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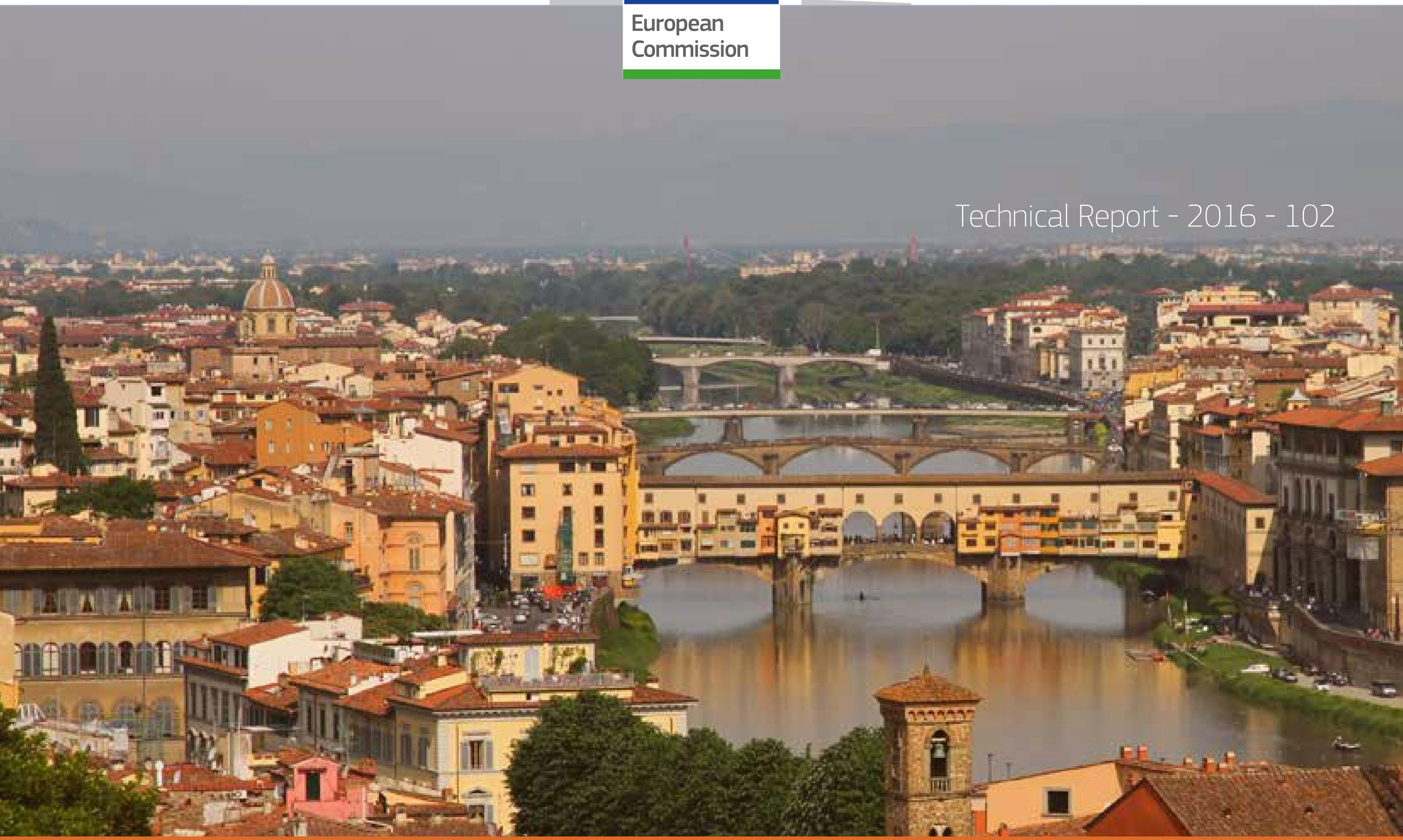

Technical Report - 2016 - 102

Mapping and Assessment of Ecosystems and their Services

Urban ecosystems
4th Report

Final May 2016

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Summary

The mapping and assessment of ecosystems and their services in EU - MAES - is an initiative of the European Commission, which aims to improve the knowledge and evidence base for biodiversity policy as defined under Target 2 Action 5 of the EU Biodiversity Strategy to 2020. The fourth MAES report provides guidance for mapping and assessing urban ecosystems and includes an indicator framework to assess the condition of urban ecosystems and services, which used at European, Member State and local level.

This study is an initiative of the working group MAES and was chaired by the Joint Research Center and the Dutch National Institute for Public Health and the Environment (RIVM). It has been conducted in close collaboration with the cities of Barcelona, Cascais, Lisbon, Oeiras, Oslo, Padua, Poznań, Rome, Trento, Utrecht, the Portuguese directorate-general for territory, the European Environmental Agency and the European Commission.

CONTENTS

EXECUTIVE SUMMARY

Action 5 of the EU Biodiversity Strategy to 2020 requires member states to Map and Assess the state of Ecosystems and their Services (MAES). This report provides guidance for mapping and assessment of urban ecosystems. The MAES urban pilot is a collaboration between the European Commission, the European Environment Agency, volunteering Member States and cities, and stakeholders. Its ultimate goal is to deliver a knowledge base for policy and management of urban ecosystems by analysing urban green infrastructure, condition of urban ecosystems and ecosystem services.

This report presents guidance for mapping urban ecosystems and includes an indicator framework to assess the condition of urban ecosystems and urban ecosystem services. The scientific framework of mapping and assessment is designed to support in particular urban planning policy and policy on green infrastructure at urban, metropolitan and regional scales.

The results are based on the following different sources of information: a literature survey of 54 scientific articles, an online-survey (on urban ecosystems, related policies and planning instruments and with participation of 42 cities), ten case studies (Portugal: Cascais, Oeiras, Lisbon; Italy: Padua, Trento, Rome; The Netherlands: Utrecht; Poland: Poznań; Spain: Barcelona; Norway: Oslo), and a two-day expert workshop. The case studies constituted the core of the MAES urban pilot. They provided real examples and applications of how mapping and assessment can be organized to support policy; on top, they provided the necessary expertise to select a set of final indicators for condition and ecosystem services.

