration of the city labs of Poznan, Trento and Oslo (see chapter 2) (Cortinovis et al. 2018).

Suitability of land to support recreation is calculated based on land use and on a high resolution layer of urban green (ESM) that was used to increase the value of all land use types. In fact the presence of scattered vegetation (trees and green cover not detected in a functional land use map) influences the potential availability of direct and indirect opportunity for nature based recreation (direct = directly linked to a specific activity; indirect = linked to amenity and quality of place e.g. trees in residential buildings or along bike paths). Urban green infrastructure is mapped considering public parks (extracted from Urban Atlas) and pocket parks extracted from Open Street Map. Natura 2000 sites and natural tags available in Open Street Map were also included. Water elements consist in coast geomorphology, proximity to lakes and seacoast and natural riparian areas, bathing water quality (if compliant with the Bathing Water Directive) and presence of natural springs were also considered.

The concept of proximity–remoteness has been replaced and the ROS map is now derived from the combination of the RP map with the Opportunity Map. The opportunity map depends on the presence of facilities to enjoy nature and infrastructures to reach the locations. Facilities to enjoy were extracted from Open Street Map amenities, leisure and tourism tags. Coastal areas were evaluated also considering the presence of Blue Flags. The Blue Flag Programme in fact challenges local authorities and beach operators to achieve high standards in the four categories: water quality, environmental management, environmental education and safety. The facilities to reach recreation areas depend on presence of local roads and bike paths.

The approach considers the territorial context, includes the presence of facilities and potentially takes into account different types of users. It is downscalable and allows benchmarking and comparisons of cities. On the other hand it is based on a relatively complex methodology.The concept of this approach is shown in Figure 3.3 which is an example of Recreation Opportunity Spectrum map in the Functional Urban Area of Padova. The approach outlined in Box 2 for Padova has been used across Europe to map the recreation opportunity spectrum for every functional urban area. Two indicators are derived: the total surface area of functional urban area that has a high recreation potential and the total surface area of functional urban area that has a high recreation potential AND a high availability of facilities that support the use of these areas. The second indicator has therefore values that are always lower than the values reported for the first indicator.

On average, functional urban areas are covered for 35% with urban green infrastructure that has a high potential for recreation. High values are evident in the western part of Germany and by extension in cities along the river Rhine. Also in Scandinavia high values are reported. There is also a tendency for high values in cities situated along the southern coastline of the UK and the Atlantic coastline of Portugal and Spain. A similar observation is valid for cities along the coastline of the western Mediterranean Sea between Barcelona and La Spezia (Italy). Also the cities in Greece and Cyprus appear to have high recreation potential (Map 11).

However, if we include the high availability of recreation facilities in the picture, the average percentage decreases from 35% to only 7% (Table 3.3, Map 12). Put another way, 7%, on average, of the total area of Europe's functional urban areas offers a high value for nature based recreation both in terms of potential and available facilities.

Box 2. Concept of the recreation opportunity spectrum: Areas in dark blue are top areas for nature-based recreation within the boundaries of the city offering a high recreation potential and with a high availability of facilities that support recreation.

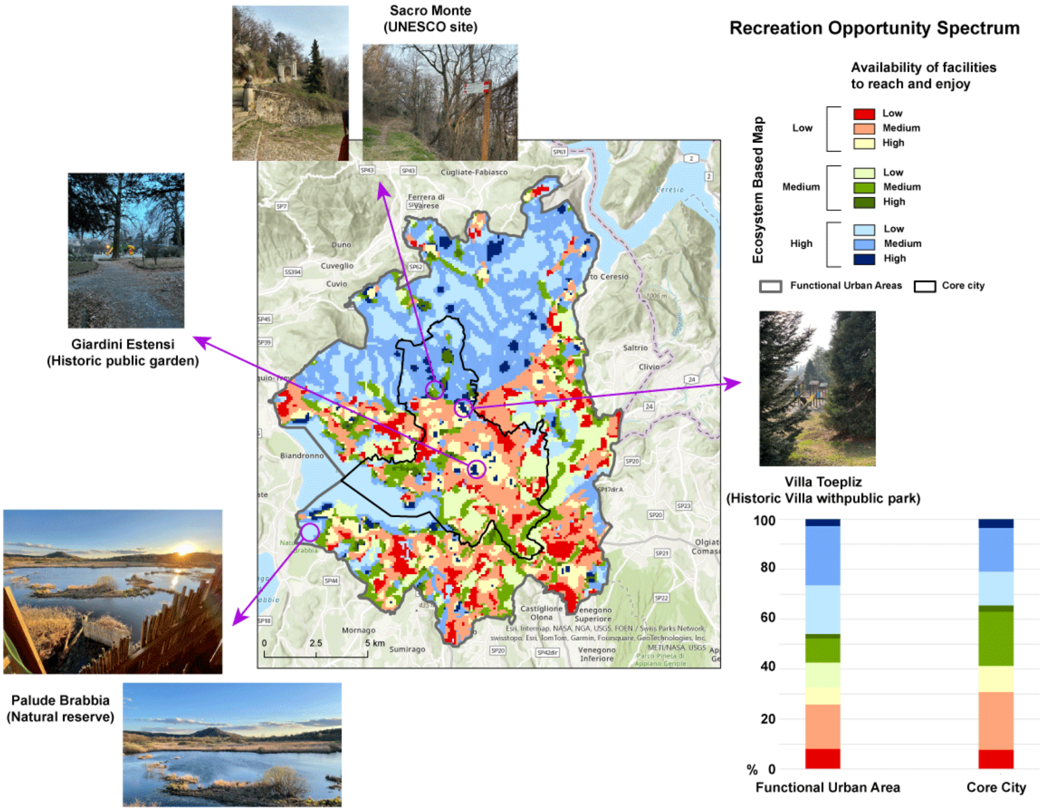


Figure 3.3. The approach for mapping recreation opportunities in cities explained for the functional urban area of Varese (Italy).

The map is a combination of two other maps: a map of the recreation potential which is set by the suitability of land to support recreational activities (urban parks, regional parks, nature reserves, water bodies) and the map which contains information about the presence of facilities that are needed to either reach recreation sites (paths and roads) or of infrastructure that supports recreational activities (e.g., pick nick or resting infrastructure). Both information flows are mapped using increasing quality levels (low, medium and high). Areas in red are areas with low recreation potential; areas in green have medium recreation potential; areas in blue have high recreation potential. For each of these areas, light colours indicate low availability of facilities; dark colours represent high availability of recreation facilities; in between colours represent a medium availability of recreation facilities. Together recreation potential and the availability of recreation facilities constitute nine classes which form the recreation opportunity spectrum in cities for nature-based recreation. Dark blue areas are top areas for nature-based recreation: they have a high recreation potential and have a high availability of facilities to reach or enjoy nature. The data can be summarized in a bar graph (or a pie chart) which represents the distribution of each of these nine types of the recreation opportunity spectrum. The two indicators at EU scale make use of this distribution: one indicator expresses the percentage of the city surface area.

3.3.7 Regulating ecosystem services: flood control and pollination

Finally this chapter reports two indicators that relate to regulation ecosystem services: pollination and flood control.

Pollination is an important ecosystem service for agriculture as wild and managed pollinators are essential to pollinate crops, chiefly fruit and vegetables. This service is also relevant for urban agriculture and food production but to a lesser extent than on farmland. But besides delivering an ecosystem service, pollinators such as wild bees and bumblebees, can also serve as indicators for the overall condition of the urban ecosystem. The benefits that humans derive from insect pollinators indeed extend well beyond food production. Pollinators are important for growing fruit and vegetables in urban gardens and peri-urban agricultural areas but they are also involved in different educational and cultural activities.

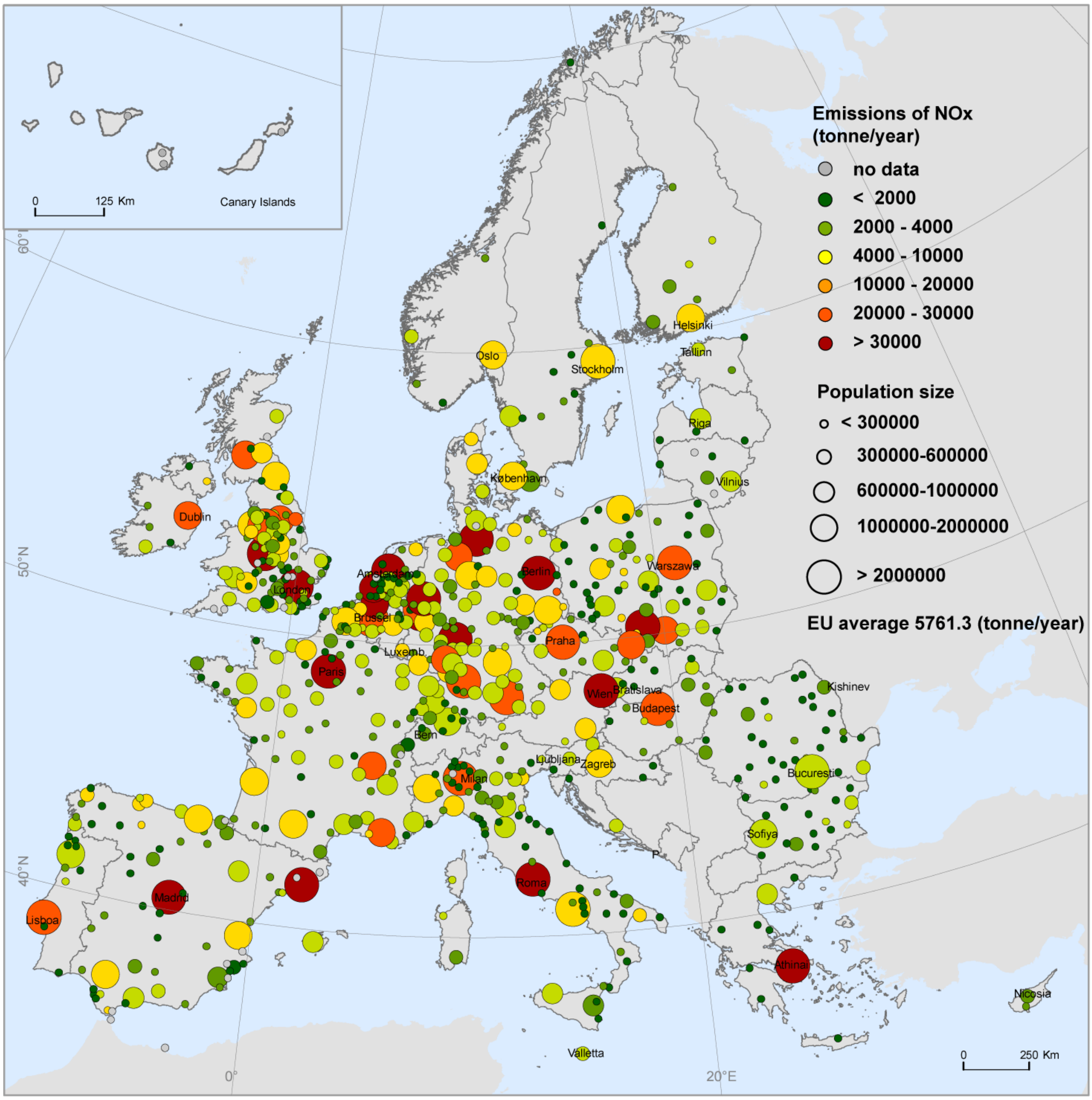
Urban pollination has been mapped using an expert-based approach originally developed at European scale (Zulian et al. 2013a) to map suitability of land to support insect pollinators. The method was used at local scale in Oslo (Stange et al. 2017) to analyse possible conflicts between wild pollinators and domestic honeybees and in Helsinki-Espoo-Vantaa to preserve and enhance a biodiverse urban structure under the pressure of infill development. Here we introduce pollination potential or the suitability of land to support pollinators more as an indicator of the overall quality of urban ecosystems or urban green space. The indicator is dimensionless so the average value at EU level is not so relevant. But it can be used to compare different city types (see also section 4 of this chapter) or cities (Map 13).

Flood risk is an important challenge for cities, certainly in view of a changing climate which may result in more extreme weather events. This chapter contains one indicator which represents the capacity of urban surfaces to control floods. The indicator is based on the JRC work on ecosystem service accounting and follows a similar methodology as described in Vallecillo et al. (2019). Detailed urban land use land cover data were used to apply the Runoff Curve Number (RCN), an approach, originally established from the Soil Conservation Service (SCS) in 1972 for the estimation of the run-off. Specific parameters for urban areas were derived from a dedicated section available in Hydrology training Series, (1989). The basic RCN was refined with information on imperviousness and slope (Vallecillo et al. 2019).

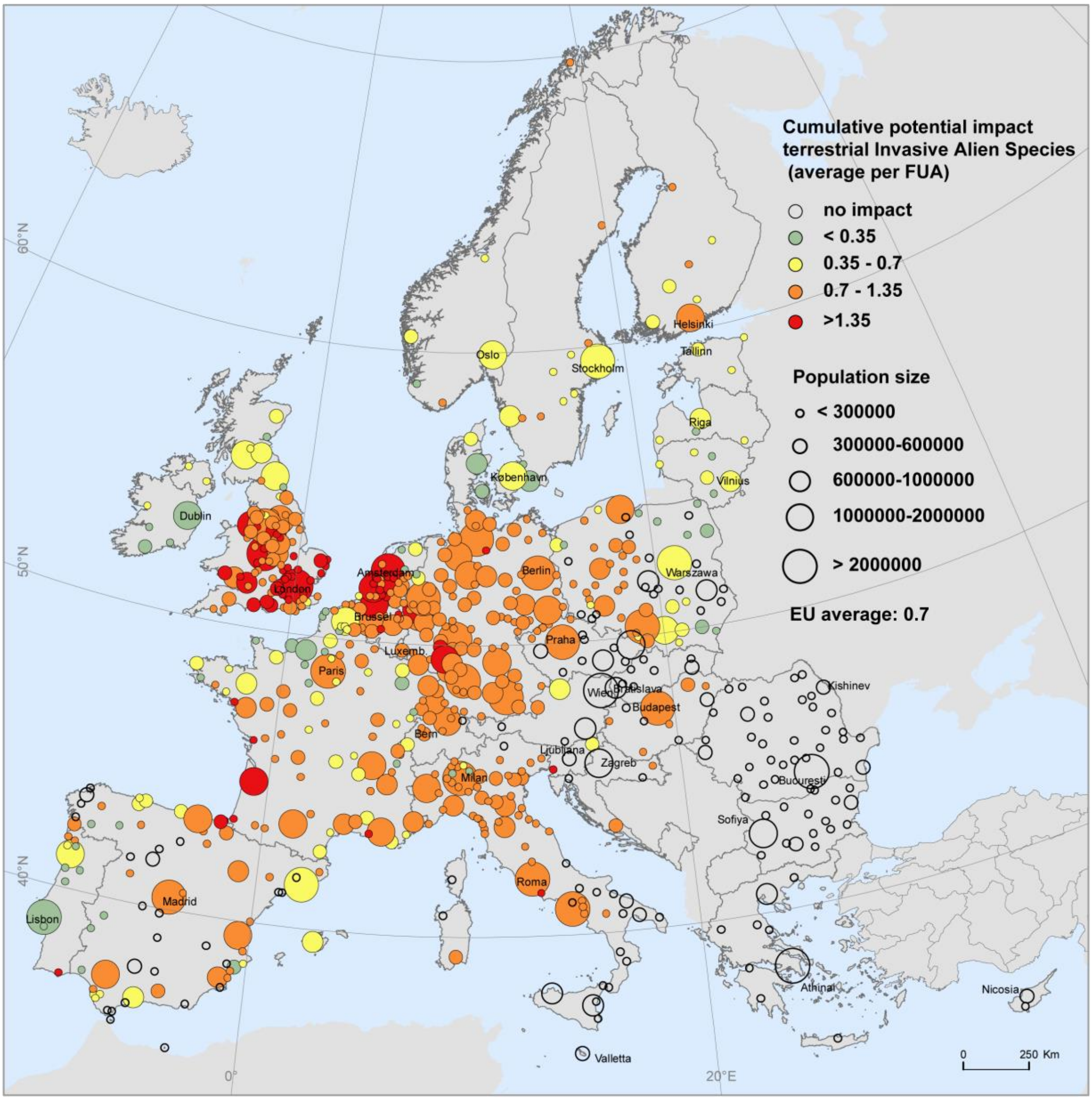
The indicator breaks down the surface area of core cities according to their capacity to control floods. The capacity is simply expressed as low, medium and high. On average the following statistic emerge (Table 3.3): 46% of the core city' surface has a low capacity, 32% of the area has medium capacity and 22% has high capacity. Map 14 shows the distribution of the percentage of land in core cities with low capacity to control floods.

3.3.8 Map section

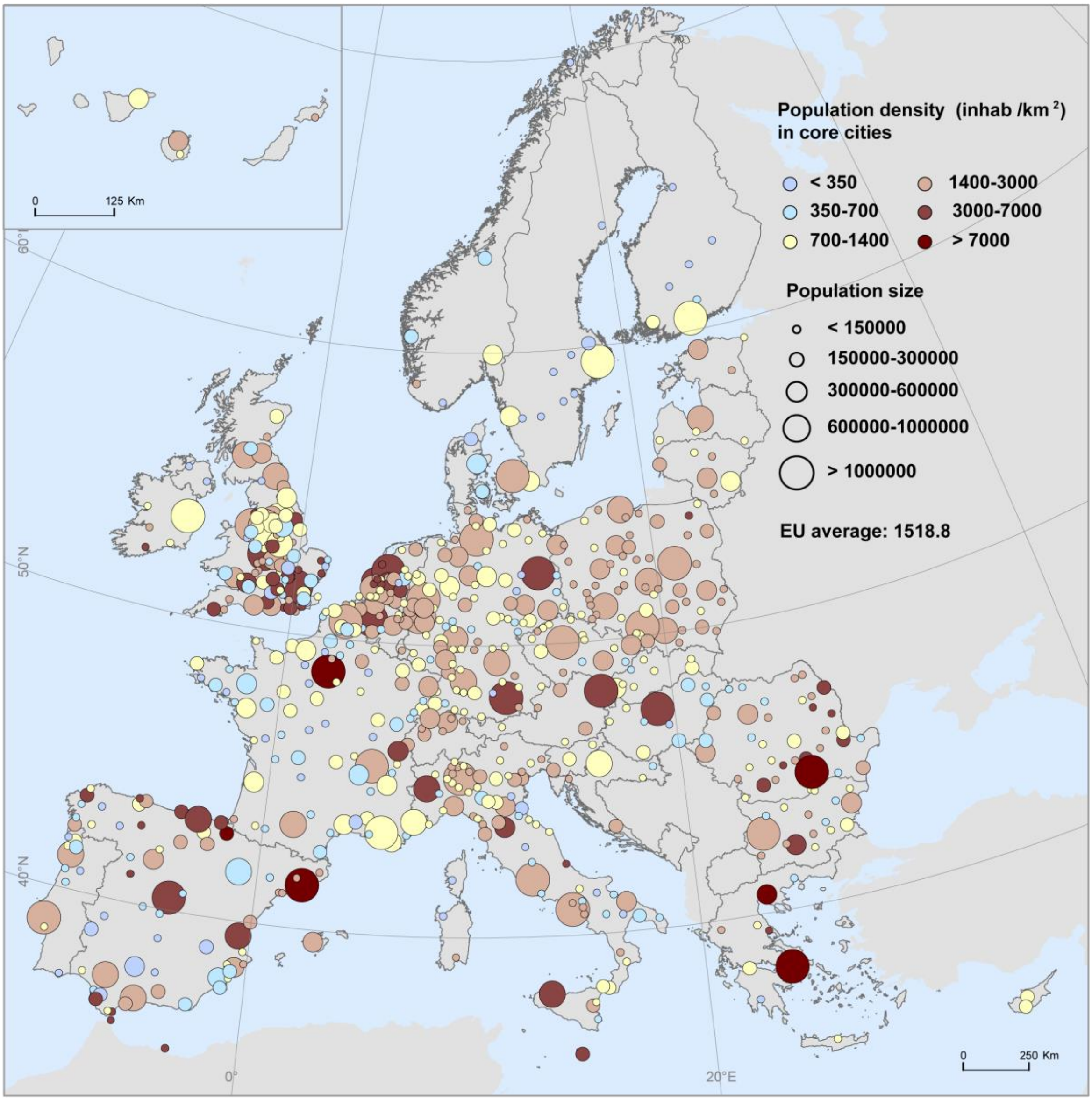
This section contains a set of maps that show the spatial distribution of key indicators that characterise urban green infrastructure in Europe.