Urban ecosystems or cities are defined here as socio-ecological systems which are composed of green infrastructure and built infrastructure. Urban green infrastructure (GI) is understood in this report as the multi-functional network of urban green spaces situated within the boundary of the urban ecosystem. Urban green spaces are the structural components of urban GI.

This study has shown that there is a large scope for urban ecosystem assessments. Firstly, urban policies increasingly use urban green infrastructure and nature-based solutions in their planning process. Secondly, an increasing amount of data at multiple spatial scales is becoming available to support these policies, to provide a baseline, and to compare or benchmark cities with respect to the extent and management of the urban ecosystem.

Concrete examples are given on how to delineate urban ecosystems, how to choose an appropriate spatial scale, and how to map urban ecosystems based on a combination of national or European datasets (including Urban Atlas) and locally collected information (e.g., location of trees). Also examples of typologies for urban green spaces are presented.

This report presents an indicator framework which is composed of indicators to assess for urban ecosystem condition and for urban ecosystem services. These are the result of a rigorous selection process and ensure consistent mapping and assessment across Europe.

The MAES urban pilot will continue with work on the interface between research and policy. The framework presented in this report needs to be tested and validated across Europe, e.g. on its applicability at city scale, on how far the methodology for measuring ecosystem condition and ecosystem service delivery in urban areas can be used to assess urban green infrastructure and nature-based solutions.

The outcome of this report is reflecting the best-available assessment of suitable data sets and indicators for mapping and assessing urban ecosystems and their services under Action 5 of the EU Biodiversity Strategy. The recommendations for the use of maps and indicators presented here should be taken as a first working version on which feedback is welcome in order to continue improving guidance to Member States.

Supporting documents from the Pilots' work can be found at https://circabc.europa.eu/w/browse/b3aa2f63-9ef8-4f23-b6b5-c7ac17ddc202

Information about MAES is available at: http://biodiversity.europa.eu/maes

Mapping and Assessment of Ecosystems and their Services

URBAN ECOSYSTEMS

1 INTRODUCTION

1.1 Context

Almost three out of four EU citizens live in urban areas and this number will further grow. All these people need an inclusive, healthy, resilient, safe and sustainable living environment. This challenge is well captured by the United Nation's sustainable development goals (SDG) that include under SDG 11 seven specific targets aiming to make 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.

The EU Urban Agenda addresses these challenges in a more practical way (see Box 1). It proposes to work on smart cities; low-carbon, climate-resilient cities with good social inclusion. It also schedules impact assessment, benchmarking and monitoring on the basis of new data.

The question is how to address these challenges. The EU Biodiversity Strategy to 2020, and within that the communication on Green Infrastructure (Figure 1), emphasize the value of nature for our welfare. This is a general conclusion, and it certainly relates to the urban environment. Protected areas such as Natura 2000 sites and ecosystems inside and around cities provide natural (nature based) solutions to many urban challenges. Trees, parks, green roofs, gardens and urban forests help improve the quality of the air, reduce noise, mitigate extreme summer temperatures or peak flood events. They also provide non-material benefits such as recreation, education, cultural and aesthetic values and maintenance of social relations. Importantly, people who live in neighborhoods with a higher density of trees on their streets or with higher amounts of green space are found to be healthier or report themselves as healthier (Kardan et al. 2015; Seresinhe et al. 2015; Dadvand et al. 2016; Jennings et al. 2016).

Maintaining functioning urban ecosystems is therefore key for future urban policy and planning. Increasing urbanization should go hand in hand with increased attention to the proper design and implication of urban GI to make cities more sustainable and increasingly resilient.

The integration of urban GI in urban planning requires vision, innovation, awareness raising among planners, stakeholders and citizens, and tools to monitor progress to policy objectives or to support policy-making. Both the potentials as the required innovation have been acknowledged by the EU research policy agenda for nature-based solutions. Horizon 2020, the EU's program for research and innovation, calls for proposals on nature-based solutions: 'nature can help provide viable solutions that use and deploy the properties of natural ecosystems and the services that they provide in a smart, 'engineered' way.' The call for proposals aims to enhance the evidence base for the effectiveness of nature based solutions to face societal challenges in particular in cities. Acknowledging this potential, more and more cities are therefore mapping their urban ecosystems to build an evidence base to find out the economic, social and environmental benefits of present and future green infrastructure (GI).