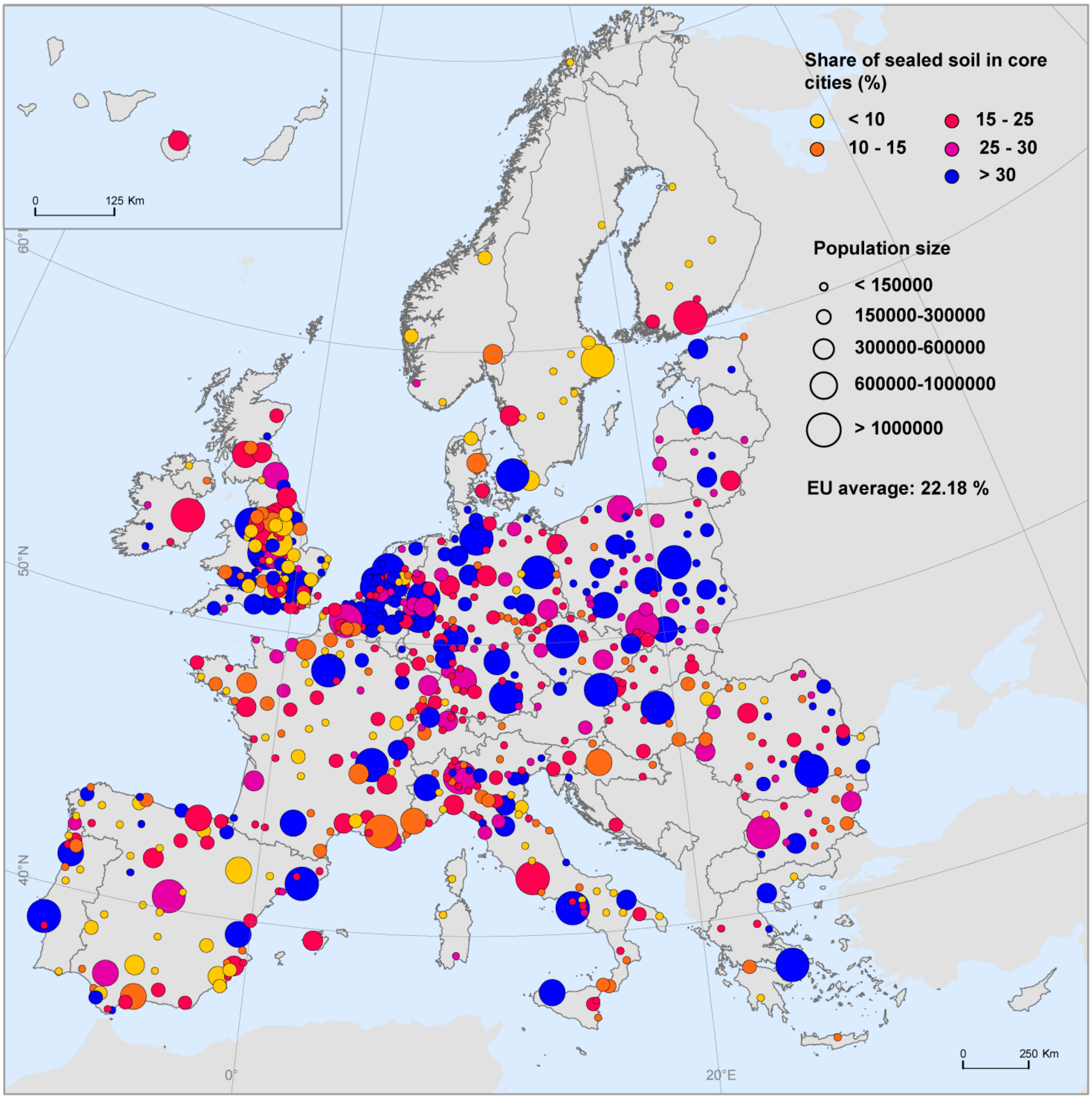
Map 1. Emissions of NOx (tonne/year) in Functional Urban Areas**.**



Map 2. Impact of Invasive Alien Species in Functional Urban Areas.

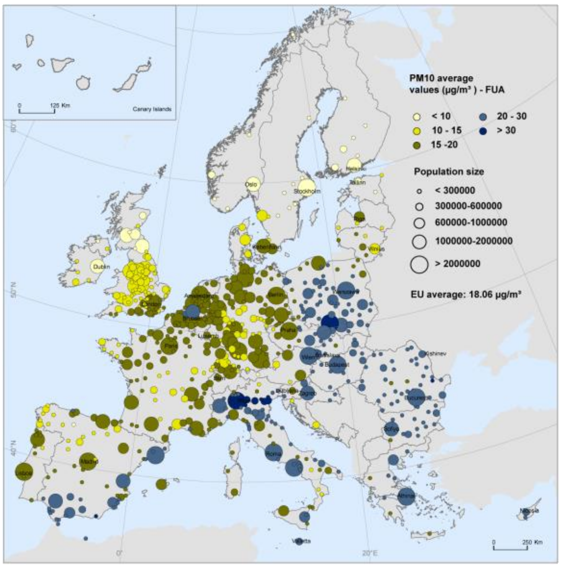


Map 3. Population density in core cities.

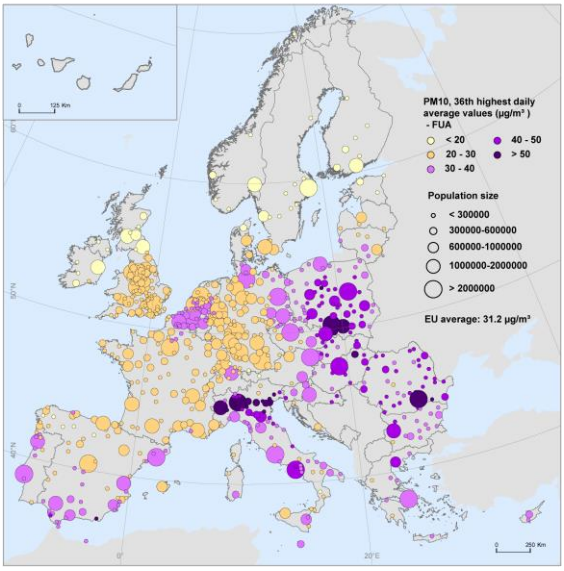


Map 4. Share of sealed soil in core cities**.**

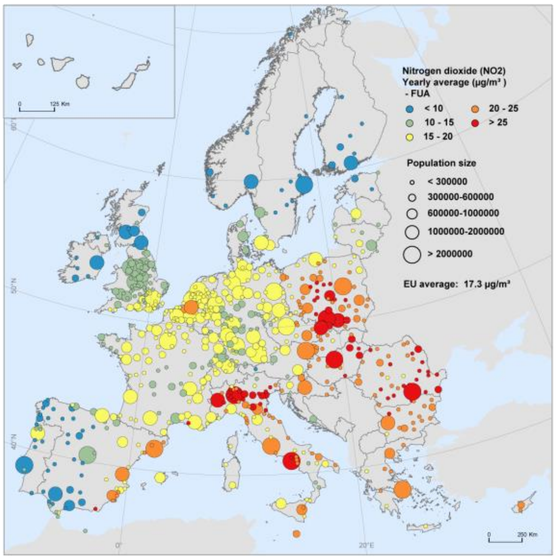
Concentration PM10 Yearly average (µg/m³)



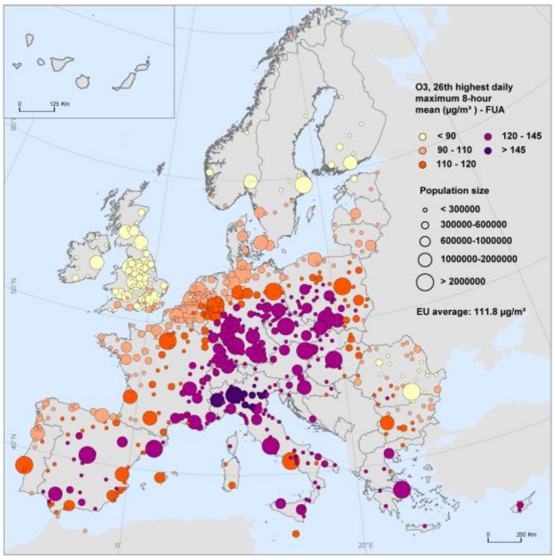
PM10: 36th highest value of daily mean PM10 concentrations (µg/m³)



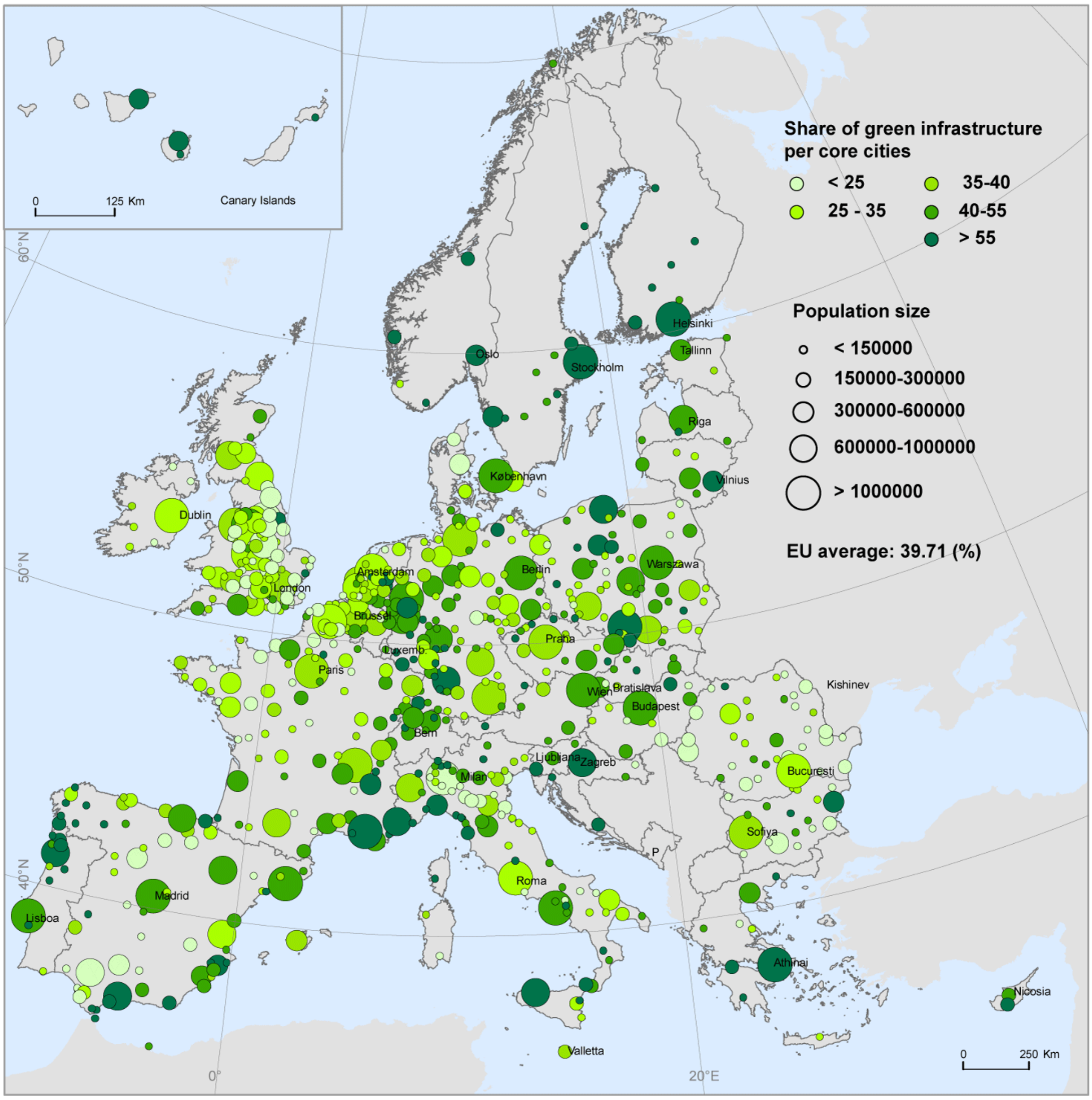
No2 Yearly average (µg/m³)



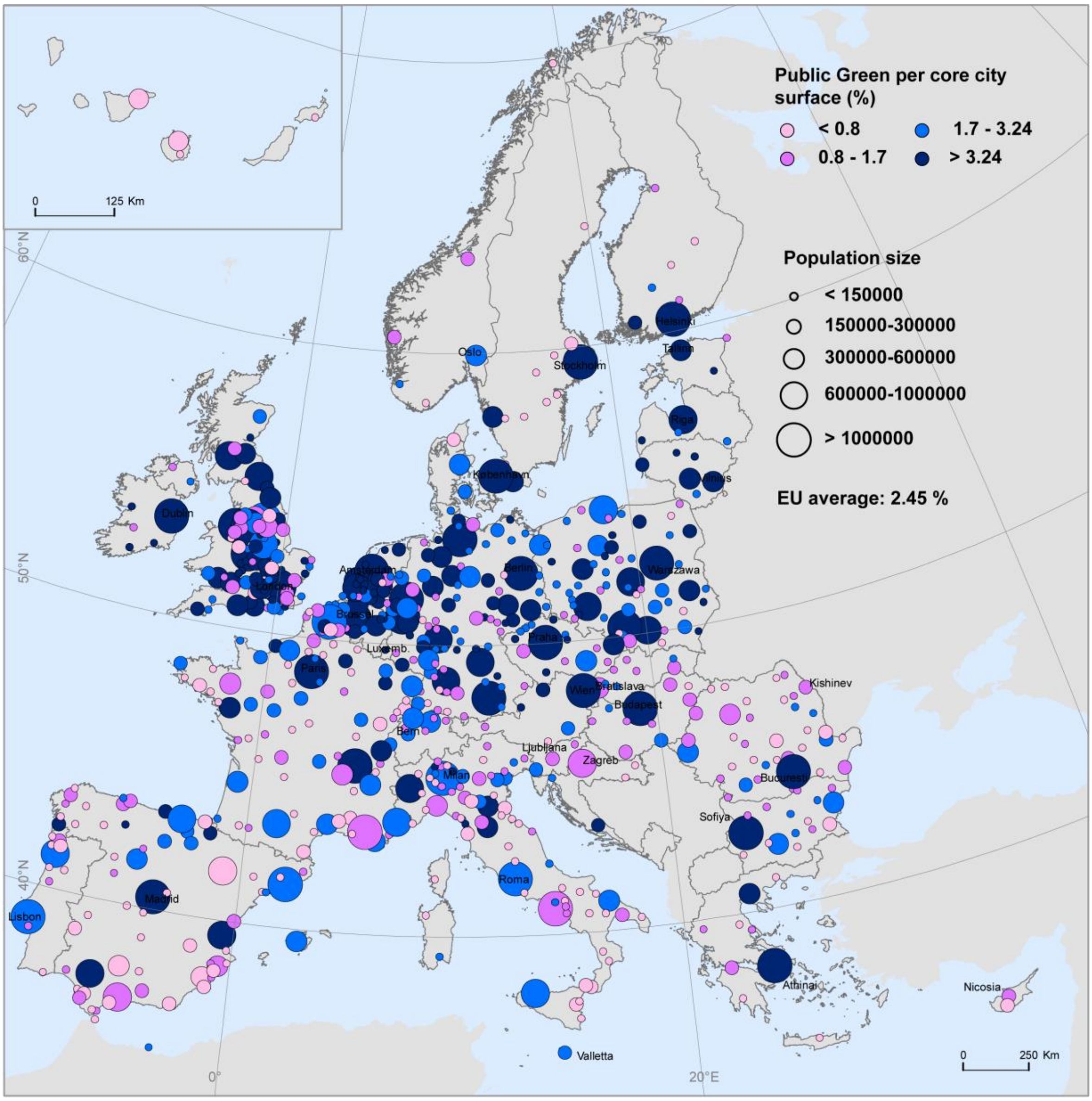
O3 26th highest daily maximum 8-hour value in µg/m³



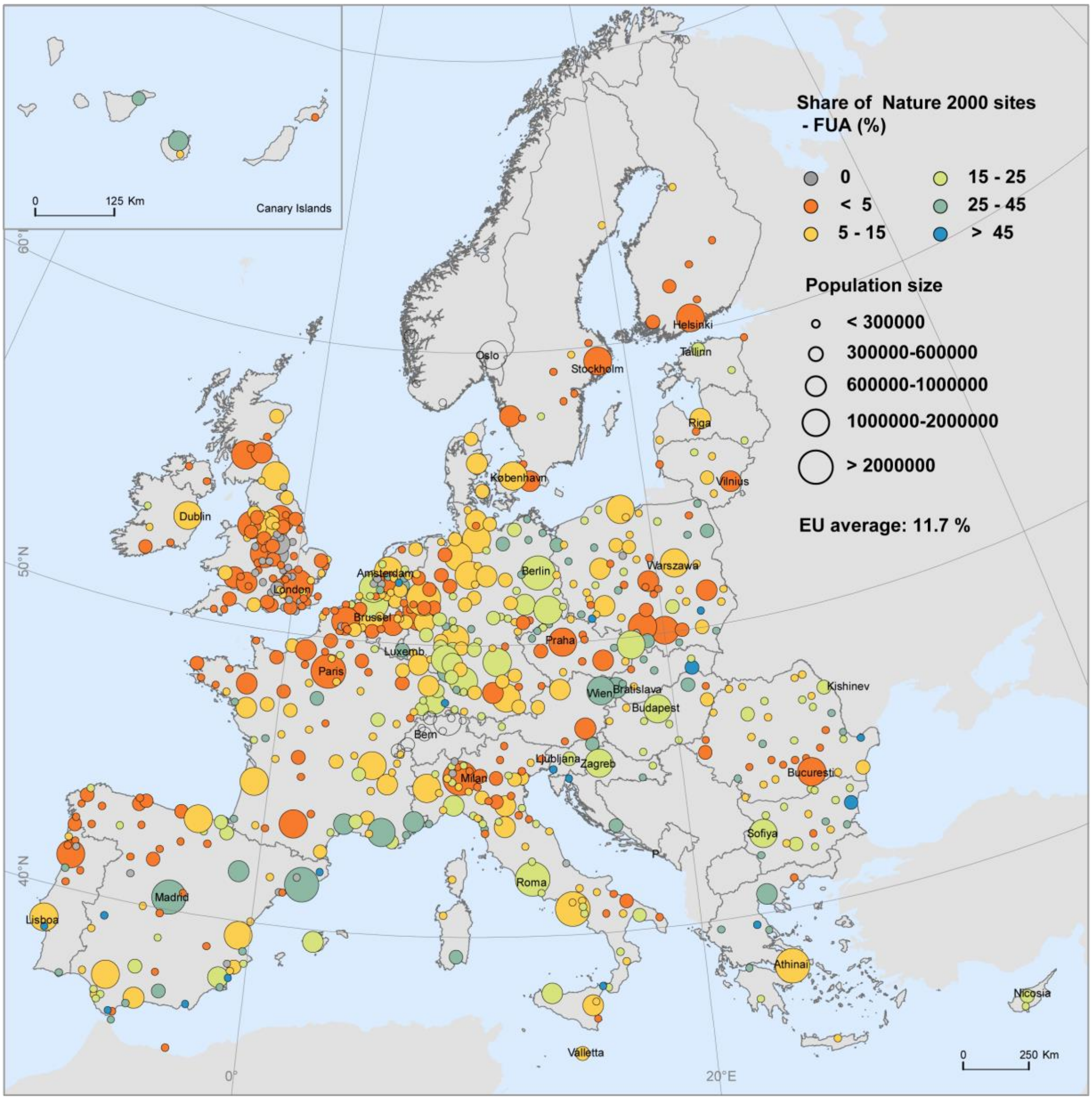
Map 5. Air pollution in Functional Urban Areas. Statistics for PM10, NO2 and Ozone (O3)



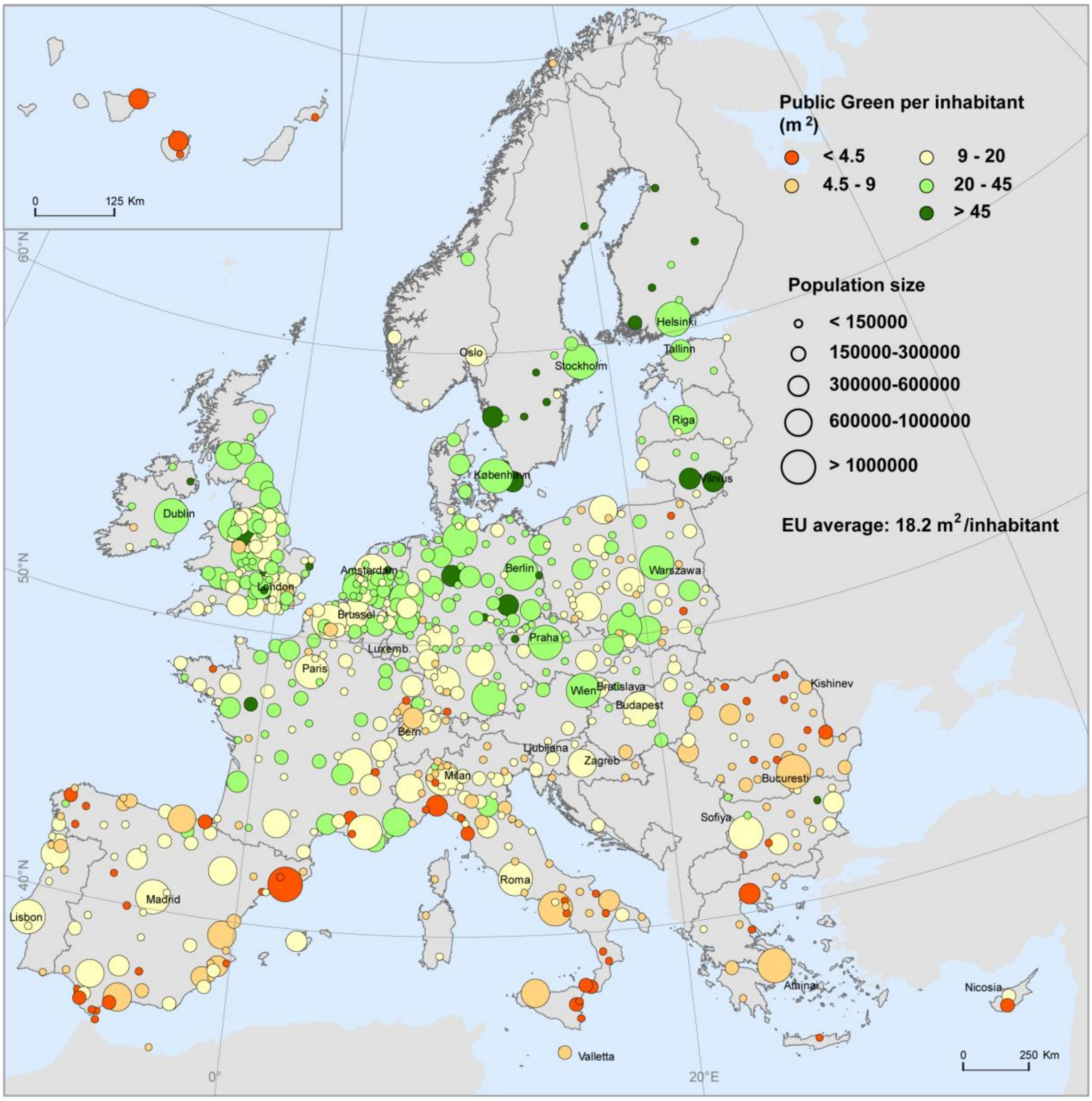
Map 6. Surface area of green infrastructure in core cities.



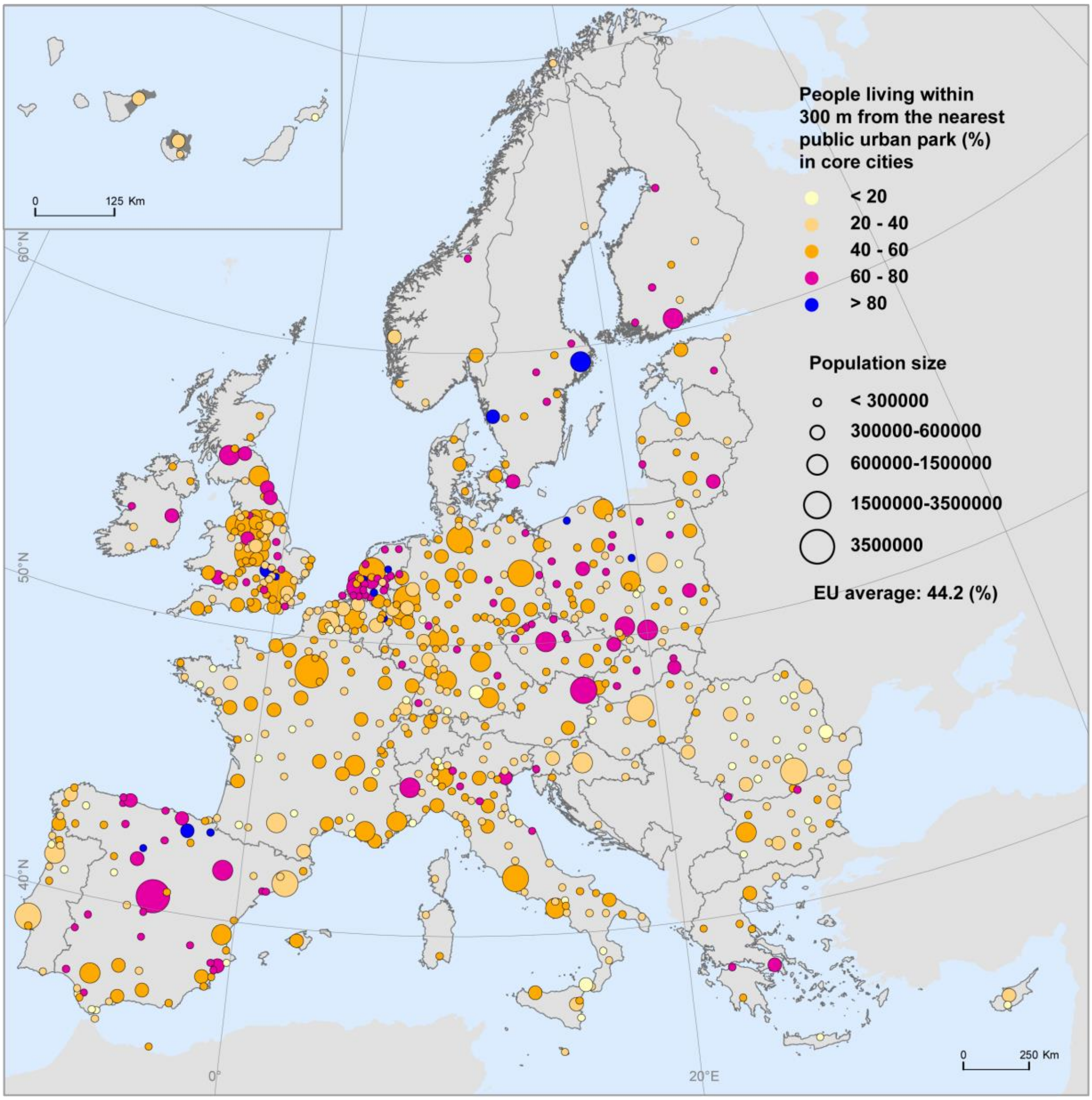
Map 7. Surface area of publicly accessible green space (public parks) in core cities.



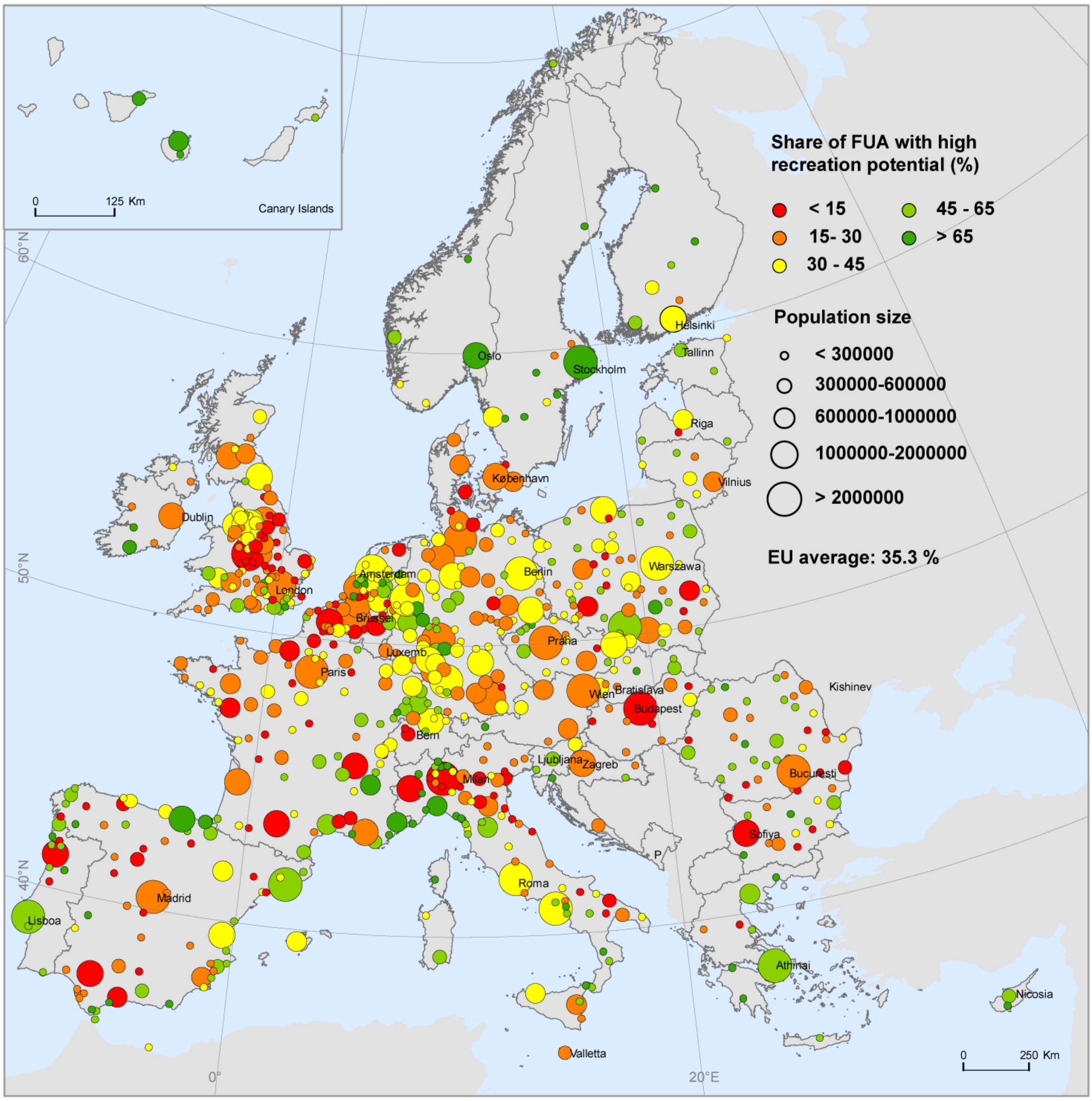
Map 8. The share of Natura 2000 sites in functional urban areas in the EU28.



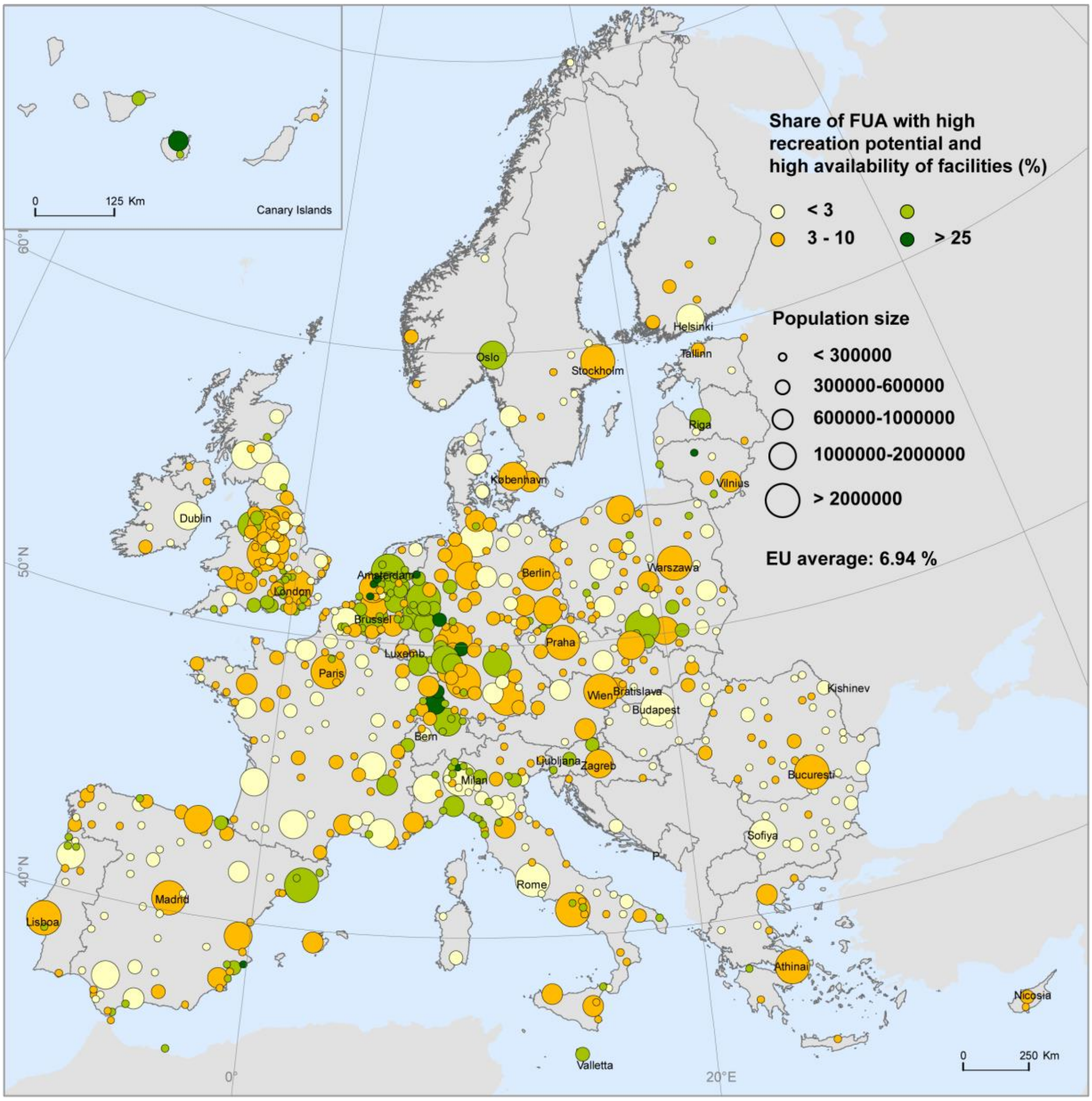
Map 9. Surface area of publicly accessible green space in core cities.



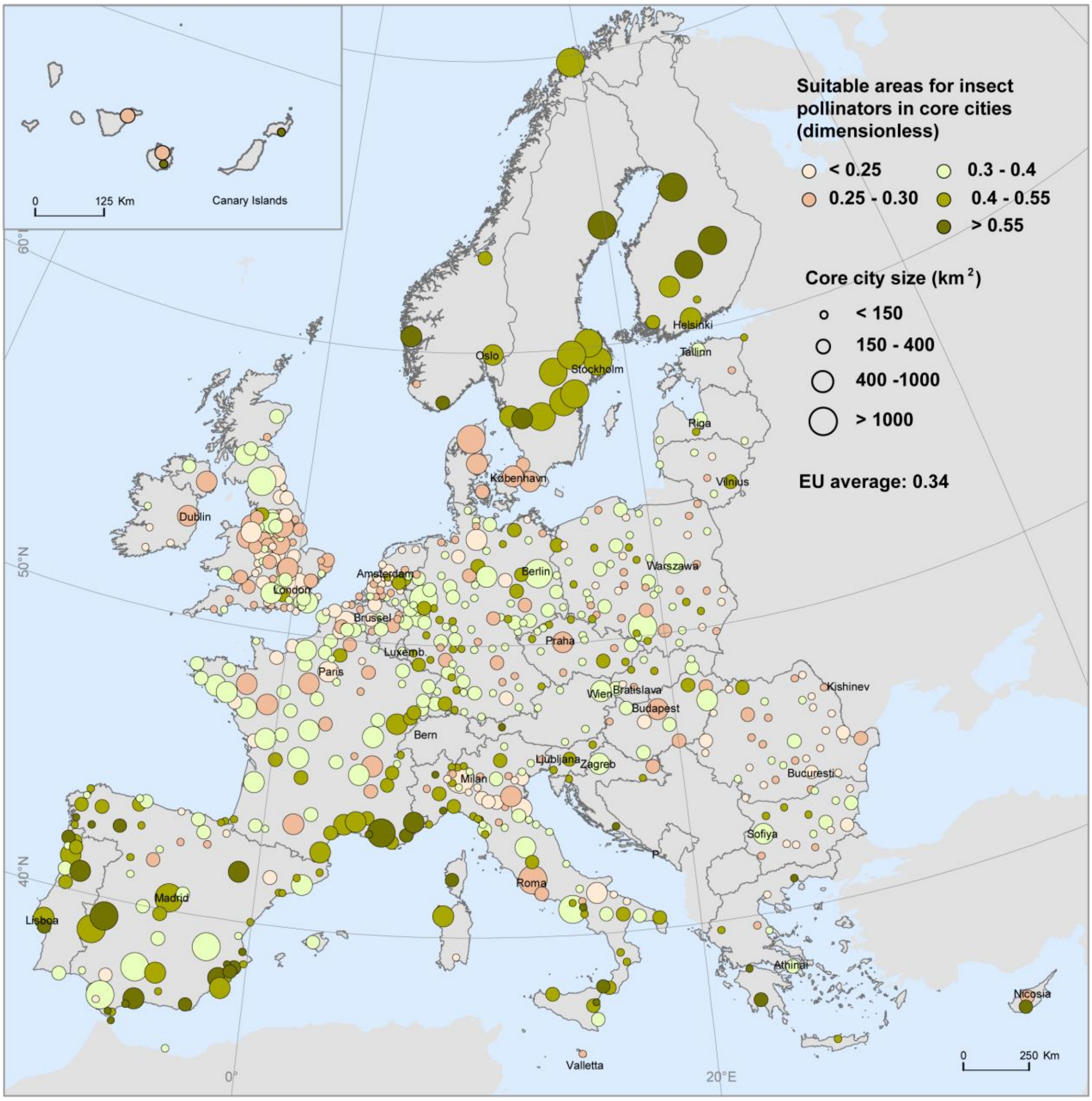
Map 10. Share of the population within 300 m from a public park in core cities.



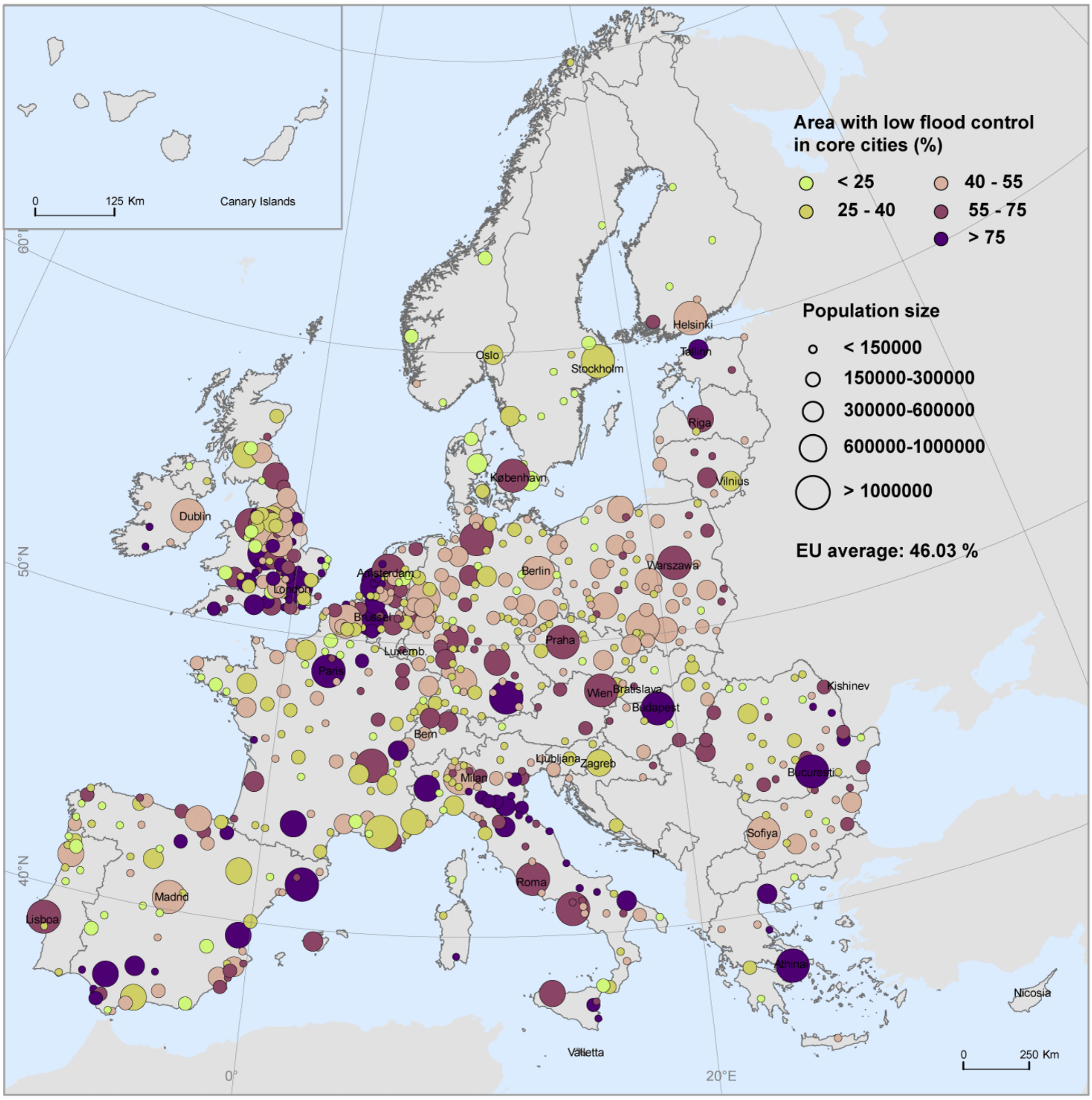
Map 11. Surface area with high recreation potential in Functional Urban Areas.



Map 12. Surface area with high recreation potential and high availability of facilities to reach and enjoy recreational sites in Functional Urban Areas.



Map 13. Pollination potential (suitability of land to support pollinators) in core cities.



Map 14. Surface area with low capacity to control flooding.

3.4 The condition of and services provided by urban green space based on spatial configuration of cities in Europe

3.4.1 Rationale for a typology of cities based on urban green infrastructure in relation to the landscape

This European assessment introduces a specific proposal to organize the collected information of urban ecosystems and their services. This proposal is based on land structure and population density. This is relevant because both land use structure and population density are crucial indicators to understand type and entity of pressures on ecosystems and ecosystem services demand, especially in very artificial systems (Grafius et al. 2018). Ecosystem services are the contributions of ecosystems to wellbeing and their quantification thus needs both environmental and socio-economic information. Land cover, land use and land configuration are key determinants of ecosystem condition and the capacity of ecosystems to provide services whereas population density is a crucial socio-economic variable to characterize cities.

High population density implies high demand of ecosystem services and, at the same time, high pressure on ecosystems that deliver the services (Endlicher et al. 2007). Land use structure and population density significantly affect biodiversity patterns (Leroux and Kerr 2013; Isbell et al. 2017); air pollution concentration (Lamsal et al. 2013) and air pollution exposure (Hixson et al. 2012).

Land configuration, defined as the combination of relative co-occurrence of land use types and characteristics of population density is an interesting criterion to explore pressures on urban ecosystems; structural ecosystem attributes and ecosystem services.

3.4.2 Mapping approach

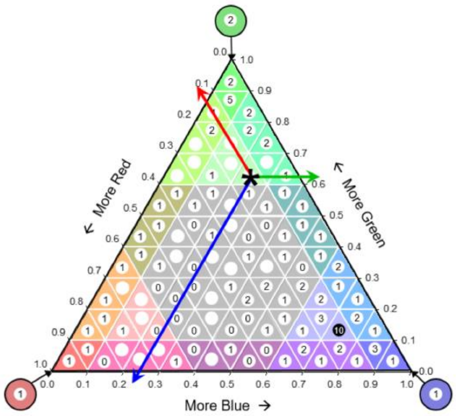
We mapped land configuration at FUAs scale, as we are interested in the structure of cities with reference to the surroundings, namely the areas they are ecologically, economically and socially connected to them (Larondelle et al. 2014).

The co-occurrence of land use types is calculated using the Guido's tool box[2] Land Mosaic Module (Vogt and Riitters 2017). The complete methodology is reported in the Technical JRC report (forthcoming).

A land mosaic is a tri-polar classification scheme that represents the land type dominance, the interface zone and the mix zone within a defined area (20.25 ha in this study). The classification uses the threshold values of 10%, 60%, and 100% along each axis to partition the tri-polar space into 19 classes. These threshold values are indicative for the presence (10%), dominance (60%), or uniqueness (100%) of each land cover type.

[2] GuidosToolbox is available for free at the following web site: http://forest.jrc.ec.europa.eu/download/software/guidos

Table 3.5. Description and examples of land mosaic types.