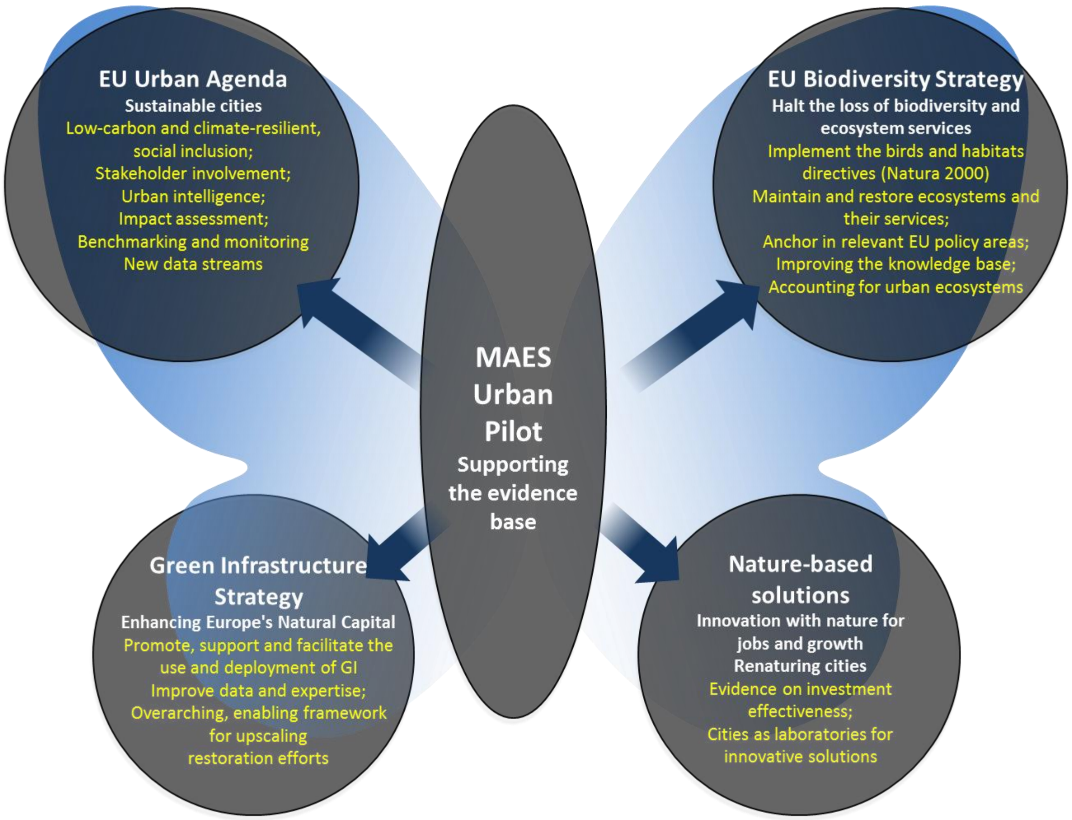


Figure 1. The role of MAES in supporting the urban policy agenda.

Both effective policymaking as well as innovation through nature-based solutions require a sound knowledge base: we must understand better the baseline situation of urban ecosystems, what this means in terms of values for society, and how possible changes affect these values. This is no common knowledge yet. It requires an effort to bring together scientific and practical knowledge. This is the main ambition of the EU working group MAES on Mapping and Assessment of Ecosystems and their Services. This working group oversees the implementation of Action 5 of the EU Biodiversity Strategy to 2020.

Urban environments are very specific. General frameworks in the 2nd MAES report based on pilot work on forests, agro-ecosystems, fresh waters and marine ecosystems cannot simply be adopted in an urban environment (Maes et al. 2014; Maes et al. 2016). Therefore, the working group MAES started in 2015 a pilot study on urban ecosystems, also referred to in this report as “the MAES urban pilot”, in order to enhance the evidence base for policy support and scientific application (Figure 1).

The MAES urban pilot is a collaboration between the European Commission, the European Environment Agency, volunteering Member States and cities, and stakeholders. Its main goal is to deliver a knowledge base for policy and management of urban ecosystems by analysing urban green infrastructure, condition of urban ecosystems and ecosystem services.

This report provides working guidance to the Member States on how to map urban ecosystems and assess their condition and services, based on the outcomes of the MAES urban pilot. The outcome of this report is considered to be based on the best-available assessment of suitable data sets and indicators. Nevertheless, the outcomes presented here should be taken as a first working version on which feedback is awaited that will be reflected in future versions.

Box 1. The EU Urban Agenda

In July 2015 the European Commission launched a public consultation on the key features of an EU urban agenda. The consultation indicated broad support among city stakeholders for an urban agenda. Europe can help cities to address common challenges and, in turn, cities can contribute to achieve the policy objective of the EU with respect to economy, energy, climate change, or resource efficiency. Cities are places where several global challenges can best be tackled. Cities are for instance ideally placed to contribute to the reduction of energy consumption and CO_2 emissions as the density of urban areas allows for more energy efficient forms of housing and transport. Cities can also be part of the solutions to tackle the biodiversity crisis and contribute to ecosystem services

Based on this consultation, the European Commission is now giving shape to the urban agenda together with the Member States. Cities are one of the major players as they directly or indirectly implement EU policies on the ground and therefore contribute to EU's major policy objectives. Action is needed at EU, national and city level to ensure that cities are able to fulfil their potential in this role. In particular the 2014-20 Cohesion Policy framework introduced a number of new instruments intended to increase the role of cities in cohesion programming and implementation and thus enhance the urban dimension of cohesion funding.

One of the promising developments in this perspective is nature-based solutions. These are understood as living solutions that are inspired or supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience, in particular in cities (H2020 Nature Based Solutions).

The MAES pilot can help achieve the ambition of the EU urban agenda and act as an example of collaboration across policy levels to promote European urban success stories, and to provide guidance for monitoring urban biodiversity, mapping urban green spaces, and assessing condition and services.

Through the EU Urban Agenda national governments, cities, European institutions and other stakeholders will be working together for a sustainable, innovative and economically powerful Europe that offers a good quality of life. Clearly, the MAES urban pilot is already an excellent illustration of collaboration across scales among researchers, stakeholders, city administrators and policy makers to improve policy and decision making in cities.

1.2 Ambition of the pilot and objectives of the report

The ambition of the MAES urban pilot is to enhance contacts between communities of practice at local regional and country level in order to exchange experiences and knowledge on mapping, assessment, valuation and implementation of urban green infrastructure, urban biodiversity and urban ecosystem services.

The concrete objectives of this report, which is based on the first year of the MAES urban pilot, are:

- Learn from experiences reported in the literature, by stakeholders or obtained through the different case studies in the MAES urban pilot;
- Build an indicator framework for mapping and assessment of urban ecosystems and their services in order to help design or implement policy on urban green infrastructure as well as to measure progress to international, national, regional or local targets with respect to sustainability and biodiversity in cities;
- Explore what policies are currently in place and what challenges cities meet to enhance the use of nature based solutions;
- Provide a methodology which allows to measure ecosystem services delivered by green infrastructure and nature-based solution policies, and which provides evidence on how they respond to challenges cities meet.

1.3 Terminology and definitions

Before presenting a framework for mapping and assessment of urban ecosystems, some of the terms used in this report need to be defined. These definitions matter; they are important for understanding how urban ecosystems can be mapped, how their condition can be assessed, and how they deliver ecosystem services.