	Class description	Example
	A location being composed of a single land cover type only (100%) is labelled with double upper letter	*DD* = 100% artificial
	Upper-class letter denotes a respective contribution of at least 60% but less than 100%;	*D* => 99% artificial *Dn* => 10-40 % natural and 60-90% artificial
	Lower-case letter denotes a respective land cover type proportion of at least 10% but less than 60%;	*Nad* 60-80% natural and 10-20 % agricultural and 10-20 % artificial
	A letter does not appear if the respective land cover proportion is less than 10%.	*Dn* has no agriculture,

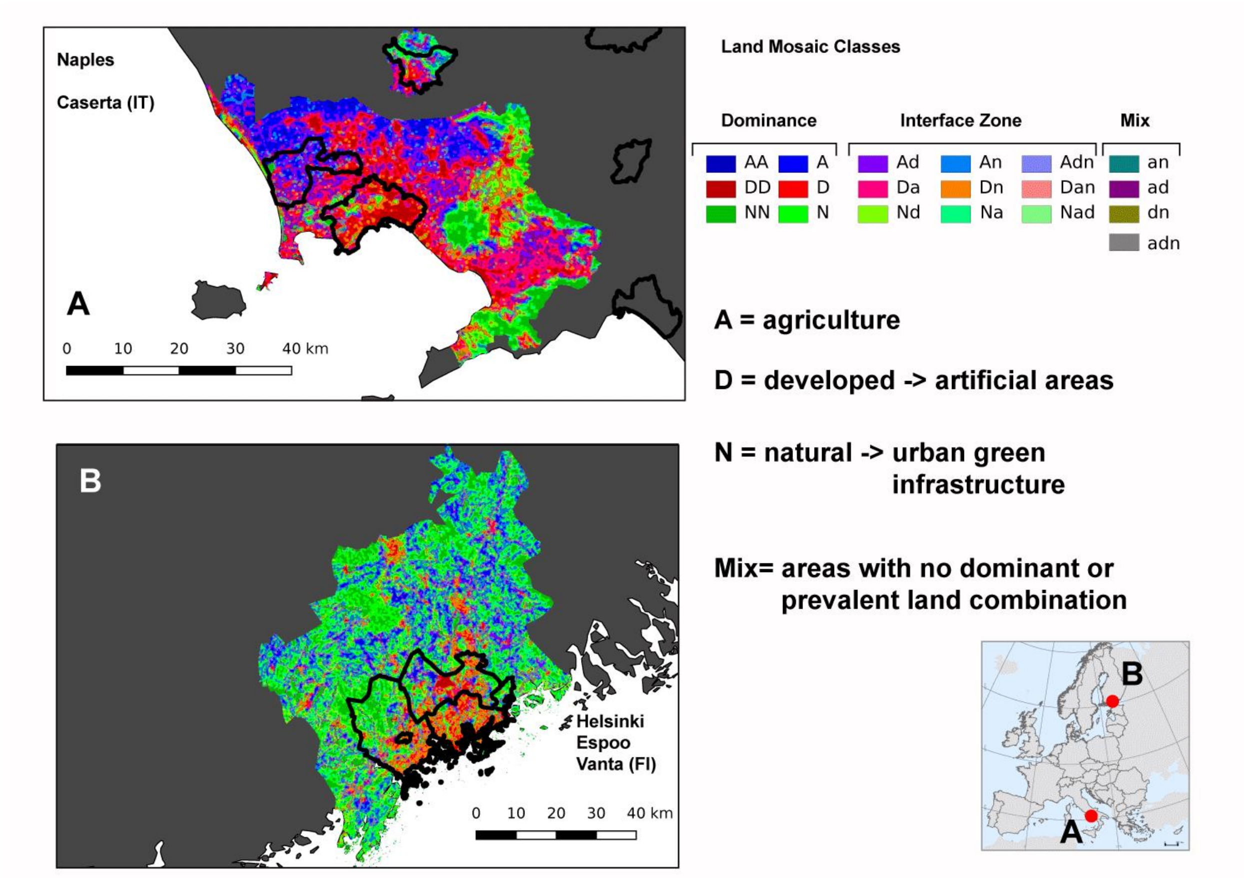


Figure 3.4. Land Mosaic maps in Helsinki (FI) and Naples (IT). A = Agriculture; D = Developed; N = natural; Mix = mixed presence of all land classes.

Using the land mosaic approach, European functional urban areas have been clustered considering three sets of spatially explicit variables (Table 3.6), as suggested in previous studies (Schwarz 2010): urban form, population density and size of the FUA.

Table 3.6. Variables included in the cluster analysis.

Group	Indicator	Notes
Urban form	Share of land mosaic type co-occurrence per FUA (%)	Spatially explicit land form analysis
Population density	Relative lived density within artificial areas in aggregated core cities. To obtain the 'relative lived density' we first computed the 'lived density' per LM types then we use the average population density in European FUAS as reference value (Acosta-Alba and Van der Werf 2011) in order to compare cities.	Using this measure we can gain a more nuanced perspective of settlement patterns and relative densities
	Ratio between city-surrounding (luz) and core population (core) density	This value gives an order of magnitude of difference in population density within the same FUA inside and outside the aggregated core city boundary
	Population density within the FUA	
	Population density within the aggregated core city	
Size	Size of FUAs	

3.4.3 Typology

Following this rationale FUAs have been clustered in 6 types attributable to three fairly homogenous sets of characteristics:

Type 1: Small compact FUAs: Small cities characterized by a relative high population density, often with absence of commuting zone (73 % of the cities belonging to type 1 do not have a respective commuting zone)

FUAs characterized by presence of semi-natural and natural areas in their surroundings (type 2; 3; 4). In this group of cities, we denote a dominance of peri-urban green infrastructure and different forms of transition to the city core.

Type 2: Mixed land cover FUAs: This group is characterised by "mixed land" or high heterogenic anthropic activity ("and" land mosaic class) and a relatively remarkable difference between population density in core city and surroundings. A mixed land cover corresponds to an absence of a dominant land type.

Type 3: Forest FUAs: The presence of natural ecosystem types (dominance of peri-UGI) characterizes this group, together with a relative low population density and the presence of areas of transition to small patches of agriculture.

Type 4: Agri-Green FUAs: This group is characterized by presence of agriculture and transition to semi natural areas in a relatively vast surface.

FUAs characterized by presence of agricultural and artificial land in their surroundings.

Type 5: Agri-artificial FUAs: This group presents dominance of agriculture and transition to artificial (Ad Land Mosaic class) in a relatively vast surface with low FUA population density.

Type 6: Artificial FUAs: This group shows a prevalence of artificial areas in transition from-to agriculture. Population density is very high. There is no significant difference between population density within and outside core cities, which means that we find high population density also outside the city (see Naples in Figure 3.4).

The distribution of the six types is presented in Figure 3.6 whereas more details per city type are presented in Table 3.7.

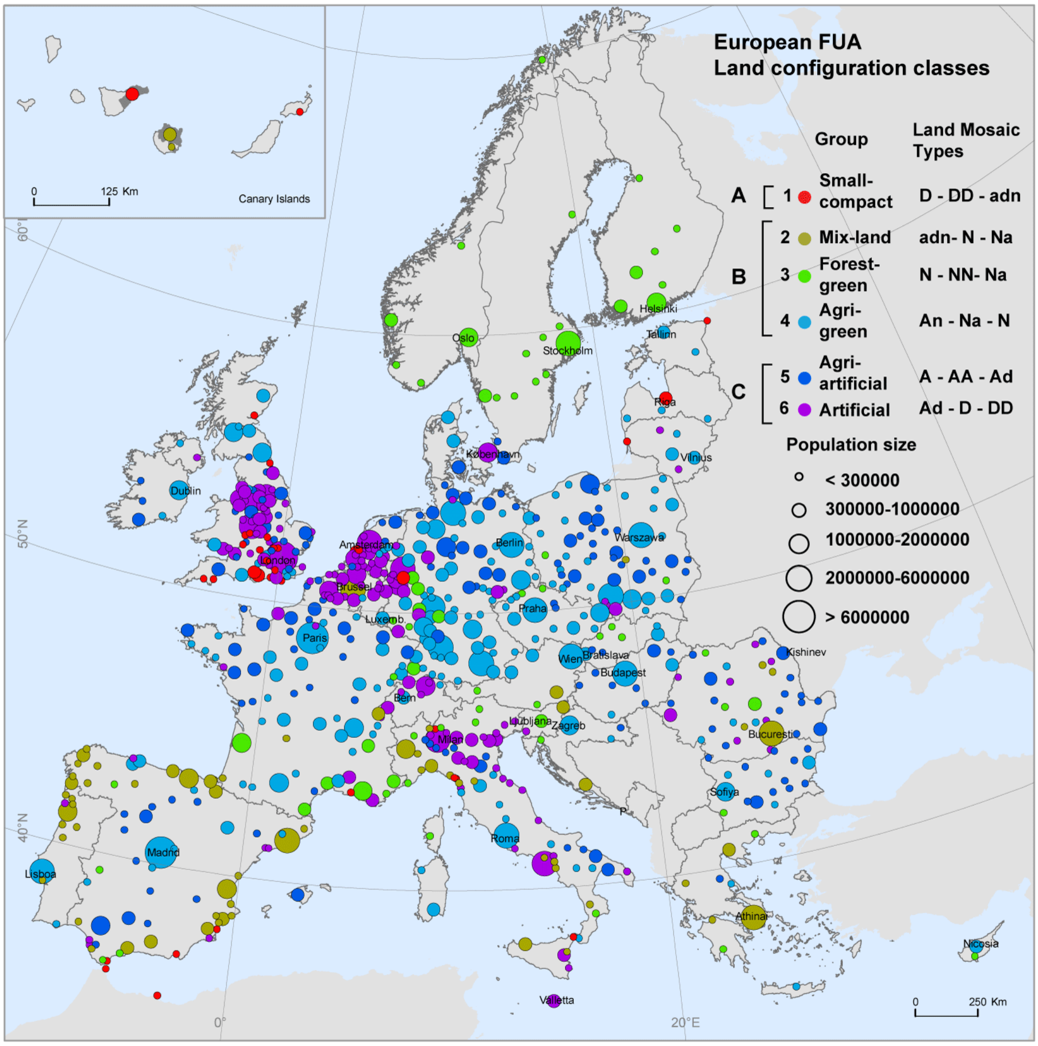
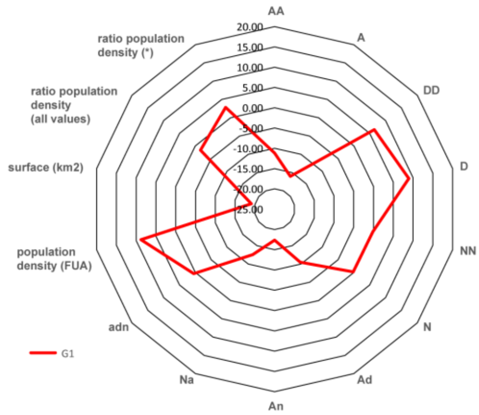
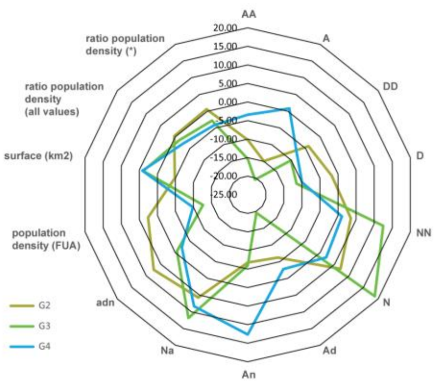
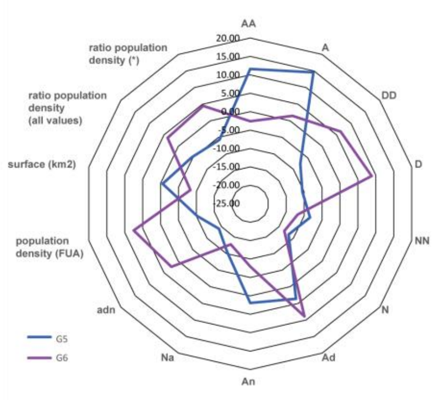


Figure 3.6. Spatial distribution of European functional urban areas with reference to land configuration.

Table 3.7. Characteristics of the different land city types.

<table>
<tr><th>Type</th><th>Figure</th><th>Description</th></tr>
<tr><td>Small compact FUAs</td><td>
</td><td>38 cities (5.5 %)
high share of developed areas with a very high population density, characterized by very small differences between the core city and the surroundings, but we have to consider that 73 % of cities within group 1 do not have a commuting zone and they have a relatively small size.</td></tr>
<tr><td>Mixed land cover FUAs</td><td rowspan="3">
</td><td>67 cities (9.7%)
High share of semi-natural areas (N) with the co-occurrence of transition to agriculture (Na) and a prevalence of mix land mosaic type (and). Population density is relatively high, with a relatively remarkable difference between population density within and outside the core city.</td></tr>
<tr><td>Forest-FUAs</td><td>67 cities (9.7%)
High share of semi-natural areas with the co-occurrence of transition with small agricultural patches.
Some of the FUAS have a relatively big size and low population density.</td></tr>
<tr><td>Agri-Green FUAs</td><td>199 cities (28.8%)
FUAS characterized by transition between Agriculture and semi-natural Areas. Some of the FUAS have a relatively big size and high core population density (e.g. Paris; Rome; Madrid).</td></tr>
</table>

Type	Figure	Description
Agri-artificial FUAs	 	169 cities (24.5%) Dominance of agriculture and transition to artificial (Ad). areas. Some of the FUAS have a relatively vast surface and low population density.
Artificial FUAs		150 cities (21.7%) Fuas characterized by high presence of artificial areas (transition from agriculture and dominance of artificial). Population density is very high, with not very relevant difference between the core city and the surroundings (which means that we find high population density also outside the city.

3.4.4 Variability of key indicators across city types

This section presents a more detailed assessment of the indicators reported in section 2 of this chapter and breaks the indicator values down over the six different city types. Figure 3.7 contains minimum, maximum and average values for the set of indicators per city type. The different city types are always ranked in descending order based on the average indicator value.

The behaviour of the indicators as presented in Figure 3.7 shows that the typology of cities with respect to urban green infrastructure and their embedment in the surrounding landscape matrix is highly relevant. Almost all the indicators exhibit a high variability in the average per city type as well as a high variability in the range of values. This is especially evident for the key indicator of this assessment, the share of green infrastructure per core city. But it is also the case for population density, share of public green space per core city, impact of invasive alien species, soil sealing, all the air quality indicators, share of Natura 2000, recreation indicators, pollination and flood mitigation.

Two indicators with a low variability in the average per city type but a high variability in the range of values: NOx emissions and the public green per inhabitant. One indicator, share of population living within 300 m, does not substantially vary over the different city types.

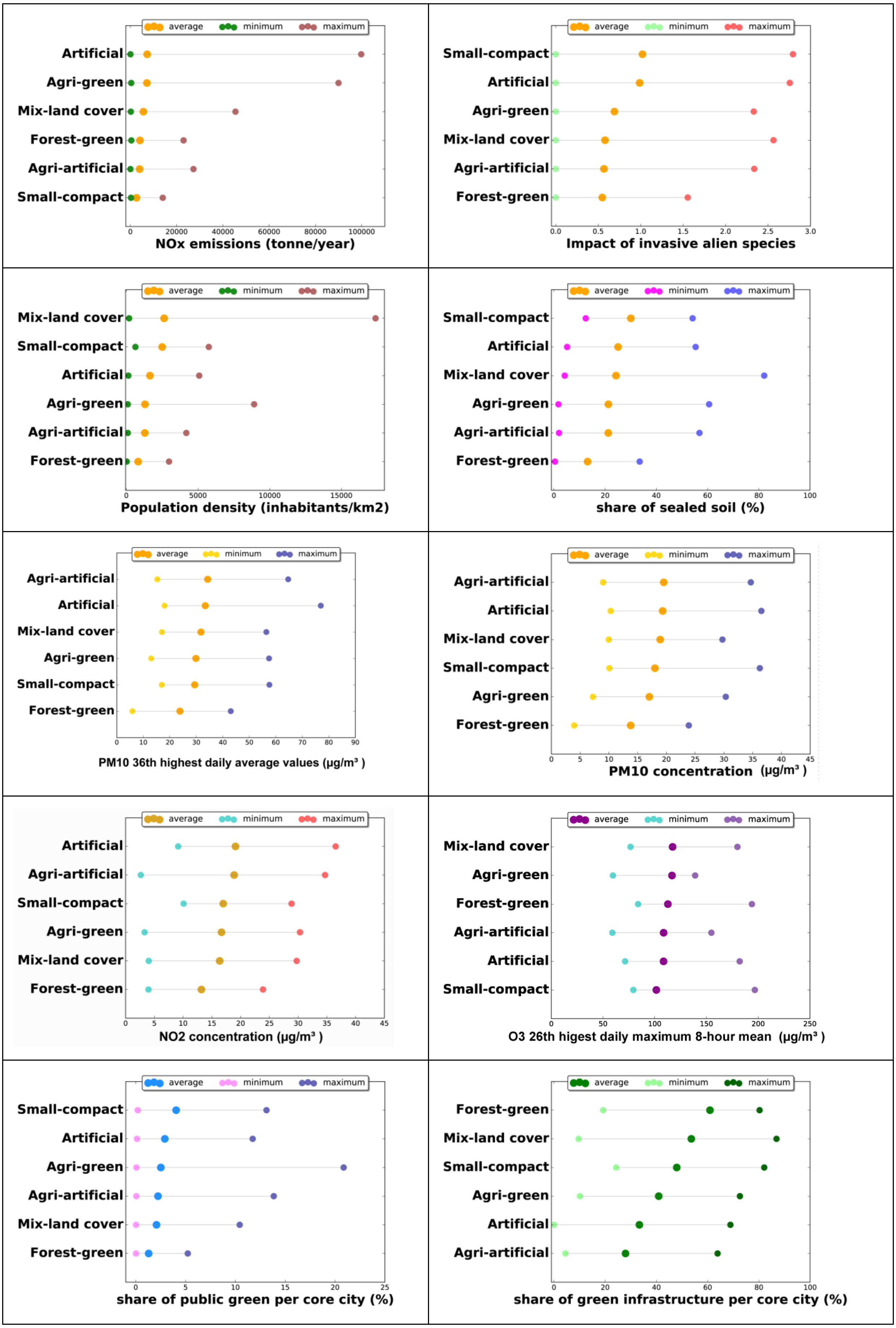
Small and compact cities have evidently a high population density and a higher average share of soil sealing. Interestingly, they also have the highest share of publicly available green space (urban parks), measured as a percentage over the total area of the core city. But in absolute terms, the average area measured in squared meters per inhabitant and the range around this average is lower than in other city types. Compact cities score well for cultural relative to other cities but they have, on average, the largest area with a low capacity to mitigate floods.

Forest-green cities have the highest values for regulating ecosystem services and for recreation potential. They have a lower than average level of soil sealing and population density. They score better for air quality indicators than other city types. The share of urban green space is high (as is the share of Natura 2000), but interestingly this seems to go at the cost of the share of public urban green space (urban parks). Nevertheless 34% of Forest-green cities are in Nordic Countries (Norway, Finland and Sweden) where people can benefit of the freedom to roam, or "Everyman's right". “Everyman's right” is the general public's right to access certain public or privately owned land, lakes, and rivers for recreation and exercise. The availability of public parks is compensated by the opportunities provided by the Everyman’s right.

Mixed land cover cities have the highest population density of all city types. In addition, no other city type has higher ozone levels. In fact, the distribution of average ozone concentrations over the different city types matches well expectations. Ozone concentrations are typically higher in rural areas relative to urban areas where ozone is degraded following reaction with NO released by traffic. This gradient is also clear from Figure 3.7 with increasing levels of ozone towards city types with a mixed land cover type. This city type has for most other indicators average values and ranks mostly between other city types.

A similar observation is valid for agri-green and agri-artificial cities, which are closer to the European average. The agri-artificial type is characterized by lower air quality than agri-green, at least for PM10 and NOx. Agri-green cities have higher values for urban green space indicators including coverage by the Natura 2000 network and for ecosystem services than agri-artificial. This latter type exhibits poor values on the recreation indicators.