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. For the purpose of MAES two different, functional components are considered: 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. This definition of urban ecosystems is a further development of the definition used in the 2nd MAES report, which is: "Urban ecosystems are areas where most of the human population lives and it is also a class significantly affecting other ecosystem types. Urban areas represent mainly human habitats but they usually include significant areas for synanthropic species, which are associated with urban habitats. This class includes urban, industrial, commercial, and transport areas, urban green spaces, mines, dumping and construction sites". The present definition recognises urban ecosystems as socio-ecological systems which is arguably important to define a baseline against which to evaluate the condition of urban ecosystems. This will be discussed in Chapter 6. Chapter 5 focusses on how urban ecosystems can be mapped.

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.

Green infrastructure (GI) is the network of urban green spaces situated within the boundary of the urban ecosystem. Therefore it can also be referred to as urban GI. How to draw the boundary of an urban ecosystem is considered further in this report (Chapter 5). Urban GI can also include other MAES ecosystem types if they are situated within the boundary of the urban ecosystem. Freshwater ecosystems and marine ecosystems are sometimes referred to as blue infrastructure, but for simplicity the term green infrastructure is used for all urban green spaces and for those parts of other MAES ecosystem types which are situated within the boundary of the city of the urban ecosystem. Just as built infrastructure, urban GI has a **functional** (actually a multi-functional) connotation. The definition of urban GI used in this report is well aligned with the definition adopted by the Green Infrastructure Strategy: "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 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."

Urban green spaces are the structural components of urban GI. Urban green spaces are partly or completely covered with vegetation. They include all sorts of vegetation from a single tree to an urban forest. Examples are plants on balcony, green roofs and walls, hedges, playgrounds, cemeteries or river banks. Different typologies for urban green spaces are available and will be discussed in Chapter 5. In contrast with urban GI, urban green spaces are considered to have a **structural** connotation. The term green urban area is not used in the report but considered synonym to urban green space.

The European Commission has harmonised definitions of "**city**" and "**commuting zone**" with a spatial implementation. Therefore this report adheres to these definitions. The spatial implementation is explained in chapter 5 (Mapping urban ecosystems). Other terms such as urban area or peri-urban area are used in the case studies of the report but their use is avoided in the final chapters of this report where the mapping and assessment framework is presented.

1.4 Structure of the report

The report is structured as follows: **Chapter 2** introduces the readers to the collaborative efforts of the Member States and EU services in order to identify the data and indicators that can be used to report under Action 5. **Chapter 3** presents summaries of 10 case studies, corresponding to 10 cities in Europe. These case studies show cities have mapped and assessed urban ecosystems and urban ecosystem services in response to policy questions. **Chapter 4** summarizes the main conclusions of the pilot's different working streams to better understand the present problems, questions and challenges of policy on urban green infrastructure in Europe. Chapters 5, 6 and 7 introduce the indicator framework for mapping and assessment. **Chapter 5** outlines how urban ecosystems can be mapped. **Chapter 6** presents indicators to measure urban ecosystem condition and **chapter 7** presents the indicators for urban ecosystem services. Finally, **Chapter 8** presents an outlook for the MAES urban pilot to 2020.

2 APPROACH OF THE MAES URBAN PILOT

2.1 Members of the pilot

Following earlier pilot studies on forest, agro-ecosystems, freshwater ecosystems and marine ecosystems, the MAES working group decided in March 2015 to replicate the pilot approach for urban ecosystems. A similar set-up was proposed: the Joint Research Centre and The Netherlands were assigned co-leaders of the pilot. EC members of the pilot are the directorate-general for the environment, the directorate-general for research and innovation, and the European Environment Agency. Portugal (through its Directorate General for Territory Development) contributed as a country to the pilot. Furthermore, ten cities contributed with case studies. Finally, the pilot could profit from specific contributions from projects funded by the EC's directorate-general for research and innovation including, among others, OpenNESS and ESMERALDA.

2.2 Working procedure

The pilot started in April 2015 and lasted 12 months. In a first stage the following issues guided the work:

1. What policies are or can be addressed with this pilot and in the case studies across Europe; what are the needs and expectations of policy makers working with urban areas (at local, regional, national, European levels)?
2. How to map urban green infrastructure (i.e. the spatial structure delivering multiple ecosystem services in urban areas)?
3. How to measure or assess the condition of urban ecosystems?
4. How to quantify urban ecosystem services and their benefits to people?

These questions were answered using an exploratory, sequential multi-method approach which combined semi-quantitative and qualitative methods. Figure 2 shows the four phases of the work carried out. Each step added information which eventually is synthesized in this report.

Firstly an online survey was developed in order to collect detailed information on mapping and assessment of urban ecosystems and their services as well as to understand better what the problems and challenges are of local, regional and national policy on urban ecosystems. Besides a survey, a review of scientific literature contributed to the identification of indicators for mapping and assessment. In a second phase, different case studies became involved in the pilot. They contributed real examples of mapping and assessment. The preliminary results of the steps 1 and 2 of the pilot were discussed in a technical workshop which prepared the final drafting of the report.

2.2.1 Step 1. Online survey and literature review

An online survey was designed to collect information on urban ecosystems, related policies and planning instruments. It was jointly prepared by the JRC, the National Institute for Public Health and Environment (The Netherlands) and the European Commission's Directorate General for the Environment. It was addressed to researchers and stakeholders in order to gather different kind of opinions and experiences. A detailed description of the survey including all the results is available in a JRC technical report (Rocha et al. 2015).

The survey was designed as semi-structured questionnaire, with a few open questions and with the option to add detailed material and auxiliary documents along the process of answering. It was administrated through the online survey platform of the European Commission (https://ec.europa.eu/eusurvey) Contributions were on a voluntary basis. The final version was launched on 01/06/2015 and closed on 30/11/2015.