Cities with a predominance of artificial land cover are clearly performing worse than other city types with respect to the two pressure indicators (NOx emissions and invasive alien species), soil sealing, air quality and coverage by Natura 2000. They have a lower share of urban green infrastructure but perform reasonably well in terms of public green infrastructure. They have a low capacity for flood control. Also suitability for pollinators is low in this type.


average
minimum
maximum
Artificial
Agri-green
Mix-land cover
Forest-green
Agri-artificial
Small-compact
NOx emissions (tonne/year)
Small-compact
Artificial
Agri-green
Mix-land cover
Agri-artificial
Forest-green
Impact of invasive alien species
Mix-land cover
Small-compact
Artificial
Agri-green
Agri-artificial
Forest-green
Population density (inhabitants/km2)
Small-compact
Artificial
Mix-land cover
Agri-green
Agri-artificial
Forest-green
share of sealed soil (%)
Agri-artificial
Artificial
Mix-land cover
Agri-green
Small-compact
Forest-green
PM10 36th highest daily average values (µg/m³)
Agri-artificial
Artificial
Mix-land cover
Small-compact
Agri-green
Forest-green
PM10 concentration (µg/m³)
Artificial
Agri-artificial
Small-compact
Agri-green
Mix-land cover
Forest-green
NO2 concentration (µg/m³)
Mix-land cover
Agri-green
Forest-green
Agri-artificial
Artificial
Small-compact
O3 26th higest daily maximum 8-hour mean (µg/m³)
Small-compact
Artificial
Agri-green
Agri-artificial
Mix-land cover
Forest-green
share of public green per core city (%)
Forest-green
Mix-land cover
Small-compact
Agri-green
Artificial
Agri-artificial
share of green infrastructure per core city (%)

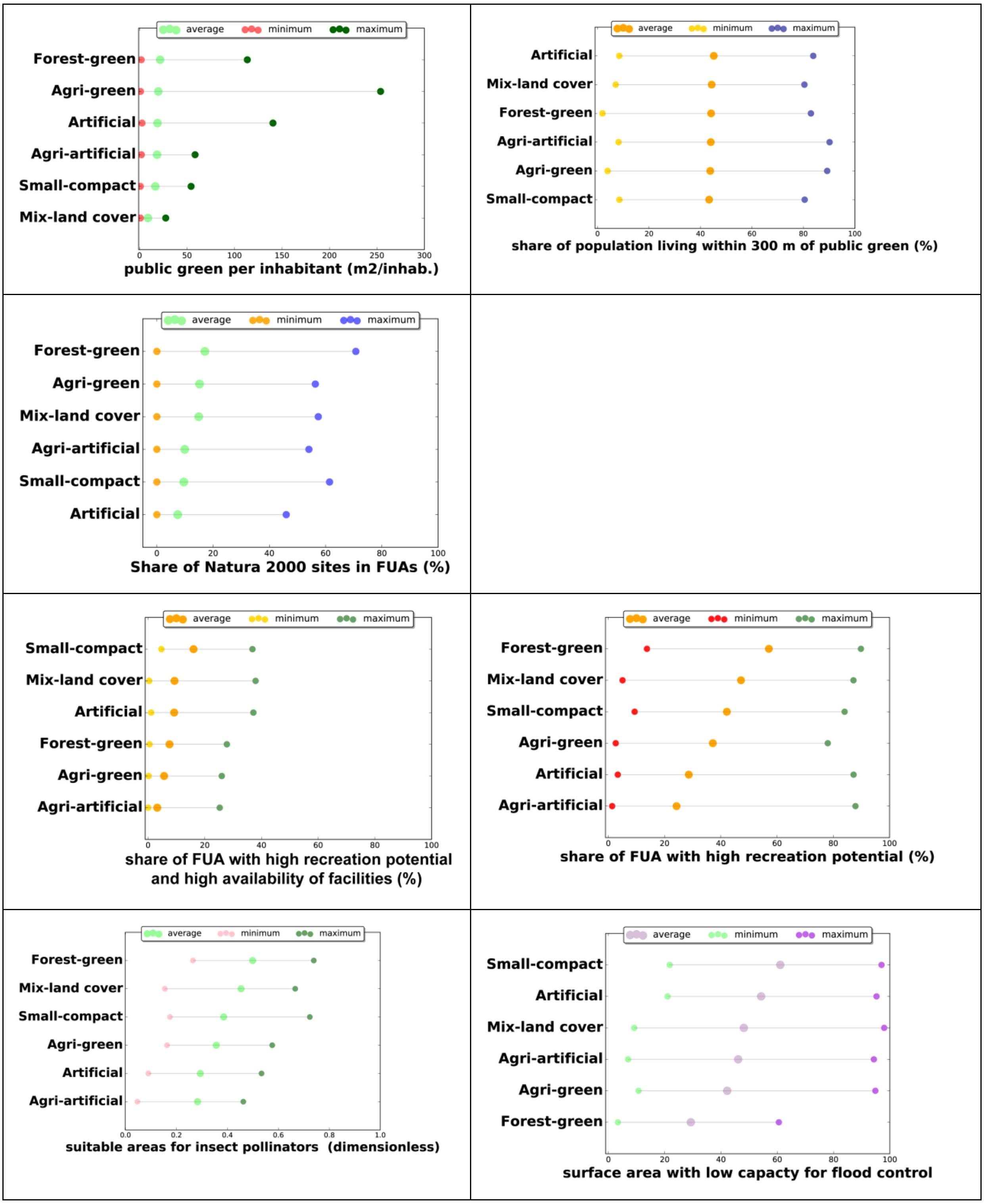


Figure 3.7. Average and range of the UGI indicators per city type.

3.5 Limitations of the approach

A first and foremost limitation is capacity. The approach developed here is very resource intensive. More indicators for ecosystem condition and ecosystem services of urban green infrastructure are under development but could not be fully developed in the frame of EnRoute. The development of one ecosystem service map at European scale, which has to be developed from zero, takes typically 12 person months. This estimate is based on the long standing experience of the JRC project team which is competent for ecosystem services mapping. So a start has been made with the development of more regulating ecosystem services maps including temperature regulation (important for mitigating the urban heat island effect) and water regulation but the development of this maps experienced several obstacles such as conceptual difficulties in finding a suitable an meaningful indicator at EU level, data storage problems (in case of the use of remote sensing data) and computing capacity, even when we have access to cluster computing facilities.

A second, important limitation is set by the urban environment itself. As stipulated in the introduction of this chapter, mapping approaches that have been developed at EU level to map and assess ecosystem services delivered by cropland, grassland, forests and semi-natural areas cannot easily be applied for urban systems. Mostly because the resolution used for these mapping exercises is simply not detailed enough for urban areas, and therefore also not relevant for policy purposes. A detailed mapping approach is necessary to understand the dynamics of urban green infrastructure.

3.6 Policy relevance

Urban policy is in the first place relevant at local governance scale. Decisions about spatial planning, transport, and well-being of citizens are taken by councils and policymakers of cities and municipalities. As a result, there is a distance between an assessment of urban green infrastructure performed at the EU scale and direct policy relevance for urban decision making and planning. However, also regional, national and EU governance levels matter for urban planning. A key result of the MAES urban pilot (Maes et al. 2016; 4th MAES report) was that cities are more likely to have a policy on urban green infrastructure if there is such a policy at higher governance level. Policy initiatives at higher governance level can support local policymaking by providing examples and case studies, guidelines, benchmarking, supporting tools, or funding. In this perspective, the creation of an EU knowledge base on urban green infrastructure, through EnRoute, is important and can support countries, regions and cities with the collection of relevant data, methodologies and tools to support local initiatives and planning involving urban green infrastructure. The data collected in this EU wide assessment will be made available on the JRC data catalogue on the MAES collection page. The tools developed under the EnRoute project have been successfully used at local scale to support cities in mapping pollinator habitats and recreation opportunities. In addition, the recognition of the different types of patterns according to which urban green infrastructure is organized is important for developing guidance on good management practices. A set of common recommendations, which considers the landscape matrix in which cities are developed, is possible.

Importantly, the indicators, maps and underpinning data will be used to support an EU wide ecosystem assessment which will evaluate the state of Europe's ecosystems and their services based on an analysis of available data. The assessment will cover the whole EU territory, including urban ecosystems. The assessment serves two main policy requests: (1) provide an evaluation of the headline biodiversity target of the EU Biodiversity Strategy to 2020 in general and of Target 2 in particular and (2) provide a baseline as well as support to the definition of smarter targets for the post-2020 biodiversity policy. The assessment will be carried out during the course of 2019 under supervision of the working group MAES.

A future application, so still to be implemented, is the contribution to green infrastructure planning at regional scale. Urban green infrastructure does not need to stand on its own but should be integrated in a larger, strategically planned network. The substantial overlap between functional urban areas and the Natura 2000 network on the one hand, and the efforts to strengthen the coherence of the Natura 2000 network through green infrastructure on the other hand, demonstrate the need to better integrate urban and regional planning of green infrastructure. This is particularly relevant in the frame of Action 12 of the Action Plan for Nature, People and the Economy, which aims to provide guidance to support the deployment of green infrastructure for better connectivity of Natura 2000 areas.

EnRoute has contributed over the course of 2018 to the drafting of the action plan of the partnership on sustainable urban land use and nature-based solutions. This partnership operates under the urban agenda of the EU. The actions are assorted under three main categories: better regulation, better knowledge, and better funding. EnRoute results can particularly support the better knowledge actions:

Action 3 (Identifying and managing under-used land): The approaches to compute urban ecosystem services can be used to assess the usage of open space.

Action 4 (Indicators of land take): The indicators on soil sealing and the approach for calculating the amount and structure of urban green infrastructure are available for use.

Action 5 (Promoting FUA cooperation as a tool to mitigate urban sprawl). Our study has tested the FUA approach for collecting and analyzing data that can support mitigation of several environmental challenges including sprawl.

Action 8 (Awareness raising in the areas of nature-based solutions and sustainable use of land (urban sprawl). The assessment data can be used to benchmark cities and compare performance on the functions delivered by urban green infrastructure among cities in Europe.

Action 9 (Agreeing on common targets and indicators for nature-based solutions, urban green infrastructure, biodiversity and ecosystem services in cities). Currently there are no such targets. The EnRoute EU wide assessment can serve as a baseline against which progress to possible targets can be measured.

3.7 Conclusions

1. This chapter presents a first EU wide assessment of the urban green infrastructure in Europe's 696 functional urban areas (FUA). The indicators used to assess urban green infrastructure (UGI) span a variety of measurements: pressures, pollution levels, soil sealing, the amount and configuration of UGI, the coverage by Natura 2000 sites, recreation opportunities and specific metrics to assess the level of three regulating ecosystem services.

2. The assessment reveals that core cities in Europe are for about 40%, on average, covered with UGI. The amount of publicly accessible urban green space (urban parks) is, however, much less and estimated at 2.45%, on average. The relatively high coverage of UGI should be used as an argument to increase the relevance of urban green infrastructure in policy and planning processes.

3. Urban dwellers in Europe have, on average, 18 m^2 publicly accessible urban green space to their availability which is double the standard recommended by the World Health Organisation. However, less than halve of the citizens can easily reach public urban green space: they have to walk or travel more than 300 m to reach the nearest public park. 7 % of the FUA, on average, is delivering high recreation potential and high availability of facilities for recreation. Large spatial variation of these numbers across Europe is evident. Recreation is a key function of urban green infrastructure. The numbers reported in this study as well as the tools developed to assess where and what share of the population has access to green space represent a first baseline for further action and for improving the quantity and quality of urban green spaces in an inclusive way.

4. 46% of the FUA area, on average, has a low capacity to mitigate floods. The share has to decrease at the benefit of areas with medium or high capacity to mitigate floods and flood risk. Increased flooding risk is an important concern of cities, as also shown in Chapter 2. The strategic implementation of UGI will be an essential nature-based solution to address this challenge.

4 What factors define a successful science-policy interface on urban green infrastructure?

4.1 Introduction

The collaboration between scientists and policymakers is often referred to as the science-policy interface (hereafter abbreviated to SPI). Scientific information can play a positive, informing role in the development of policies. This was confirmed by the outcomes of the urban pilot (Maes et al. 2016; 4th MAES report). The MAES urban pilot, which preceded EnRoute, made proposals for mapping and assessment of urban ecosystems, green infrastructure and ecosystem services and analysed the policy relevance of MAES at a local scale. The pilot study concluded that the assessment of urban green infrastructure could play a positive role in engaging urban green infrastructure (UGI) to fulfil different societal goals.

EnRoute elaborates on the outcomes of the MAES urban pilot. In particular the project explored how scientific information is used in policy and planning processes at local scale and how it could inform policy/planning in operational terms. The implementation of scientific knowledge in (local) policies is, however, not always perfect. In 2017, Vodopivec and Vries did a first, qualitative survey using interviews with experts to analyse obstacles in SPIs on urban green infrastructure (see Zulian et al. 2018; EnRoute Progress report). This study revealed that (1) the type and format of the information delivered by scientists determines how policymakers use this information, and (2) understanding the timing and complexity of policy cycles in terms of planning and implementation processes constitutes a main barrier for scientists. For the group of experts interviewed in the study, the used scientific and administrative terminology was not a problem, although studies of Young *et al.* (2013), Weichselgartner and Kasperson (2010) and Timaeus *et al.* (n d.) also identified the use of specific jargon as a main obstacle in SPIs. These authors point out that the personal relationship between scientists and policymakers can enhance or hinder mutual collaboration, a key point which will return also as an obstacle for the SPI on urban green infrastructure presented in this chapter.

Furthermore, Janse (2008) who focused his survey on SPI communication channels showed that different expectations of relevant topics and outcomes could impede a successful implementation of further goals and guidelines. All these studies show the importance of **good communication, knowledge, terminology and the relationship itself in a successful SPI**. Young *et al.* (2013) and Timaeus et al. (n. d.) went one step further and refer also to the importance of SPI functions, objectives and given resources as an important reason for their success.

Considering these points, a second survey in the EnRoute project used the different phases of the urban planning cycle (see Felson *et al.*, 2013; URBACT Guide, 2016) as a frame to guide the participants of the survey through the development, implementation and assessment of an UGI project by analysing the scientific relations and obstacles (Figure 4.1). The survey targeted policymakers and scientists. Additionally general questions about the SPI functions and personal background were asked to crosscheck with the occurrence of obstacles and the use of science. Hence, the following questions are investigated by the survey:

1. Which obstacles occur where in the planning cycle between policymakers and scientists?

2. Which scientific support is required by policymakers in the different planning steps?
3. What is the scientific contribution in an UGI project?

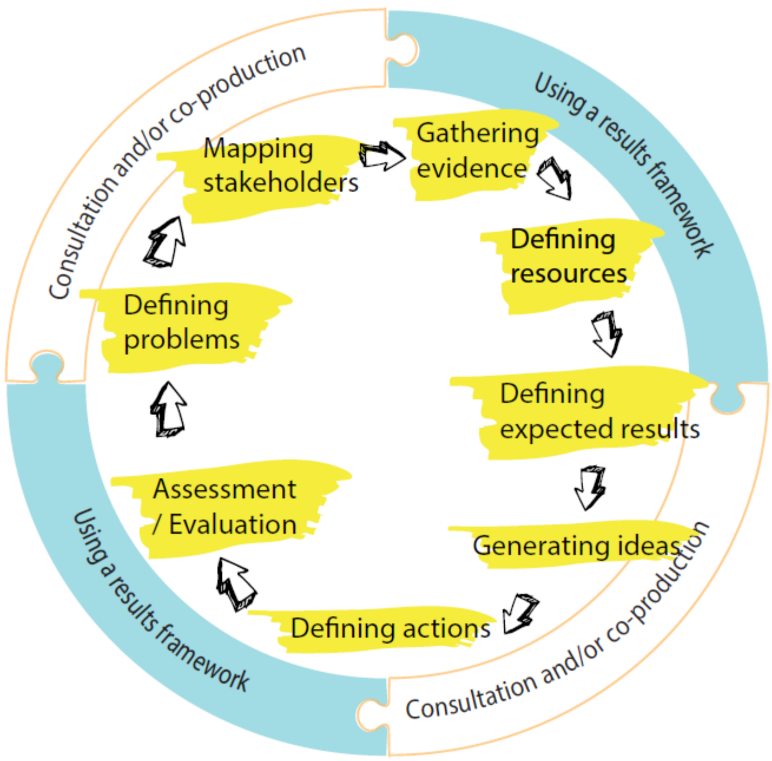


Figure 4.1. Action-Planning cycle used as a frame to organise the EnRoute online survey on science policy interface on urban green infrastructure (URBACT, 2016).

4.2 Methods and structure of the survey

4.2.1 Methods

A web-based quantitative survey approach was implemented based on a broader empirical analysis of location and number of participants and by using a predetermined set of questions.

EUSurvey was used as web-tool to visualise the questionnaire as well as for the collection of results. The platform provides a range of question types and the degree of complexity needed. Furthermore, the official tool from the European Commission generates confidence among the participants and hence, might have increased the rate of answers.

By sending the survey to local policymakers, city planners and research institutes all over Europe a spectrum of experience and planning background was covered. We used the projects as well as our research network to spread the survey including a request to send the link of the survey to own local, regional, national or supranational contacts. A second strategy to invite participants in different countries was to search for UGI papers with city test cases and write to the authors with the request to send the link of the survey to the project participants.

4.2.2 Structure of the online survey

Taking into account the findings of the literature review and the research questions, the survey covered in the first part the scientific impact along the administrative-planning cycle. The four city-planning steps were implemented in the survey based on the action-planning cycle of the URBACT Guide (2016) (Figure 4.1) and the design process phases from Felson et al. (2013). The work of the latter authors, dividing UGI projects into the different sub-planning steps, allowed marking the intensity and output of collaboration of policymakers and scientists for each step. Also considered in this part was the needed and given information of policymakers and scientists. In the second part, the questions covered the SPI functions and structure as well as the personal experience. Hence the survey questions were organized along a sequence of seven parts: the initial contact, the city planning, SPI functions and personal experience, also shown in Annex 1. By applying multiple choice questions, the intensity is measured from no collaboration to full collaboration. See Table 1 in the Annex 1 for the full questionnaire, type of question and indicators.

To distinguish the participants based on their experience in UGI different "filter questions" were applied before starting with the main survey, which addressed only respondents involved in a full SPI. Hence, the sequence of questions the participants get was depending on their first answers. In the questionnaire of the policymakers, a broader introduction part was chosen to clarify the focus and topic of the survey and cover the different background and terminology within UGI projects. The rest of the survey questions and structure was similar to each other to reflect the two perspectives. The structure and sequence of questions in the survey are summarized in Table 4.1.

Table4.1. Structure of the survey and information about the different sections or the survey.

Section of the survey	Description
Initial contact to filter the role and expertise of the participant	The initial contact had two functions: to distinguish scientists from policymakers and to categorize participants by their experience with UGI projects. Depending on their answers, different questions appear on screen. If participants had never been involved in an UGI project the questions focused on knowledge and information to understand the obstacles even before collaboration started. If they had been involved in a GI, questions focused on collaboration, information and communication. **a) Science section**: two pathways were possible. Scientists never involved in an UGI project and scientists involved at least once. The first group was only asked about the reasons of non-participation before the survey ended. The second group was asked about the initiative of the first contact and the awareness of scientists about their role as information provider. The kind of contact related to the personal background and experience of the scientist can be one reason for a good implementation of a

	SPI. The awareness of the information they provided can have a relation to the background but also be a reason for obstacles or a good implementation. **b) Policy section**: three pathways are possible. Policymakers who have never been involved (handled like the first group of scientist). The second group had been involved into an UGI project using scientific information but without including scientists to the project. This group is later called "incomplete SPI". Here questions about the knowledge transfer were asked. The first and the second group were guided directly to the personal information section to consider the same questions as in the science part. The third group were policymakers who had been involved in an UGI project with scientists and is referred to as "complete SPI". As in the science part, the initiative of the first contact and the knowledge scientists had about the role of their information are asked.
Phase 1 of the project: Contact and Framework, Scope of the scientific engagement	This section analysed the scope of the scientific involvement defining the different parts of the policy action plan and expected outcomes.
Phase 2 of the project: Consultation and implementation: explores the impact of the scientists	This section showed what type of implemented project actions were supported by scientists
Phase 3 of the project: Post-Processing: Long-term effect acquisition	This last section out of the policy-action cycle had naturally a strong scientific relation and the outcome can be advisory for other projects.
Phase 4 of the project: Assessment and evaluation: Explores the outcomes of the collaboration	This section referred to the SPI in terms of including specific scientific outcomes into a policy action plan (complete or successful SPI). Also included were questions about (1) the reasons of a failure of scientific impact into long-term actions and (2) the obstacles participants faced but which could be successfully addressed. Relating the latter with the personal background, SPI functions and intensity of scientific impact constitute a good indicator for a well-functioning SPI.
SPI functions exploring the complexity of the interactions	The dimension, complexity and experience of the specific SPI is important to assess failed or successful SPIs.

Personal background: Explored the type of experience of the respondents	As discussed in the introduction, success of a project refers to the person itself. So the final section draws near the personal impact and asks about the relationship between scientists and policymaker and hence an understanding of each's background of terminology and working procedures as well as the person's amount of experience.

4.3 Results

A complete list of questions and the frequency of answers per question is provided in Annex 1. The survey was made available online from March 2018 until May 2018. Despite using publicity on several online platforms and website of research projects related to nature- based solutions, urban sustainability and green infrastructure, only 97 valid replies were recorded. It is difficult to assess how meaningful this number is. Urban green infrastructure is a specific scientific discipline as well as a policy which still needs to be mainstreamed in key socio-economic policies such as urban development. Unfamiliarity with the concept can be a reason for a low response rate but also the complex structure and the limited time people spend on online surveys are evident bottlenecks. Still, we will use this sample in an analytical way in order to understand what factors define the success of an operational science policy interface on urban green infrastructure.

Figure 4.2 represents a summary as well as an interpretation of the key statistics and conclusions of the survey. It is set up as a tree following to some extent the structure of the survey while containing information about the frequency of answers given to a specific question. At the same time, Figure 4.2 can serve as a guide for scientists and policymakers on do's and don'ts when setting up a green infrastructure project in a city.

Depending on profession (scientist of policymaker), the left or right branch of the tree should be taken. A second question discriminates between professionals of each group who had or had not been involved in a green infrastructure project. Scientists are expected to engage in a complete SPI on UGI if there is opportunity for a project which implements new GI or restores current GI in a city, if they have sufficient thematic knowledge, and if they have a contact person in the city's administration who is responsible for the implementation of the project. But success is only warranted if during the project scientists translate scientific outcomes, e.g. with respect to the delivery of ecosystem services by urban ecosystems, in understandable information for policymakers.

The right branch of the tree also filters policymakers who have been involved in UGI project(s). An operational SPI on UGI depends on several factors: the inclusion of scientists during the implementation of a project (i.e., not only at the initial stage but also during the project and possibly also when monitoring of the impact of the project); the understanding of scientific information and regular personal contacts with scientists during the project. Success is only warranted if scientists also understand the complexity of the administrative planning cycles so as to deliver information and results when they are needed most. Otherwise the SPI risks to be incomplete or only partially successful.

In what follows the different components of the survey are presented in more detail with additional statistics from the survey.

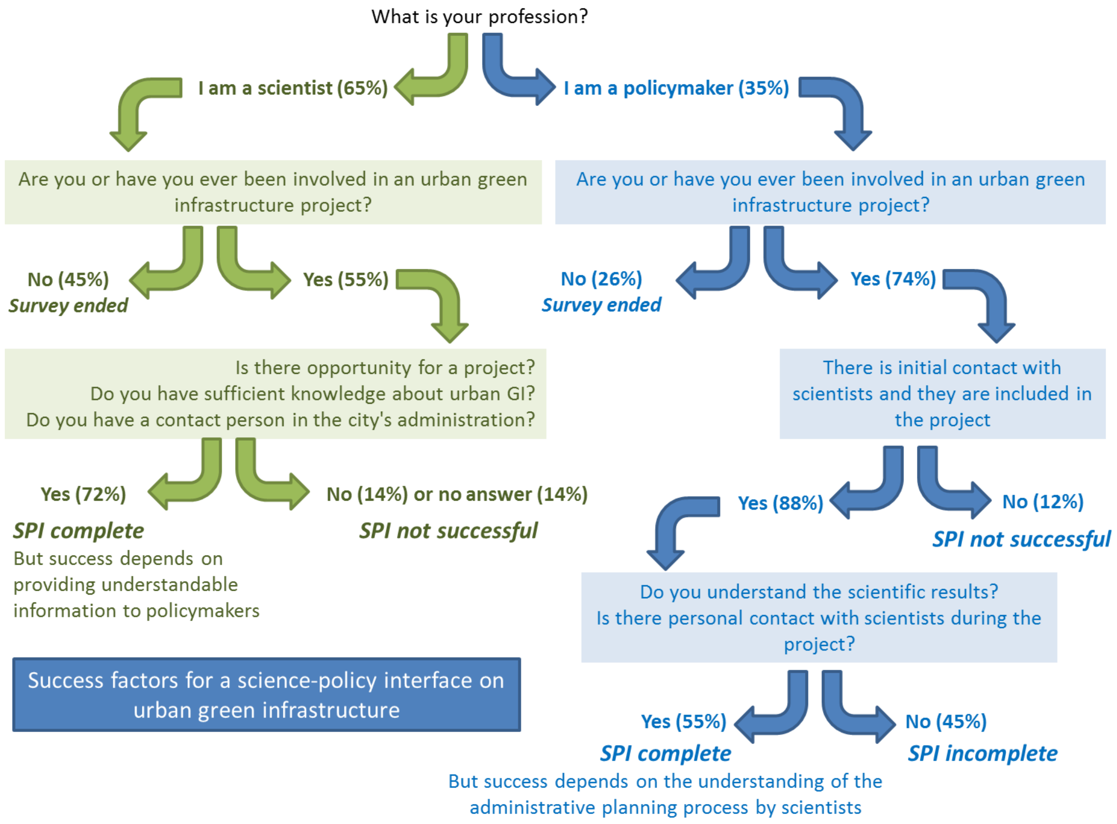


Figure 4.2. Summary of the key results of the online survey on urban green infrastructure science policy interface. The summary is set up as a decision tree with questions and answers. The percentages behind each answer show the frequencies recorded by the survey.