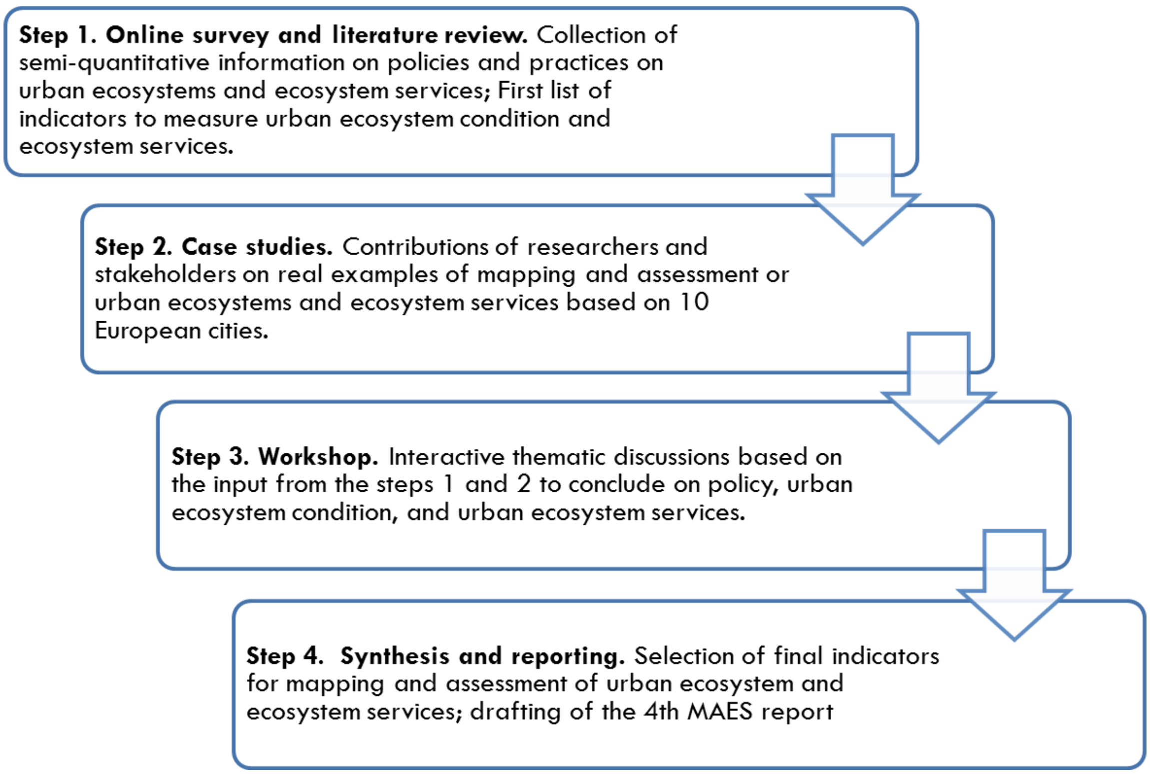


Figure 2. Approach of the MAES urban pilot

A total of 64 answers was submitted originating from 15 European countries and 42 cities or regions (Figure 3). Given the substantial effort needed to complete the survey (between 1.5 and 2 hours) we believe that this number represents a good response.

In addition to the survey, a literature review of 54 scientific papers complemented the survey results. The purpose was to assemble information regarding methods and indicators used to: 1) Map urban green infrastructure; 2) Assess the condition of urban ecosystems; 3) Measure ecosystem services delivered by urban ecosystems.

Information was collected from published scientific articles only. The following search key words were used for a literature search using Science Direct in order to identify suitable case studies: (i) urban AND ecosystem*, (ii) urban AND ecosystem service*, (iii) urban AND ecosystem* OR urban AND ecosystem service* AND case stud*, (iv) urban AND green infrastructure. Generally these terms cover the main search area of urban ecosystem services and urban green infrastructure. Due to the interdisciplinary nature of the subject, results arose from a varied range of scientific disciplines (ecology, geography, geology, land use planning, forestry, and others).

After an initial screening, the resulting scientific papers were checked for relevance. The process of selection was based on the following criteria:

- Are urban ecosystem services explicitly stated?
- What types of ecosystem services are studied (provisioning, regulating and maintenance, cultural)?
- What are the main objectives of the study?
- Which indicators are used? (with reference to indicators and units)
- In which city or region is the case study located?

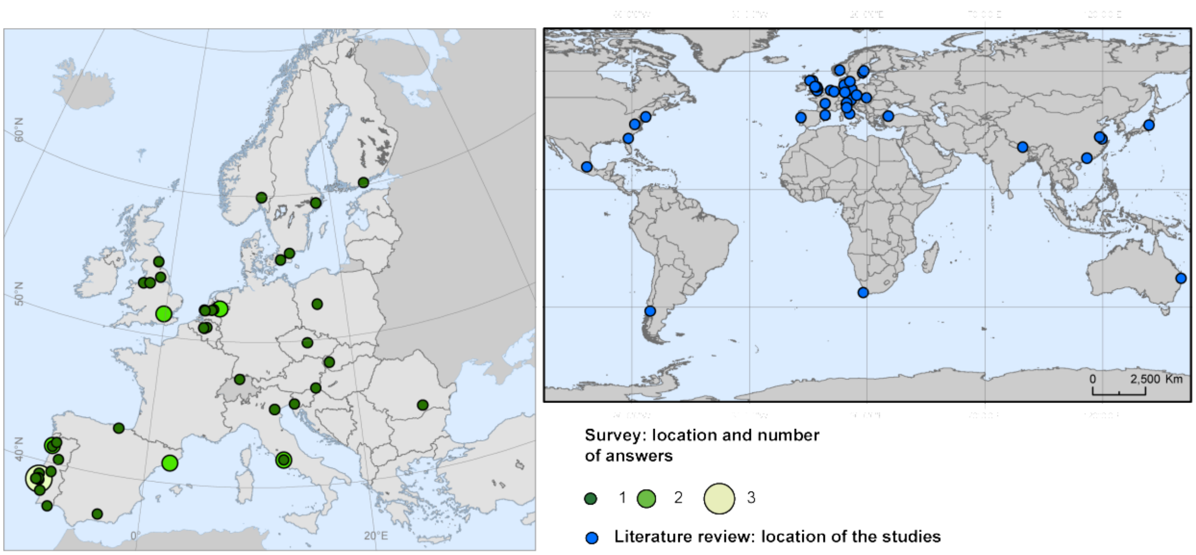


Figure 3. Origin of the information submitted via the online survey and location of the cities reported in the literature review.

2.2.2 Step 2. Case studies

Following a call from the MAES working group, ten case studies participated, on a voluntary basis, to the MAES urban pilot: three cities from Portugal (Cascais, Oeiras and Lisbon), three cities from Italy (Padua, Trento and Rome), one city from the Netherlands (Utrecht), one city from Poland (Poznań), one city from Spain (Barcelona) and finally one city from Norway (Oslo).

The cities were represented by policy makers or actors involved in the public administration, researchers or both. Table 1 gives a short description; Figure 4 presents their location in Europe and their different boundaries (see also Chapter 5 for the spatial delineation of cities).

The names of cities are given in English; some documents to which case studies refer are only available in the national language. In the report the language of the document is indicated with squared brackets, for instance [PT] means that the reference is in Portuguese.

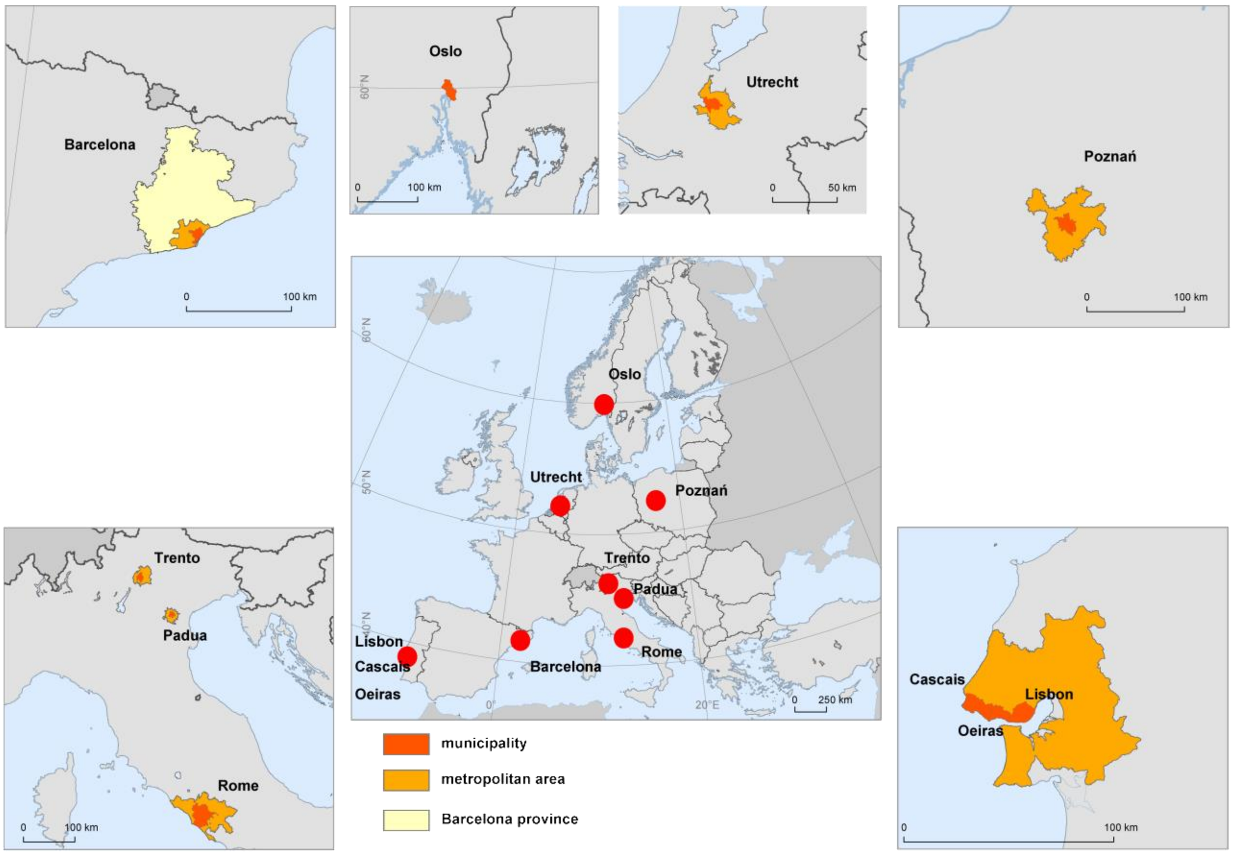


Figure 4. Location of the ten case studies that contributed to the MAES urban pilot.

The case studies contribute in multiple ways to the MAES urban pilot. Each case study documented what policies related to urban ecosystems and urban GI are in place and how maps of biodiversity, ecosystem condition and ecosystem services are used. They all contributed as experts to the workshop and provided feedback to the indicator framework which is presented in the following chapters.

2.2.3 Step 3. Expert workshop

An expert workshop was co-organised by the pilot leaders, the Portuguese Directorate-General for Territory Development (DGT) and the municipality of Lisbon to review the different contributions of these partners and to prepare a set of draft conclusions to be adopted in the final MAES report on urban ecosystems. The workshop took place in Lisbon on 18-19 February 2016.

The workshop was also set up as preliminary exercise aimed at starting a community of practices on the mainstreaming of urban ecosystem services into policy design. Thirty-five experts were invited with the purpose of discussing three key issues: policies related to urban green infrastructure; concepts and indicators related to the condition of urban ecosystem and their services. The discussions were organised using the world café concept and were instrumental to define a final version of the indicator framework. A short description of the workshop questions is provided in CIRCABC while the results are integrated in the following chapters.

Table 1. Description of case studies.