4.3.1 General information about the participants of the survey and the cities

Of the 97 participants to the survey 65% were scientists. Of this share, 55% have been involved in a UGI project. Policymakers represented 35% of the respondents, of which the major part has been involved in either a complete or an incomplete SPI.

As explained, the number of participants answering certain questions depended on their profession, experience and the type of answers they gave (the way how participants were guided through the survey). Hence, the number of participants and the number of answers usually varies per question.

In general, the main part of respondents had more than 3 years of experience in their profession and they could rely on experience from a previous UGI project. The UGI projects were implemented in particular at city level with an average size of 100.000 – 1 million inhabitants (Figure 4.3). Correspondingly, the biggest group of policymakers worked at city level as well. When asked about the number of stakeholders involved the answers varied: there is no relation between the size of the project extend and the number of stakeholders. UGI projects usually take longer than one year (Figure 4.3).

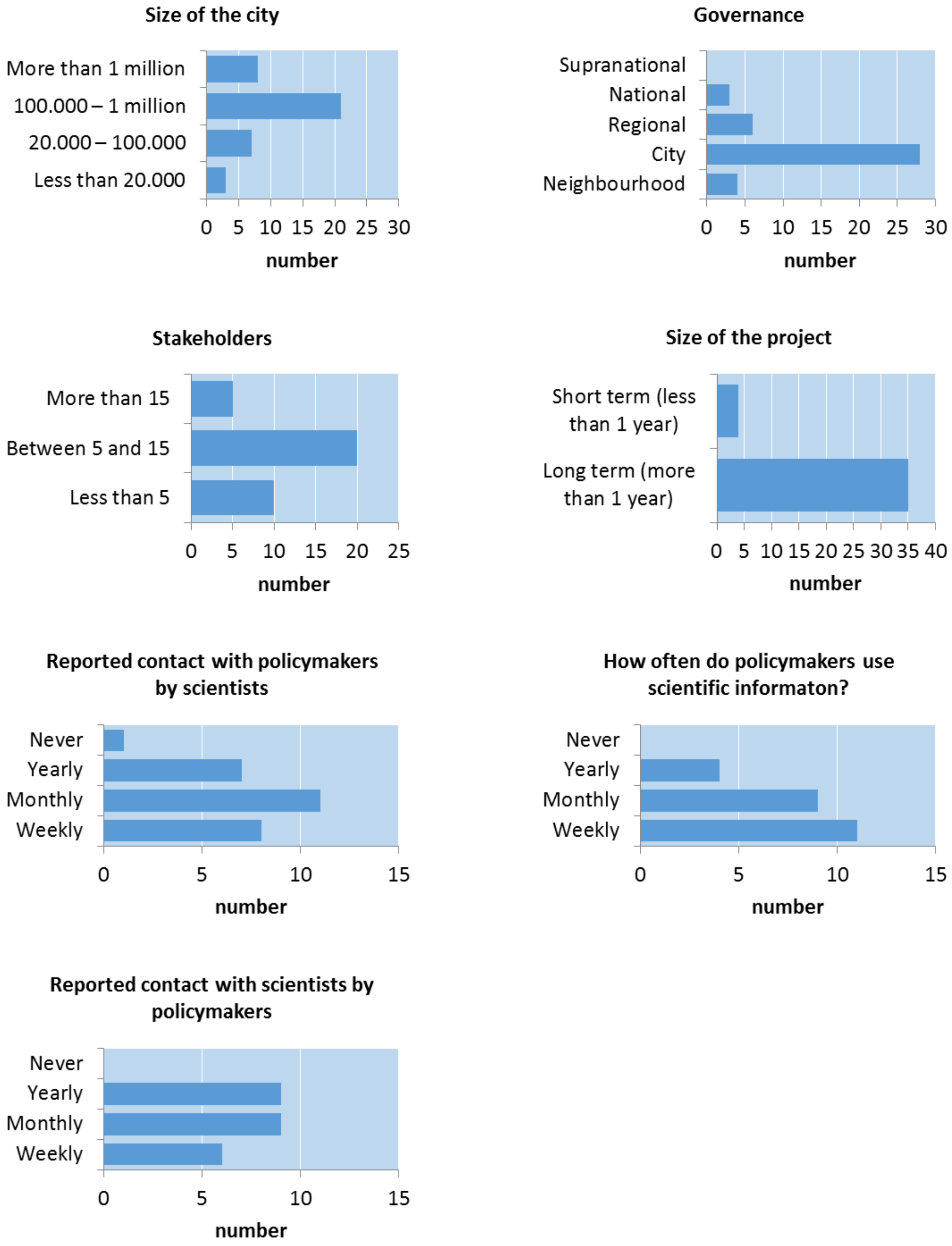


Figure 4.3. Average profiles of survey participants and cities included in the survey expressed in numbers of answers.

4.3.2 How do contacts between scientists and policymakers evolve during the project and how is scientific information exchanged?

The policymakers who have been involved in a UGI project had all contact with scientists (Figure 4.3). The contact was mainly restricted to monthly or yearly meetings, whereas they indicated to use scientific information on a weekly to monthly basis. Scientists who participated in UGI projects indicated to have weekly to monthly contacts with policymakers.

Although all policymakers who have been involved in in a UGI project indicated to have contact with scientists, nearly 40% did actually not included scientists in the various phases of the UGI project. To integrate UGI solutions they used their own experience, the advice of colleagues or information of scientific presentations and reviewed articles. In half of the cases a third party, i.e. an environmental agency was retained to make scientific information better understandable for the policymaker.

In case of a complete SPI the contact started mostly from the policy side. If so, policymakers as well as scientists indicated a request for scientific advice as a main reason to start the contact. For policymakers it was also important to include a scientific study in the UGI project and to estimate cost and benefits of the project. This is also reflected in the second most important answer of scientists who were asked from policymaker to point out arguments to justify a UGI project. Whilst the reason to establish a contact seem to be clear, as it does for all participants from the policy side, one third of the scientists did not feel well informed by the policymaker for what need, reason or purpose the scientific information is needed.

If a scientist took the initiative to establish for the first time a contact with a policymaker, the choice for personal contact with an interesting approach was mostly selected as an answer. Indeed, most answers refer to a talk at an event or a direct appointment between a scientist and the policymaker to discuss a possibly interesting proposal for an UGI project.

During the project phase the most important information delivered by scientists are scientific reports (75%), presentations (69%) as well as case studies and examples of other projects. After the project, the contact between the two groups remained in most cases. 76% of the scientists remained in contact with policymakers once the project ended. This number is confirmed by policymakers (see Table 1 of Annex 1).

4.3.3 What sort of scientific information is necessary at what time during the UGI project?

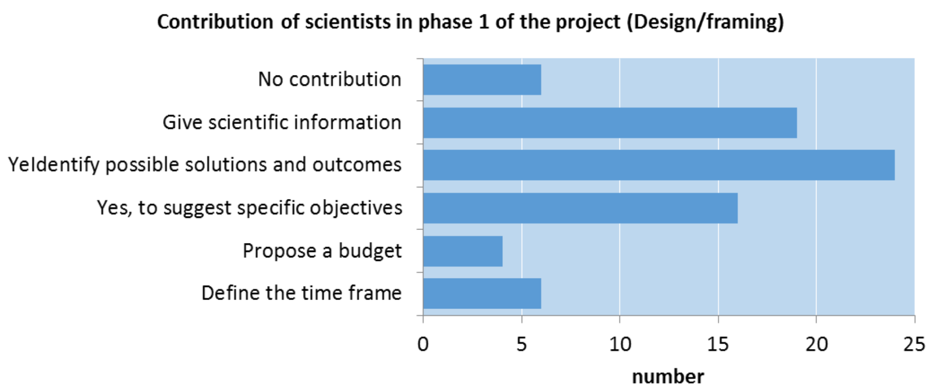
The statements of policymakers and scientists in the first three project phases (framing, consultation and implementation of the project and post processing; see also Table 4.1) are very similar and confirm the answers from the contact part. Perhaps surprisingly, a considerable amount of UGI projects of the survey sample start with a scientific proposal (Figure 4.4), in which scientists are asked to identify possible solution and outcomes of the project, to suggest specific objectives or to give scientific information to prepare the project. For policymakers it seems also quite important that scientists propose a budget.

During the implementation and consultation phase scientists contribute mainly by making an own scientific study in the frame of the UGI project (for instance to understand the impact of the green infrastructure plan or project on the well-being of citizens; monitored the trend of bird species in an new park), providing scientific information, bringing scientific information into practice and clarifying the project design. Policymakers did not check the possible answers about the contact with scientific and non-scientific institutions, which could be a sign of unawareness about the work scientists do in the background in order to deliver the final outcomes.

During the post-processing phase scientists contributed mainly monitoring the impact of the project (for instance on biodiversity, ecosystem services, human well-being) or more in general in the final project evaluation (Figure 4.4).

The survey results suggest a high uptake of scientific results. When asked if the scientific results were used for a final policy output (for instance guidelines, recommendation, action plan, or further green infrastructure projects) all policymakers replied positively whereas also 83% of the scientist agreed with the statement.

Interestingly, as the UGI proceeds and enters a next phase, the involvement of scientists decreases as suggested by the total number of answers to each of the questions. In other words, the survey results suggest that the scientific involvement in an UGI project is highest at the start of the project.

<table>
<tr><th>Project phase (number of answers from policymakers)</th><th>Contribution of science to the UGI project</th></tr>
<tr><td>Phase 1. Design and framing of the UGI project</td><td>
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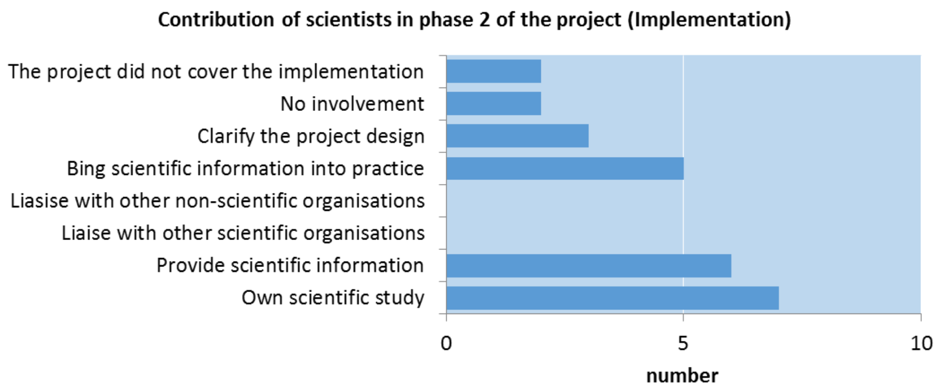
<tr><td>Phase 2: Implementation of the UGI project</td><td>
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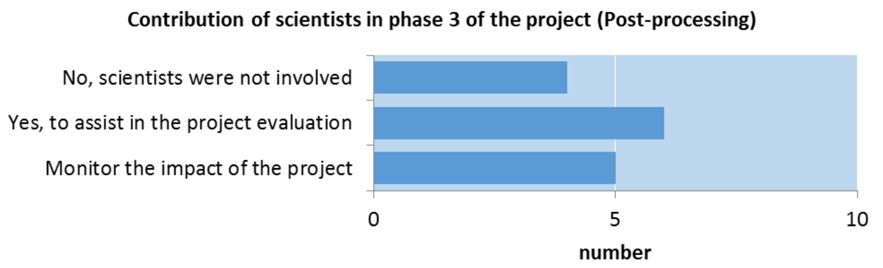
<tr><td>Phase 3. Post-processing</td><td>
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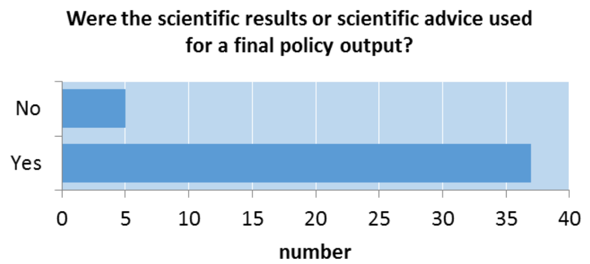
<tr><td>Phase 4. Assessment and evaluation of the project (number of answers from policymakers and scientists combined)</td><td>
</td></tr>
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Figure 4.4. The contribution of science to each phase of UGI projects.

4.3.4 What are the main obstacles for a science policy interface of urban green infrastructure?

A first, important obstacle occurs even before a project starts as has been demonstrated by the number of people that participated to the survey but who have never been involved in an actual UGI project. More than half of the scientists who claim to do research on UGI did not have had the opportunity to participate in an implementation of a project. Other scientists indicated missing contact persons and the lacked knowledge or administrative skills are needed to enter or to start a project. So there is a lot of potential knowledge which remains untapped and not used for application.

Policymakers who were in contact with scientists and actually used scientific information did sometimes fail to include scientists as stakeholders in UGI projects. It is not fully clear as to why this is the case.

In projects both policymakers and scientists indicated to experience communication problems as well as difficulties with the administrative procedures in the urban planning cycle. 48% of the scientists agreed that he communication with policymakers was sometimes difficult; a similar percentage experienced challenges with the administrative planning procedure; 17% admitted that green infrastructure can be a complex concept. Also policymakers faced communication problems: 42% agreed communication with scientists was difficult; 17% admitted that scientific terminology was hard to follow (Table 1 of Annex 1)

4.3.5 A synthesis of the survey based on the rule of majority

Here we present two median profiles, one for a policymaker and one for a scientist who both participated to the survey. This profile is based on taking the most frequent answer as inferred from Table 1 of the Annex 1.

	The median policymaker	**The median scientist**
Experience	A policymaker in the area of urban green infrastructure works for the city and has usually over 10 years of experience.	A scientist in the field of urban green infrastructure has a widely varying experience ranging from PhD student to university professor.
Scale of the city and scale of the UGI project	He or she implements UGI projects at city scale with a timeline over 1 year and in a city of over 100 000 inhabitants. The project includes more than 5 stakeholders in the project. He or she uses scientific information on a weekly basis and meets a scientist a few times per year.	He or she waits for the opportunity to get involved in a project on UGI in case of which the project is a city scale in a city of over 100 000 inhabitant, includes over 5 stakeholders, and takes over 1 year.
First contacts and policy requests	Before starting a project on urban green infrastructure a policymaker usually collects	Policymakers contact the scientist with specific request for scientific advise and to a

	scientific information about UGI and takes the initiative to contact a scientist with specific requests.	lesser extent to deliver arguments to justify the green urban infrastructure project.
Project design	When designing the project, a scientific study is launched to suggest specific objectives, to identify possible solutions and outcomes, to propose a budget, or to give general scientific information.	According the scientist UGI projects usually start with a scientific study to predominantly identify possible solutions and outcomes to certain challenges
Project implementation	When implementing the project, the policymaker will still include scientists (but possibly not covered under the budget).	During the implementation of the project, the scientist is involved for making specific studies for own objectives (e.g. related to impact or monitoring), but also to provide scientific information and to bring scientific information into practice. He or she reports to the city using reports and presentations.
Project evaluation	After the implementation, he or she includes scientists to help evaluate the project but the participation of scientists drops when the project proceeds.	After the implementation, scientist can continue monitoring the impacts of the project but drop out at this stage is likely.
Project evaluation	The policymaker includes scientific advice in the final policy outputs.	His or her scientific results are effectively used for a final policy output
	The policymaker admits that communication with scientists is difficult but remains in contact with scientists after the project ends.	The scientist admits that communication with policymakers and understanding the policy cycle are difficult but remains in contact with policymakers after the project ends.

4.3.6 Limitations

The technical options of EU Survey do not allow implementing a rather a complex questionnaire as the one presented here.

A single survey for the entire EU, even if it was translated in several languages, may mask out different administrative procedures to project implementation that exist across Europe which results in biased outcome.

The terminology about urban green space, green infrastructure, and projects differs across countries which makes communication more difficult. Usually green infrastructure is translated differently in other languages so that the concept of GI risks becoming vague for people who are not native English speakers or who don't understand English. This was in particular an issue for policymakers. The survey failed to ask why policymakers who are implementing an UGI project which effectively relied on scientific knowledge ultimately did not invite scientists as stakeholders in the project.

4.4 Conclusions and lessons learned

1. The EnRoute online survey on science policy interface aimed at better understanding the factors that contribute to or determine whether or not an SPI on urban green infrastructure is functional and successful.

2. The survey was completed by 97 participants, a sample size that lies below our expectations. Hence the results should be treated with caution. A positive note is that most participants indicated a substantial experience on urban green infrastructure which means that their answers are based on a long standing professional knowledge.

3. The main obstacles to an operational SPI on UGI are firstly, the lack of opportunities to establish professional contacts between scientists or policymakers and secondly, difficulties in communication. Addressing these challenges is possible but requires efforts from both sides. Enhancing opportunities to bring scientists and policymakers in contact is exactly an objective of EnRoute, as well as of many other projects funded under Horizon 2020 or other financing mechanisms. It is also an objective of MAES and good examples and practises are made available, e.g. through ESMERALDA of how to enhance exchanges between scientists and policymakers. In addition, it requires better communication: from scientists to make their science comprehensible to policymakers and from policymakers to enlighten scientists about the different steps in the policy process that requires specific scientific data, results or inputs.

4. Once these challenges are overcome, the survey results paint a rather positive picture of science policy of urban green infrastructure: both scientists and policymakers acknowledge that scientific evidence finds its way to the policy making process and is included in policy outputs and deliverables. Moreover, contacts between scientists and policymakers, once established in the frame of a project, last also after the project.

5. The key message to a successful SPI on UGI is therefore to seize the opportunity to establish a personal contact as soon as possible in the process and to maintain this contact throughout the entire project.

5 Building a community of practise on urban green infrastructure

An important objective of EnRoute was to enhance the contacts between communities of practice at local, regional and national level in order to exchange experiences and knowledge on mapping, assessment, valuation and implementation of urban green infrastructure, urban biodiversity and urban ecosystem services. Through the 18 city labs EnRoute created a network of cities collaborating as a community of practice. This was particularly enforced during a series of four meetings which aimed to mainstream the concepts of urban green infrastructure in urban planning and biodiversity policy. Furthermore, EnRoute also supported other research and policy agenda's during the course of the project, notably the EU urban agenda and the Horizon 2020 cluster of projects on nature-based solutions. EnRoute was indeed closely connected to several H2020 projects on nature-based solutions. It actively contributed to the task force on indicators and helped develop an updated version of the impact assessment framework for nature-based solutions.

5.1 EnRoute events: key outcomes

EnRoute organized a series of events in line the rotating EU Presidencies in 2017 and 2018. Meetings took place in Valletta (Malta), Tallinn (Estonia) and Sofia (Bulgaria). The meetings were supported by the city labs of Valletta, Tallinn and Karlovo.

5.1.1 Evidence-based planning for greener cities

The one-day conference 'Evidence-based planning for greener cities' (June 2017) at the Institute of Applied Sciences of the Malta College of Arts, Science and Technology was organized in collaboration with the Maltese presidency of the EU and brought together circa 70 scientists and policymakers. The conference opened with a policy session on the role, challenges and opportunities of urban green infrastructure to improve the quality of life for European citizens. Representatives from the city of Lyon, the Maltese Planning Authority, the European Commission dg Environment, and the Institute for applied sciences presented their views on the importance of green infrastructure for urban challenges. Commissioner for Environment, Maritime Affairs and Fisheries Mr. Karmenu Vella in a video message stressed the need for a better understanding of urban ecosystem services to make informed decisions.

This session was followed by a series of presentations that showed local and international examples of how urban green infrastructure can be included in the urban planning process. Showcases involved recreation, health, climate change adaptation, and biodiversity.

5.1.2 Nature-based solutions

As part of the Presidency of the Estonian Republic of the Council of the European Union, a flagship conference "Nature-based Solutions: From Innovation to Common-use" was organized by the Ministry of the Environment of Estonia and the University of Tallinn (Tallinn, 24-26 October 2017). EnRoute organized a side event on the conference with a focus on how the project can contribute to the knowledge base supporting nature-based solutions in cities. EnRoute was presented in the plenary session of the first day of a conference regarding the nature-based solutions projects of H2020. Next to this we discussed how EnRoute can contribute to the science, practice and policy of nature-based solutions. We concluded that there are several ways to do so: (1) by providing scientific knowledge of how urban ecosystems can support urban planning; (2) by delivering guidance on the creation, management and governance of urban green infrastructure; (3) by promoting collaboration between scientists and policymakers.

5.1.3 Biodiver-City: Enhancing urban biodiversity and ecosystem services to make cities more resilient

EnRoute organized a special conference on urban biodiversity together with the Bulgarian Academy of Sciences as an event of the Bulgarian Presidency and as side event of the European Green Week 2018. The conference addressed the following key questions: What is our present knowledge of urban biodiversity? What indicators are used and what do the current patterns and trends reveal about urban biodiversity? Why is urban biodiversity important? What are the links between urban biodiversity, urban ecosystem services and well-being? Is a high urban biodiversity important for citizens and other stakeholders? How can citizens monitor biodiversity? How can urban green infrastructure be designed and managed to maintain and enhance urban biodiversity and ecosystem services?

The conference highlighted the structural and functional role of urban biodiversity in underpinning urban green infrastructure. Key threats to urban biodiversity are in particular the high rates of habitat conversion and fragmentation, local pollution and eutrophication, traffic, and introductions of invasive alien species. However, there is also substantial evidence that in some cities biodiversity is higher than in the adjacent, (agricultural) areas. A meta-analysis based on 87 scientific articles concluded that urban biodiversity can be enhanced by providing more green infrastructure under particular management, an appropriate vegetation structure and ensuring the presence of water. Cities can contribute to global efforts in protecting biodiversity but this requires evidence based management of the city's biodiversity (so better monitoring is crucial). Urban biodiversity needs to be managed by considering the functions of plant species and their role in delivering key ecosystem services. For instance, a mixture of certain tree species delivers a variety of morphological, physiological and phenological traits which are crucial in the removal of air pollutants, such as particulate matter (PM10) and ozone (O3). The synergism observed between plant species highlights the need to preserve biodiversity, particularly in metropolitan areas and in a climate change context. European sustainability goals may be achieved by increasing forest cover, especially in urban areas, characterized by high pollution levels, through Green Infrastructure planning.

Participants of the conference commonly developed a set of awareness raising facts and possible actions which are needed to stimulate different levels of governance to take up more responsibility in the protection of urban nature. These conclusions were developed with the aim to engage the participants in the development of key policy messages regarding urban biodiversity. Protecting urban biodiversity is a shared responsibility across different levels of governance and sectors. Therefore it is appropriate to address a wide community of policymakers.

Policymakers from cities, regions, countries and the EU should be aware of the fact that:

1. Cities have an important role in achieving the objectives of the EU Nature Legislation and the EU biodiversity targets. Biodiversity and green infrastructure are also

indispensable for the health and wellbeing of urban residents, who are key stakeholders and should be actively engaged in urban planning and decisions

2. Many cities have set specific targets to maintain or enhance urban biodiversity. Specific urban biodiversity targets can focus on the protection of particular species and habitats or on the enhancement of certain ecosystem services and urban green infrastructure which underpin these services and the benefits of urban ecosystems for people – and ideally, on synergies among these two aspects. However, specific urban biodiversity targets depend on the local context and are therefore not easily up-scalable. This means that possible national or European targets for urban biodiversity need to factor in the differences that exist among cities; targets expressed qualitatively or in percentage could for instance allow for this flexibility.

3. Participation of citizens and local stakeholders is essential when setting urban biodiversity targets or an action plan for urban nature. Culture is an important facet of urban biodiversity.

4. Several European projects contribute to a knowledge base on urban nature such as the EnRoute project and the several projects funded under Horizon 2020 on nature-based solutions in cities. In addition, the partnership on sustainable land use and nature-based solutions under the EU urban agenda aims at developing an action plan for more nature in cities.

Policymakers from cities, regions, countries and the EU could act by:

5. Developing a policy framework for urban biodiversity across multiple levels of governance with objectives that are mutually reinforcing across different scales (EU, national, metropolitan, urban). This means that possible European and national targets can be translated into specific urban biodiversity targets which depend on the local socio-economic and environmental context. Such a policy framework would also need to include actions that enhance the involvement and engagement of citizens, policymakers and civil society in protecting urban biodiversity.

6. Raising awareness about the values of urban biodiversity for all people and our dependency on nature, starting with early childhood, primary and secondary education, through to professional education and on-the-job training, as well as part of lifelong learning. This can be done for instance (i) by developing awareness raising and educational materials and curricula on urban biodiversity and green infrastructure; (ii) by improving access to information about biodiversity and skills to work with this information tailored to specific professional fields, (iii) by informing potential beneficiaries about the specific support opportunities available under EU-programs and initiatives on urban biodiversity, green infrastructure and ecosystem services, (iv) by using language that is understandable to everyone, and (v) by assessing and explaining to stakeholders, including business, the risks of losing urban and peri-urban biodiversity and ecosystems.

7. Providing guidance to implement and mainstream urban biodiversity, and the health and social benefits from urban nature, into other policies. An effective policy on urban biodiversity requires standard methods to monitor and assess urban biodiversity, green infrastructure and urban ecosystem services.

These points demonstrate that, with novel ideas on nature based solutions and clever urban planning, cities can contribute to the global biodiversity objectives such as conservation of habitats and species (protected areas), reducing pressures on biodiversity (e.g., by connecting networks of natural areas), and maintaining ecosystems and ecosystem services (green infrastructure, restoration), and sustainable use of biological resources (e.g. pollination).

5.2 EnRoute networking

Through the meetings the EnRoute partnership has made efforts to strengthen the network of cities involved in the project and to reach out to other cities. The EnRoute meetings usually contained networking sessions which allowed us to provide more insights in developing a network and to understand the dynamics of the EnRoute network.

5.2.1 What constitutes a good network?

There are (at least) 4 factors that make a network viable

Shared values & believes & goals. A network is a group of people that are relatively loosely bound. There are no hierarchical relationships, no formal procedures, no physical structures that define the group. This makes the existence of strong values & believes all the more important. They are the cement that replaces the 'skeleton' of a more formal organization. Values can be recognized by words like 'we think it is important that…'. Believes can be identified by words like 'we think that…' or 'we believe that…'. The goals of the network are less important and more personal than the believes. They are obviously in line with them, but are often more related to the individual context in which people of the network are working

Concrete activities. A network that does not actively do something is doomed to vanish rapidly. The participants in the network should have shared activities in the context of their believes and by doing so bringing their believes into practice and helping each other to achieve their goals. It is their way to move forward and it could be seen as the networks structure.

Leadership & other roles. Although a network has no formal structure it does need certain roles to keep the network going. A group of people does not decide to come together. It is someone within the group who decides to make the call. So in the end it comes down to the individuals within the network. A network such as EnRoute needs at least one or more leaders who take initiative and indicate directions, creators who actively contribute to the discussions and participate in the activities and at least one collector; the person who brings everything together and makes the results transparent. It is well possible that one person plays different roles.

Technical means. To keep a network going one needs facilities to bring people together and facilitate discussions. These facilities may consist of physical subjects (e.g., a gathering space or shared tools), or non-physical aspects such as an internet platform and finances. Financing is conditional. A network will not be able to continue when there is no financing available to ensure meetings and finance at least one person that is able to invest time to do the necessary preparing work.

5.2.2 How does the EnRoute network score on these indicators?

Shared values & believes & goals. We have discussed these aspects the kick off meeting in Rome and during the meeting in Malta. We conclude that 'The participants in the EnRoute network think highly of the potential value of urban nature to contribute to addressing various societal challenges that cities have to face. They believe that these challenges could be better addressed when the values of urban nature are made transparent and incorporated in the urban policy processes. To enhance this incorporation they develop practical evidence and tools in the assumption that based on this evidence and tools local policymakers will be able to make better urban policies‘. EnRoute has developed during the project a solid network with lots of interpersonal confidence and a good conviction that we are working on an important subject. However, it proved to be difficult to have a strong appearance in the ‘outer world’. Communicating EnRoute felt sometimes short.

Concrete activities. We have a number of concrete activities that have been described in the inception report. The city labs are the core-activity. They bring science and policy together and work on scientific progress. This has been a unique setting, certainly in the context of the implementation of MAES.

Leadership & other roles. As project leader, JRC had a clearly defined role but also certain city labs could be characterised as front-runner cities in the conceptualisation and implementation of urban green infrastructure, urban biodiversity and nature-based solutions.

Technical means. EnRoute has used a page on OPPLA for internal and external communication but it is difficult to assess if the page was useful. Still OPPLA supports EnRoute with improving the page and supporting outreach. Financing is always a problem after finalization of a project.

5.2.3 What possible strategies can be followed as a follow-up?

All EnRoute partners expressed the interest to continue the network. The preference of most partners, but not all, goes to developing a more formal network, connected to e.g. the MAES working group or the working group for GI with central budget and management. The key challenge is to find finance. All the other ingredients for a good network are there. The quality of the ingredients may be enhanced, but they are sufficient for the continuation of the network. In this light it is useful to know that the European Parliament has given the green light for a new pilot project on enhancing the science policy interface of urban green infrastructure, which is in fact a nice message to conclude this report.

6 Conclusions

"En route" is French for "on the way". As a research project funded by the European Parliament and designed and managed by the European Commission, EnRoute aimed at testing the guidance of MAES on Mapping and Assessment of Ecosystems and their Services in real test cases. It intended to make knowledge about urban ecosystems available, understandable and applicable for policy and management of urban green infrastructure (UGI) and for mainstreaming it into urban planning. So did EnRoute arrive at its destination?

EnRoute has been a challenging project with high ambitions. The budget was developed having in mind 10 city labs but this number almost doubled and more cities showed interest to join but had to be refused. The high interest of many cities across Europe for enhancing UGI and use the functions it provides and the ecosystem services it delivers to address urban challenges is already a key outcome and demonstrates the necessity of projects like EnRoute that enable science and policy to collaborate.

The main achievement of EnRoute and a key indicator for its success is the work delivered by the city labs. With low financial support but with high levels of commitment, the city labs have demonstrated that MAES can be put in practise: working together on an ecosystem knowledge base that is relevant for policy. Whereas the city labs have been relevant at local scale, albeit with different policy outcomes, they also have shown that important parts of the scientific work as well as science-policy experiences can be upscaled and used by other cities in Europe. Developing, maintaining and updating high resolution data of the distribution of urban green space and the benefits it delivers proved to be a common conclusion of the city labs. Both the EU's Copernicus programme and local data collection by cities but also through citizen's science are will become essential data providers to support UGI policy and management.

The European assessment of UGI coped with a particular challenge: how to develop a set of indicators which cover the scale of Europe so that they can be used for comparing or benchmarking cities but which have sufficient spatial resolution to be relevant for urban policy. EnRoute used Functional Urban Areas as assessment and reporting system, a system that is now also proposed by the partnership on sustainable land use and nature-based solutions under the Urban Agenda of the EU for promoting cooperation among cities. The assessment delivered also a knowledge base which will be used to support the final evaluation of the EU Biodiversity Strategy and, if needed, to help set new biodiversity targets. The assessment also proposed a typology of how UGI is embedded in the landscape matrix that would enable to integrate it in regional networks. Importantly, tools and methodologies developed for assessing UGI and ecosystem services at European scale have been successfully applied at local scale and are available for further applications.

Some challenges remain. Not all the EnRoute ambitions could be achieved. More work is needed on cross-scale analysis of UGI. The question as to how the European data can be used to support local policy still remains to be addressed by comparing outcomes from the city labs with EU level data. Further work is needed to deepen our knowledge on the determinants for establishing a successful science policy interface. Continuing our efforts to promote and activate the civil society in knowledge sharing and collecting best practises of green cities and green urban environments will remain essential "en route" to a sustainable urban environment.

References

Acosta-Alba I, Van der Werf MH (2011) The Use of Reference Values in Indicator-Based Methods for the Environmental Assessment of Agricultural Systems. Sustainability 3

Apparicio P, Abdelmajid M, Riva M, Shearmur R (2008) Comparing alternative approaches to measuring the geographical accessibility of urban health services: Distance types and aggregation-error issues. International Journal of Health Geographics20087:7 https://doi.org/10.1186/1476-072X-7-7

Breuste J, Rahimi A (2015) Many public urban parks, but who profits from them? The example of Tabriz, Iran. Ecol Process 4(1): 6. doi: 10.1186/s13717-014-0027-4

Capotorti G, Alós Ortí MM, Copiz R, Fusaro L, Mollo B, Salvatori E, Zavattero L (2017) Biodiversity and ecosystem services in urban green infrastructure planning: A case study from the metropolitan area of Rome (Italy). Urban For Urban Green. doi: https://doi.org/10.1016/j.ufug.2017.12.014

Cortinovis C, Zulian G, Geneletti D (2018) Assessing Nature-Based Recreation to Support Urban Green Infrastructure Planning in Trento (Italy). Land 7(4): 112. doi: 10.3390/land7040112

Copernicus Land Monitoring Service (2016) Mapping Guide v4.7 for a European Urban Atlas. : 39. doi: 10.2775/74781

Derkzen ML, van Teeffelen AJ, Nagendra H, Verburg PH (2017) Shifting roles of urban green space in the context of urban development and global change. Curr Opin Environ Sustain 29(December): 32–39. doi: 10.1016/j.cosust.2017.10.001

Dickinson DC, Hobbs RJ (2017) Cultural ecosystem services: Characteristics, challenges and lessons for urban green space research. Ecosyst Serv 25(Supplement C): 179–194. doi: https://doi.org/10.1016/j.ecoser.2017.04.014

EEA (2011) Urban soil sealing in Europe.

Egorov AI, Mudu P, Braubach M, Martuzzi M (2016) Urban green spaces and health. Copenhagen

Endlicher W, Langner M, Hesse M, Mieg HA, Kowarik I, Hostert P, Kulke E, Nützmann G, Schulz M, van der Meer E, Wessolek G, Wiegand C (2007) Urban Ecology - Definitions and Concepts.

European Commission (2013) Green Infrastructure (GI) — Enhancing Europe's Natural Capital. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions (COM(2013)249 final)

European Union (2016) URBACT Guide Applying the results framework to Integrated Actions Plans.

EuroStat (2016) Urban Europe.

Felson AJ, Pavao-Zuckerman M, Carter T, Montalto F, Shuster B, Springer N, Stander EK, Starry O (2013) Mapping the Design Process for Urban Ecology Researchers. Bioscience 63(11): 854–865.

Ferri S, Siragusa A, Sabo F, Pafi M, Halkia S (2017) The European Settlement Map 2017 Release; Methodology and output of the European Settlement Map (ESM2p5m).

Fischer LK, Honold J, Botzat A, Brinkmeyer D, Cvejić R, Delshammar T, Elands B, Haase D, Kabisch N, Karle SJ, Lafortezza R, Nastran M, Nielsen AB, van der Jagt AP, Vierikko K, Kowarik I (2018) Recreational ecosystem services in European cities:

Sociocultural and geographical contexts matter for park use. Ecosyst Serv. doi: https://doi.org/10.1016/j.ecoser.2018.01.015

Grafius DR, Corstanje R, Harris JA (2018) Linking ecosystem services, urban form and green space configuration using multivariate landscape metric analysis. Landsc Ecol 33(4): 557–573. doi: 10.1007/s10980-018-0618-z

Hixson M, Mahmud A, Hu J, Kleeman MJ (2012) Resolving the interactions between population density and air pollution emissions controls in the San Joaquin Valley, USA. J Air Waste Manag Assoc 62(5): 566–575. doi: 10.1080/10962247.2012.663325

Hostetler M, Allen W, Meurk C (2011) Conserving urban biodiversity? Creating green infrastructure is only the first step. Landsc Urban Plan 100(4): 369–371. doi: 10.1016/j.landurbplan.2011.01.011

Isbell F, Gonzalez A, Loreau M, Cowles J, Diaz S, Hector A, Mace GM, Wardle DA, O'Connor MI, Duffy JE, Turnbull LA, Thompson PL, Larigauderie A (2017) Linking the influence and dependence of people on biodiversity across scales. Nature 546(7656): 65–72.

Janse G (2008) Communication between forest scientists and forest policymakers in Europe - A survey on both sides of the science/policy interface. For Policy Econ 10(3): 183–194. doi: 10.1016/j.forpol.2007.10.001

Kabisch N, Strohbach M, Haase D, Kronenberg J, Strohbach M, Haase D, Kronenberg J (2016) Urban green space availability in European cities. Ecol Indic 70: 586–596. doi: http://dx.doi.org/10.1016/j.ecolind.2016.02.029

Kienast F, Degenhardt B, Weilenmann B, Wäger Y, Buchecker M (2012) GIS-assisted mapping of landscape suitability for nearby recreation. Landsc Urban Plan 105(4): 385–399. doi: 10.1016/j.landurbplan.2012.01.015

Larondelle N, Haase D, Kabisch N (2014) Mapping the diversity of regulating ecosystem services in European cities. Glob Environ Chang 26: 119–129. doi: http://dx.doi.org/10.1016/j.gloenvcha.2014.04.008

Leroux SJ, Kerr JT (2013) Land Development in and around Protected Areas at the Wilderness Frontier. Conserv Biol 27(1): 166–176. doi: 10.1111/j.1523-1739.2012.01953.x

Liquete C, Piroddi C, Macías D, Druon J-N, Zulian G (2016) Ecosystem services sustainability in the Mediterranean Sea: Assessment of status and trends using multiple modelling approaches. Sci Rep. doi: 10.1038/srep34162

Maes J, Zulian G, Thijssen M, Castell C, Baró F, Ferreira AM, Melo J, Garrett CP, David N, Alzetta C, Geneletti D; Cortinovis C, Zwierzchowska I, Louro Alves F, Souto Cruz C, Blasi C, Alós Ortí MM, Attorre F, Azzella MM, Capotorti G, Copiz R, Fusaro L, Manes F, Marando F, Marchetti M, Mollo B, Salvatori E, Zavattero L, Zingari PC, Giarratano MC, Bianchi E, Duprè E, Barton D, Stange E, Perez-Soba M, van Eupen M, Verweij P, de Vries A, Kruse H, Polce C, Cugny-Seguin M, Erhard M, Nicolau R, Fonseca A, Fritz M, Teller A (2016) Mapping and Assessment of Ecosystems and their Services. Urban Ecosystems. Publications Office of the European Union, Luxembourg.

Maryanti MR, Khadijah H, Muhammad Uzair A, Megat Mohd Ghazali MAR (2016) The urban green space provision using the standards approach: issues and challenges of its implementation in Malaysia. WIT Trans Ecol Environ 210: 369–379. doi: 10.2495/SDP160311

Niemelä, J., Saarela, S-R., Söderman, T., Kopperoinen, L., Yli-Pelkonen, V., Väre, S., Kotze, D.J. 2010. Using the ecosystem services approach for better planning and conservation of urban green spaces: a Finland case study. Biodiversity and Conservation 19(11): 3225-3243.

Oh B, Lee KJ, Zaslawski C, Yeung A, Rosenthal D, Larkey L, Back M (2017) Health and well-being benefits of spending time in forests: systematic review. Environ Health Prev Med 22(1): 71. doi: 10.1186/s12199-017-0677-9

Paracchini ML, Zulian G, Kopperoinen L, Maes J, Schägner JP, Termansen M, Zandersen M, Perez-Soba M, Scholefield PA, Bidoglio G (2014) Mapping cultural ecosystem services: A framework to assess the potential for outdoor recreation across the EU. Ecol Indic. doi: 10.1016/j.ecolind.2014.04.018

Poelman H (2016) A walk to the park? Assessing access to green areas in Europe's cities.

Pröbstl U, Wirth V, Elands BHM, Bell S (2010) Management of Recreation and Nature Based Tourism in European Forests. Springer, Berlin, Heidelberg

Schwarz N (2010) Urban form revisited—Selecting indicators for characterising European cities. Landsc Urban Plan 96(1): 29–47. doi: 10.1016/j.landurbplan.2010.01.007

Söderman, T., Kopperoinen, L., Yli-Pelkonen, V., Shemeikka, P. 2012. Ecosystem services criteria for sustainable development in urban regions. Journal of Environmental Assessment Policy and Management 14(2): 1250008-1 - 1250008-48. DOI: 10.1142/S1464333212500081.

Stange EE, Zulian G, Rusch GM, Barton DN, Nowell M (2017) Ecosystem services mapping for municipal policy: ESTIMAP and zoning for urban beekeeping. One Ecosyst 2: e14014.

Statistics G and regional (2017) Methodological manual on city statistics – 2017 edition. Luxembourg: Publications Office of the European Union, 2017

Timaeus J, Neßhöver C, Wittmer H Science-Policy Interfaces for Biodiversity: Research, Action, Learning FP7 Collaborative Project', Spiral-Project.Eu.

Tsiamis K, Gervasini E, Deriu I, D'Amico F, Nunes AL, Addamo AM, Cardoso AC, D'Amico F, Nunes AL, Addamo AM, Cardoso AC, D'Amico F, Nunes AL, Addamo AM, Cardoso AC (2017) Baseline distribution of invasive alien species of Union concern. European Union, 2017 The, Luxembourg: Publications Office of the European Union

Vallecillo S, La Notte A, (forthcoming) Ecosystem services accounting: Part II. Luxembourg: Publications Office of the European Union

Van Herzele A, Wiedemann T (2003) A monitoring tool for the provision of accessible and attractive urban green spaces. Landsc Urban Plan 63(2): 109–126. doi: 10.1016/S0169-2046(02)00192-5

Vogt P, Riitters K (2017) GuidosToolbox: universal digital image object analysis. Eur J Remote Sens 50(1): 352–361. doi: 10.1080/22797254.2017.1330650

Weichselgartner J, Kasperson R (2010) Barriers in the science-policy-practice interface: Toward a knowledge-action-system in global environmental change research. Glob Environ Chang 20(2): 266–277. doi: 10.1016/j.gloenvcha.2009.11.006

Whitford V, Ennos AR, Handley JF (2001) "City form and natural process"—indicators for the ecological performance of urban areas and their application to Merseyside, UK. Landsc Urban Plan 57(2): 91–103. doi: https://doi.org/10.1016/S0169-2046(01)00192-X

WHO (2010) Urban planning, environment and health: from evidence to policy action - Meeting report -. World Heal Organ Reg Off Eur : 119. doi: http://dx.doi.org/10.1016/j.biomaterials.2008.12.054

Young JC, Watt a. D, van den Hove S, The SPT (2013) The SPIRAL synthesis report: A resource book on science-policy interfaces. : 102.

Zulian G, Maes J, Paracchini M (2013a) Linking Land Cover Data and Crop Yields for Mapping and Assessment of Pollination Services in Europe. Land 2(3): 472–492. doi: 10.3390/land2030472

Zulian G, Paracchini M-L, Maes J, Liquete Garcia MDC (2013b) ESTIMAP: Ecosystem services mapping at European scale. European Commision

Zulian G, Stange E, Woods H, Carvalho L, Dick J, Andrews C, Baró F, Vizcaino P, Barton DN, Nowel M, Rusch GM, Autunes P, Fernandes J, Ferraz D, Ferreira dos Santos R, Aszalós R, Arany I, Czúcz B, et al (2017) Practical application of spatial ecosystem service models to aid decision support. Ecosyst Serv. doi: https://doi.org/10.1016/j.ecoser.2017.11.005

Zulian, G., Thijssen, M., Günther, S. Maes, J., Enhancing Resilience Of Urban Ecosystems through Green Infrastructure (EnRoute). Progress report, EUR 29048 EN, Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92-79-77697-7, doi:10.2760/958542, JRC110402.