Case study	Represented by	Spatial extent	Collaboration with universities or research institutes
Province of Barcelona (ES)	Barcelona Provincial Council (Diputació de Barcelona)	Regional/Metropolitan	Institute of Environmental Science and Technology (ICTA) – Autonomous University of Barcelona (UAB); Ecological and Forestry Applications Research Centre (CREAF)
Municipality of Oslo (NO)	NINA research Institute	Urban	NINA Research Institute
Municipality of Poznań [1](PO)	Adam Mickiewicz University	Metropolitan	Adam Mickiewicz University
Municipality of Oeiras (PT)	Municipality of Oeiras	Urban	NO
Municipality of Cascais (PT)	Municipality of Cascais	Urban	NO
Municipality of Lisbon (PT)	Municipality of Lisbon	Urban	University of Lisbon
Municipality of Trento (IT)	University of Trento and Municipality of Trento	Urban	University of Trento
Municipality of Padua (IT)	Municipality of Padua	Urban	NO
Metropolitan area of Rome (IT)	Italian Botanical Society Italian Ministry for the Environment and the Protection of Land and Se	Metropolitan	Sapienza University of Rome
Municipality of Utrecht (NL)	Alterra	Urban	Alterra

2.2.4 Step 4. Synthesis and reporting

After the workshop, the pilot leaders formulated a proposal for an indicator framework containing indicators for urban ecosystem condition and urban ecosystem services. The draft framework was based on the JRC technical support and on the outcomes of the workshop. All pilot participants were asked to include (where necessary) new indicators and to score the indicators with respect to their importance and relevant scale (urban, metropolitan and regional, see Chapter 5). The excel tables which are used as input for the final indicator framework are available on CIRCABC.

Table 2 summarizes the indicator selection process for both ecosystem condition and ecosystem services.

Following step 1 the JRC technical report proposed 29 indicators to assess urban ecosystem condition (divided over pressures, state and biodiversity). Only 15 were submitted to Step 3 following a decision to refer to the 2nd MAES report for indicators for other ecosystem types. During and immediately after the workshop 46 additional indicators were suggested by the experts bringing the

[1] Mapping ecosystem services in urban areas in Poland is currently under development. The first Study in this field was commissioned by Ministry of the Environment according to agreement no DLP/4/2015, 23rd March 2015. The study "Urban MAES – ecosystem services in urban areas", provides methodological approach for mapping and assessing urban ecosystem services and compares 10 agglomerations in Poland.

total to 61 condition indicators. The final indicator framework for condition contains 26 indicators after removing indicators that may convey very similar information under different names. This avoids redundancy, double counting and excess of information (Haase et al. 2014).

A similar procedure was followed for ecosystem services indicators with 76 indicators after step 1, 115 indicators at the end of step 3 and finally 40 indicators in the final framework. In the case of provisioning services the indicators refer to services delivered by other MAES ecosystem types but in particular cropland, grassland and freshwater ecosystems. In the case of regulating and maintenance services it was recommended to include indicators related to noise reduction and microclimate regulation; also new options for air quality regulation were suggested. In case of cultural ecosystem services, the MAES pilot experts recommended to map accessibility to urban green space according to different typologies of public green areas and to evaluate cultural heritage and aesthetics.

So it is important to underline that this chapter does not present an exhaustive list of all indicators and models available for a spatially explicit assessment of UES; rather it provides a structured framework that can be implemented at a local, metropolitan and regional level as a support of policies and planning purposes. The framework is consistent with the results of previous comprehensive literature reviews on the topic (Andersson et al. 2014; Gómez-Baggethun & Barton 2013; Haase et al. 2014; Martínez-Harms & Balvanera 2012) as well as with applied research (Derkzen et al. 2015; McPhearson et al. 2014) and with the results of the survey, the literature review and the participatory workshop carried on in 2015-2016 during the first exploratory part of the pilot (Rocha et al. 2015).

In literature, there is a general agreement on the type of urban ecosystem services to be considered. Researchers agree that urban ecosystems are important especially for the delivery of services that directly affect citizens' health, safety and well-being such as air quality regulation, cooling effect and noise reduction, run-off mitigation, flood protection, recreation and food locally produced.

Table 2. Total number of indicators retained at the end of steps 1, 3 and 4 of the MAES urban pilot (for the different steps see Figure 2).

	Step 1 JRC technical report	**Step 3.** Workshop and experts feedback			**Step 4.** Final Indicator framework
		Indicators submitted to **Step 3**	Additional indicators suggested by the pilot members (based on **Step 2**)	Indicators submitted to **Step 4**	
Ecosystem condition indicators					
Drivers and pressures	16	7	13	**20**	**6**
State	11	6	19	**25**	**16**
Biodiversity	2	2	14	**16**	**4**
Ecosystem service indicators					
Provisioning	**27**	26	12	**38**	**6**
Regulating and maintenance	**34**	38	15	**53**	**19**
Cultural	**15**	15	9	**24**	**15**

N.A: Not available

2.3 The role of EU research projects

Several research projects have been instrumental to achieve the objectives of the MAES urban pilot. Some project have directly contributed to the report; for instance through the case study work or by providing specific results. Also indirectly, these projects constitute a network of experts and expertise which is essential to create the conditions for carrying out the pilot work. The different deliverables of many projects and the exchanges among researchers through workshops and meetings provide the inspiration for the proposals for mapping and assessment of urban ecosystems and their services which are presented in the different chapters of this report.

Table 3 provides a list of research projects with which we have collaborated or which provided inputs to the MAES urban pilot. These projects are funded under various funding schemes. All of them carry out dedicated work on urban green infrastructure and ecosystem services.