List of abbreviations

ES	Ecosystem services
EU	European Union
FUA	Functional Urban Area
LAU	Local Administrative Unit
LC	Land configuration
LM	Land Mosaic
MAES	Mapping and Assessment of Ecosystems and their Services
SPI	Science-policy interface
UGI	Urban green infrastructure

Annex 1: Supplement of Chapter 4

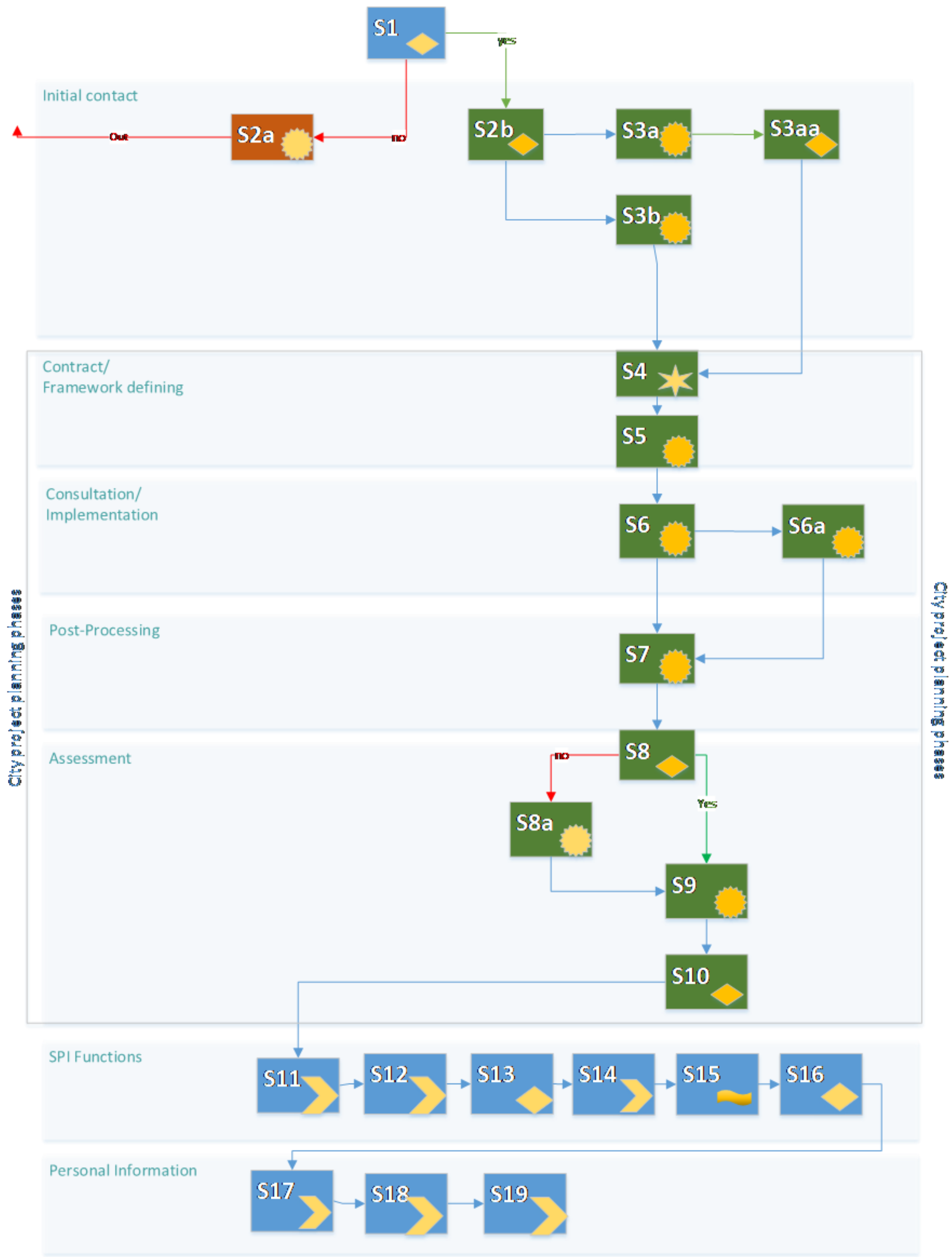

Figure 1. Flowchart of the questions for scientists participating to the survey

Table 1. List of survey questions asked to participants who identified themselves as scientist and summary statistics (frequency or percentage per possible answer).

Question no	Question	Answer	Number	Total number of answers	%	Number of participants
S1	Did you ever provide scientific support to an urban green infrastructure project? *(if ticked "No" participants are out)*	Yes	34	63	54.0	63
	SC	No	29		46.0	
S2b	Who started the contact between you and the policy? *(if ticked "A colleague" go on with 3b; if ticked "A policymaker" go an with 3a)*	A colleague, another scientist or I did	17	34	50.0	34
	SC	A "policymaker"	17		50.0	
S3a	The "policymaker" asked me:	To provide information	8	35	47.1	17
	MC	To give scientific advice	14		82.4	
		To point out arguments to justify the green urban infrastructure project	9		52.9	
		To understand if there is sufficient support among citizens for the urban green infrastructure project	0		0.0	
		For advice to upscale experience about green infrastructure projects to regional or national level	3		17.6	
		Other	1		5.9	
S3aa	Did the "policymaker" articulate clearly for which need(s), reason(s) or purpose(s) he required your support? *(only if ticked S3a before)*	Yes	11	17	64.7	17
	SC	No	6		35.3	
S3b	How did you get in contact with the policy side?	I talked to a "policymaker" about a	5	18	29.4	17

		possible project at an event or conference				
	MC	I went to a "policymaker" with an interesting proposal	4		23.5	
		My observation or a research finding triggered the attention of a "policymaker"	4		23.5	
		Other	5		29.4	
Contact and Framework Phase (1. project phase) Think about the start of the UGI project:						
S4	Was the urban green infrastructure project based on a scientific proposal?	Yes	20	34	58.8	34
	SC	No	10		29.4	
		I don't know	4		11.8	
S5	Did a "policymaker" or the city administration involve scientists in the project proposal?	Yes, to define the time frame	6	75	18.2	33
	MC	Yes, to propose a budget	4		12.1	
		Yes, to suggest specific objectives	16		48.5	
		Yes, to identify possible solutions and outcomes	24		72.7	
		Yes, to give scientific information	19		57.6	
		No, scientists were not involved in the project proposal	6		18.2	
Consultation Phase (2. project phase) Think about the actual implementation of the UGI project:						
S6	Have scientists been involved?	Yes, to make a scientific study (for instance to understand the impact of the green infrastructure plan or project on the well-being of citizens; or they monitored the trend of bird species in an new park)	18	70	54.5	33
	MC	Yes, to provide	16		48.5	

		scientific information				
		Yes, to make contact with other scientific organisations	4		12.1	
		Yes, to make contact with other non-scientific organisations	3		9.1	
		Yes, to bring scientific information into practice	15		45.5	
		Yes, to clarify the project design	9		27.3	
		No, scientists were not involved in the actual implementation	3		9.1	
		No, the project did not cover the implementation	2		6.1	
S6a	In which form did you provide the scientific information? *(only if ticked "Yes to provide scientific information" go on with 6a)*	Examples and case studies of other projects	10	49	62.5	16
	MC	Report	12		75.0	
		Scientific article	6		37.5	
		Website	3		18.8	
		Presentation	11		68.8	
		Policy brief	3		18.8	
		Social media	1		6.3	
		Other	3		18.8	
		Post-Processing (3. project phase) Think about the end of the UGI project:				
S7	Have scientists been involved?	Yes, to monitor the impact of the project (e.g. on biodiversity, ecosystem services, human well-being etc.)	13	34	39.4	33
	MC	Yes, to assist in project evaluation	8		24.2	
		No, scientist were not involved	13		39.4	
		Assessment (4. project phase)				
S8	Were the scientific results used for a final policy output (for instance	Yes	25	30	83.3	30

	guidelines, recommendation, action plan, or further green infrastructure projects) *(if ticked “No” than go to 8a)* *SC*	No	5		16.7	
S8a	What was the reason not to use scientific results? MC	The scientific output was not applicable	0	6	0.0	4
		The scientific data were insufficient to support policy	1		25.0	
		The research needed more time than was available	1		25.0	
		The research outcomes were not relevant	0		0.0	
		The scientific results did not match the expectations (for instance an impact is expected but could not be shown)	0		0.0	
		The communication of the outcomes was insufficient	0		0.0	
		Institutional regulations, laws, old practices complicate new political actions	2		50.0	
		There was a political change (for instance following elections)	1		25.0	
		Political motives prevented changes (for instance sensitive outcome; fear of losing elections)	1		25.0	
S9	Did you face problems during your experience?	Yes, the communication with "policymakers" was sometimes difficult	14	41	48.3	29
	MC	Yes, the topic of green infrastructure is too complex	5		17.2	
		Yes, there were difficulties with	14		48.3	

		the administrative planning procedure				
		Other	3		10.3	
		No, I did not face problems	5		17.2	
S10	After finishing the urban green infrastructure project, do you still have contact with the "policymaker(s)"?	Yes	22	29	75.9	29
	SC	No	7		24.1	
		SPI Functions				
S11	At what governance level was the urban green infrastructure project carried out?	Neighborhood	2	29	6.9	29
	SC	City	22		75.9	
		Regional	3		10.3	
		National	2		6.9	
		Supranational	0		0.0	
S12	How many stakeholders were involved in the urban green infrastructure project?	Less than 5	8	27	29.6	27
	SC	Between 5 and 15	15		55.6	
		More than 15	4		14.8	
S13	The urban green infrastructure project was:	Long term (more than 1 year)	23	27	85.2	27
	SC	Short term (less than 1 year)	4		14.8	
S14	How many people live in the city where the urban green infrastructure project was realised?	Less than 20.000	3	27	11.1	27
	SC	20.000 – 100.000	3		11.1	
		100.000 – 1 million	13		48.1	
		More than 1 million	8		29.6	
S15	In which city or region was the urban green infrastructure project located?	see map				
S16	Have you been involved in a green infrastructure project before?	Yes	17	27	63.0	27
	SC	No	10		37.0	
		Personal Background				
S17	What is your position?	Student or Junior	7	27	25.9	27

		Researcher (for instance Master, PhD)				
	SC	Post Doctoral Researcher	6		22.2	
		Senior Researcher	6		22.2	
		Professor/ Head of Department	6		22.2	
		Other	2		7.4	
S18	For how many years have you been working in your current profession?	Less than 3	6	27	22.2	27
	SC	Between 3 and 10	9		33.3	
		More than 10	12		44.4	
S19	How frequent are you in contact with "policymakers"?	Weekly	8	27	29.6	27
	SC	Monthly	11		40.7	
		Yearly	7		25.9	
		Never	1		3.7	
			No SPI			
S2a	What was the reason you could not participate in an urban green infrastructure project?	I had no opportunity	18	35	62.1	29
	MC	I did not find a contact person	3		10.3	
		There was no interest from the policy side	2		6.9	
		I had no convincing showcase	0		0.0	
		My topic was not relevant for the policy	1		3.4	
		I have no knowledge about how to enter or to start a project in the policy	3		10.3	
		I am not working on urban green	7		24.1	
		Other	1		3.4	

MC Multiple choice
SC Single choice

Figure 2. Flowchart of the questions for policymakers participating to the survey

Table 2. List of survey questions asked to participants who identified themselves as policymaker and summary statistics (frequency or percentage per possible answer).

Question no	Question	Answer	Number	Total number of answers	%	Number of participants
P1:	Have you ever been involved in a urban planning project regarding the physical environment? *(If ticked "No" survey stopps)*	Yes	25	34	73.5	34
	SC	No	9		26.5	
P1.2	Did that project include natural areas and elements or environmental ("green") features, further considered as urban green infrastructure? *(If ticked "No" go to P2a; no SPI)*	Yes	25	25	100.0	25
	SC	No	0		0.0	
P2b	Was scientific information used in this project? (if ticked "no" go to question P3a; no SPI)	Yes	22	25	88.0	25
	SC	No	3		12.0	
P8	Were there any scientists involved in this project? (if ticked "No" go to P9, no full SPI)	Yes	12	22	54.5	22
	SC	No	10		45.5	
P11	Who started the contact between you and the scientists? (if ticked "a scientist" go on with P11a; if ticked "a colleague… go on with P11b")	A colleague, a "policymaker" of the municipality or I did	10	12	83.3	12
	SC	A scientist did (from a university or research institute)	2		16.7	
P11a	How did you get in contact with the scientist?	I talked to a scientist about a possible project at an event or conference	0	2	0.0	2
	MC	A scientist came to me with an interesting proposal	2		100.0	
		An observation or a research finding about green infrastructure in cities triggered my attention	0		0.0	
		Other	0		0.0	
P11b	Why did you or your colleagues contact a scientist?	To get an overview of the topic (for instance	1	16	10.0	10

	MC	water management, air quality)				
		For scientific advice in an existing or new green infrastructure project	5		50.0	
		To estimate the environmental costs and benefits (including the economic benefits of the environmental service)	3		30.0	
		To figure out possible nature-based solutions	2		20.0	
		To include a scientific study in the green infrastructure project	4		40.0	
		Other	1		10.0	
P11b2	In the contact with the scientist(s), did you inform them for which specific need(s), reason(s) or purpose(s) the scientific information was required? SC	Yes	10	10	100.0	10
		No	0		0.0	
Contact and Framework Phase (1. project phase) Think about the start of the UGI project:						
P12	Was the green infrastructure project based on a scientific study? SC	Yes	7	12	58.3	12
		No	4		33.3	
		I don't know	1		8.3	
P13	Were scientists involved in the project proposal? MC	Yes, to define the time frame	1	21	8.3	12
		Yes, to propose a budget	3		25.0	
		Yes, to suggest specific objectives	5		41.7	
		Yes, to identify possible solutions and outcomes	5		41.7	
		Yes, to give scientific information	6		50.0	
		No, scientists	1		8.3	

		were not involved in the project proposal				
Consultation Phase (2. project phase) Think about the actual implementation of the UGI project:						
P14	Have scientists been involved? *(if ticked "Yes, to provide scientific information" go to P14a)*	Yes, to make an own scientific study (for instance to understand the impact of the green infrastructure plan or project on the well-being of citizens; monitored the trend of bird species in an new park)	7	25	58.3	12
	MC	Yes, to provide scientific information	6		50.0	
		Yes, to make contact with other scientific organisations	0		0.0	
		Yes, to make contact with other non-scientific organisations (NGO)	0		0.0	
		Yes, to bring scientific information into practice	5		41.7	
		Yes, to clarify the project design	3		25.0	
		No, scientists were not involved in the actual implementation	2		16.7	
		No, the project did not cover the implementation	2		16.7	
P14a	In which form did you receive scientific information?	Examples and case studies of other projects	3	17	50.0	6

	MC	Report	5		83.3	
		Scientific article	2		33.3	
		Website	1		16.7	
		Presentation	5		83.3	
		Policy brief	1		16.7	
		Social media	0		0.0	
		Other	0		0.0	
Post-Processing (3. project phase) Think about the end of the UGI project:						
P15	Have scientists been involved?	Yes, to monitor the impact of the project (for instance on biodiversity, ecosystem services, human well-being)	5	15	41.7	12
	MC	Yes, to assist in the project evaluation	6		50.0	
		No, scientists were not involved	4		33.3	
Assessment (4. project phase)						
P16	Were the scientific results or scientific advice used for a final policy output (for instance guidelines, recommendation, action plan, or further green infrastructure projects) *(If ticked "No" go on with P16a)*	Yes	12	12	100.0	12
	SC	No	0		0.0	
P16a	What was the reason not to use scientific results?	The scientific output was not applicable	0	0	0.0	0
	MC	The scientific data were insufficient to support policy	0		0.0	
		The research needed more time than was available	0		0.0	
		Research outcomes were not relevant	0		0.0	
		Communication of the outcomes was insufficient	0		0.0	
		Institutional regulations,	0		0.0	

		laws, old practices prevented changes				
		There was a political change (for instance following elections)	0		0.0	
		Political motives prevent changes (for instance sensitive outcome. fear of losing elections)	0		0.0	
		The scientific results did not match the expectations (for instance an impact is expected but could not be shown)	0		0.0	
P17	Did you face problems during your experience?	Yes, communication with scientists was sometimes difficult	5	13	41.7	12
	MC	Yes, I did not always understand the scientific terminology	2		16.7	
		Yes, the topic of green infrastructure is too complex	1		8.3	
		Yes, the scientists did not understand the administrative planning procedure (for instance bureaucracy)	0		0.0	
		No, I did not face any problems	5		41.7	
P18	After finishing the urban green infrastructure project, do you still have contact with the scientists who were involved?	Yes	11	12	91.7	12
	SC	No	1		8.3	

		SPI Functions				
P19	At what governance level was the urban green infrastructure project carried out?	Neighbourhood	2	12	16.7	12
	SC	City	6		50.0	
		Regional	3		25.0	
		National	1		8.3	
		Supranational (for instance the European Union, the United Nation)	0		0.0	
P20	How many stakeholders were involved in the urban green infrastructure project?	Less than 5	2	12	16.7	12
		Between 5 and 15	5		41.7	
	SC	More than 15	5		41.7	
P21	The urban green infrastructure project was	Long term (more than 1 year)	12	12	100.0	12
	SC	Short term (less than 1 year)	0		0.0	
P22	How many people live in the city where the urban green infrastructure project was realised?	Less than 20.000	0	12	0.0	12
	SC	20.000 – 100.000	4		33.3	
		100.000 – 1 million	8		66.7	
		More than 1 million	0		0.0	
P23	In which city or region was the urban green infrastructure project located?	see map				
P24	Have you been involved in a green infrastructure project before?	Yes	9	11	81.8	11
	SC	No	2		18.2	
		Personal Background				
P25	For which governance level are you working?	City	19	24	79.2	24
	SC	Regional	3		12.5	
		National	2		8.3	
		Supranational	0		0.0	
P26	How many years have you been working in your current profession?	Up to 3	0	24	0.0	24
	SC	3 to 10	9		37.5	
		More than 10	15		62.5	
P27	How frequently do you use scientific information?	Weekly	11	24	45.8	24
	SC	Monthly	9		37.5	
		Yearly	4		16.7	
		Never	0		0.0	
P28	How frequently are you in contact with scientists?	Weekly	6	24	25.0	24
	SC	Monthly	9		37.5	
		Yearly	9		37.5	
		Never	0		0.0	

		No SPI				
P3a	Would you be interested in scientific information or a collaboration with scientists to work on urban green infrastructure? *(If ticked "No" participants are out)*	Yes	3	3	100.0	3
	SC	No	0		0.0	
P4	What information source about urban green infrastructure could be helpful for you?	Information from distinct experts panels	1	7	33.3	3
	MC	A briefing made by other colleagues	0		0.0	
		A scientific presentation (on a workshop, a conference, or a seminar)	1		33.3	
		Participation of scientists in policy advisory committees	1		33.3	
		A policy brief (one page or less)	2		66.7	
		A review article (several pages)	1		33.3	
		A scientific article	0		0.0	
		Other	1		33.3	
P5	On which subject(s) would you like to get more knowledge about the added value of urban green infrastructure? *(go on with personal Background)*	Climate	2	17	66.7	3
	MC	Water managemen t	2		66.7	
		Coastal resilience	1		33.3	
		Green space managemen t	1		33.3	
		Air quality	2		66.7	
		Urban regeneration	2		66.7	
		Participatory planning	1		33.3	
		Social justice	1		33.3	
		Public health	3		100.0	
		Economic opportunitie s	2		66.7	
P2a	Did you know that urban green is important for: Water management Cooling the city during hot summer days Human well being? *(If ticked "No" go to P3a; if*	Yes	0	0	0.0	0

	ticked "Yes" go to P3b) SC	No	0		0.0	
P3b	Was the implementation of urban green infrastructure considered in the project?	Yes	0		0.0	
	SC	No	0		0.0	
		I don't know	0		0.0	
P6a	Why was urban green infrastructure not considered?	Lack of information	0	0	0.0	0
	MC	Difficulties with regulation	0		0.0	
		No funding	0		0.0	
		No political interest	0		0.0	
		I don't know	0		0.0	
P6b	What hindered the implementation of urban green infrastructure?	Lack of information	0	0	0.0	0
	MC	Difficulties with regulation	0		0.0	
		No funding	0		0.0	
		No political interest	0		0.0	
		I don't know	0		0.0	
P7	How did you find information about urban green infrastructure?	My colleagues in formed me	0	0	0.0	0
	MC	I attended a presentation given by scientists (on a workshop, a conference or a seminar)	0		0.0	
		From scientists in policy advisory committees	0		0.0	
		I read a policy brief (of one page or less)	0		0.0	
		I read a review article (of several pages)	0		0.0	
		I read scientific articles	0		0.0	
		Others	0		0.0	
		No full SPI				
P9	Who informed you about the important role of green infrastructure in cities? *(If ticked "Scientific information" go to P9a)*	My colleagues	5	28	50.0	10
	MC	"Policymake rs" in my country	3		30.0	
		"Policymake rs" from other countries	2		20.0	

		"Policymakers" from international organisations (for instance the European Union or the United Nations)	3		30.0	
		People from non-governmental organisations (NGOs)	1		10.0	
		Scientific information	5		50.0	
		My own experience	8		80.0	
		Other	1		10.0	
P9a	Where did you find scientific information about benefits of urban green infrastructure?	In a policy brief (one page or less)	0	11	0.0	5
	MC	In a scientific presentation (on a workshop, a conference, or a seminar)	4		80.0	
		From scientists in policy advisory committees	1		20.0	
		In a review article (several pages)	3		60.0	
		In a scientific article	1		20.0	
		Other	2		40.0	
P10	Within the urban green infrastructure project, have there been other people involved who made scientific information easier understandable for you? *(go anwith personal background)*	Yes, people from an environmental consultancy	4	10	40.0	10
	SC	Yes, people from a non-governmental organisation (NGO)	0		0.0	
		Yes, other	1		10.0	
		No, nobody	5		50.0	

MC Multiple choice
SC Single choice

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