Table 3. EU funded research projects with contribution to the MAES urban pilot

Project acronym (full name)	**Funding scheme**	**Website**	**Type of input**
ESMERALDA (enhancing ecosystem services mapping for policy and decision making)	Horizon 2020	http://www.esmeralda-project.eu/	Instrumental in providing support to the MAES process and guidance to the pilot
OpenNESS (operationalisation of natural capital and ecosystem services)	7th framework program	http://www.openness-project.eu/	Essential contribution to the case study work
GreenSurge (green infrastructure and urban biodiversity for sustainable urban development and the green economy)	7th framework program	http://greensurge.eu/	Typology of urban green spaces
OPERAs (ecosystem science for policy & practice)	7th framework program	http://www.operas-project.eu/	Important source of inspiration to guide the work in the MAES urban pilot
URBES (urban biodiversity and ecosystem services)	Biodiversa	http://cbc.iclei.org/About-URBES	Important source of inspiration to start the MAES urban pilot
GreenInUrbs (Green Infrastructure approach: linking environmental with social aspects in studying and managing urban forests)	COST	http://www.greeninurbs.com/	Can contribute to the dissemination of the outcomes

2.4 Supporting documents

Supplementary material is available on CIRCA BC, a platform of the European Commission to share information. The following link hosts annexes and additional tables to this report:

https://circabc.europa.eu/w/browse/b3aa2f63-9ef8-4f23-b6b5-c7ac17ddc202

3 CASE STUDIES

This chapter compiles the experiences of local MAES type ecosystem assessments in cities. These case studies have provided instrumental input the final framework for mapping and assessment that is proposed in the subsequent chapters. The case studies of the MAES urban pilot demonstrate what knowledge is available to support current the local policy on urban ecosystems.

These contributions are a synthesis of the case study work carried out in the MAES urban pilot. More complete descriptions are available on CIRCABC.

3.1 Barcelona

3.1.1 Case study area

The Barcelona province, located North-East of Spain is one of the largest and most populous regions in Europe (5.52 million inhabitants in an area of 7 725 km2, data for 2015). It comprises 331 municipalities and twelve counties. Its urban core, known as the Barcelona metropolitan area, is constituted by the municipality of Barcelona (1.61 million inhabitants) and several adjacent middle-size cities. Despite urbanization pressures it contains a rich variety of habitats attaching important ecological, landscape, and cultural values, including a variety of Mediterranean forests, grassland and scrubland, different agro-ecosystems (e.g., vineyards), and several inland water bodies and wetland areas (Figure 5). A relevant share of these habitats is part of a network of protected areas (including various Natura 2000 sites) managed by different regional and municipal authorities. Prominent examples of this network are the Montseny Natural Park, the Collserola Natural Park or the Llobregat Delta wetlands.

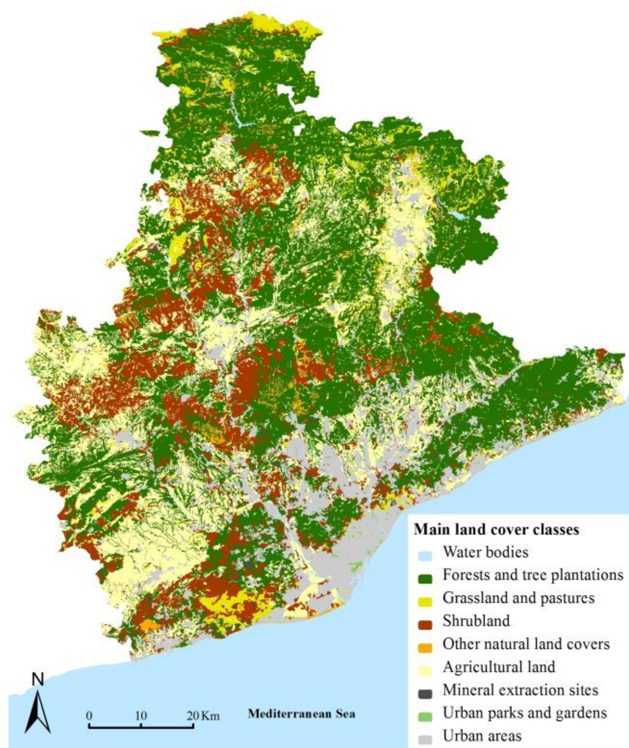


Figure 5. Main land cover classes in the Barcelona province. Source: SITxell, Barcelona Provincial Council

The Barcelona province has suffered a drastic drop in agricultural surface area (almost 58%) over the last decades, much of which has been transformed into urban land and commuting zones. In addition, afforestation took place in the mountains. These changes in land cover and use have had direct implications on the provision of and the demand for ecosystem services since the increase of urban land was to some extent proportional to the increase of population.

3.1.2 Integrating ecosystem services maps in a decision-support tool for landscape and urban planning

One of the main goals of the Barcelona Provincial Council (*Diputació de Barcelona*) is fostering territorial balance and sustainable landscape planning in the Barcelona province. In this context, one of the strategic priorities of the Technical Office for Planning and Territorial Analysis is to improve knowledge of open habitats (non-built-up land). The ultimate aim is to provide information and criteria to support local authorities in their land use planning and management responsibilities and to strengthen their participation in regional projects affecting them. Since 2001 the Barcelona Provincial Council has been developing a decision-support tool, the project SITxell[2] (acronym in Catalan for Territorial Information System for the Network of Open Areas in the province of Barcelona), which contains a categorization and assessment of non-built-up land based on the analysis of its socio-ecological characteristics. SITxell constitutes a systematic collection of data, maps and analyses that covers environmental and socio economic aspects.

The application of the ecosystem services framework, developed during last three years in collaboration with two research institutes (ICTA-UAB and CREAF), highlights the natural processes and functions which are related to benefits for people living in urban regions. This is a very useful approach for urban planners and decision-makers, who are not always specialists in natural sciences and place great importance on economic and social issues. Thus, the mapping and assessment of ecosystem services allows to demonstrate the relevance of natural and rural areas for people's wellbeing, as well as to identify key areas of ecosystem service provision (green infrastructure) for their sustainable management.

Currently maps of the most relevant ecosystem services in the Barcelona province are already used to set up a proposal of regional green infrastructure (Table 4), which is the basis for urban planning at the municipal level. Thus, urban plans do not reflect only proposals for new developments or infrastructures, but schemes for conservation and management of non-built-up areas that are of great value due to their habitat, provisioning, regulating or cultural services. Figure 6 shows a municipal example of a green infrastructure map included in the urban planning. The fact that ecosystem services maps are developed in the first place at metropolitan and regional scales ensures the integration and coherence of green infrastructure proposals at a municipal level.

[2] See http://www.sitxell.eu/en/

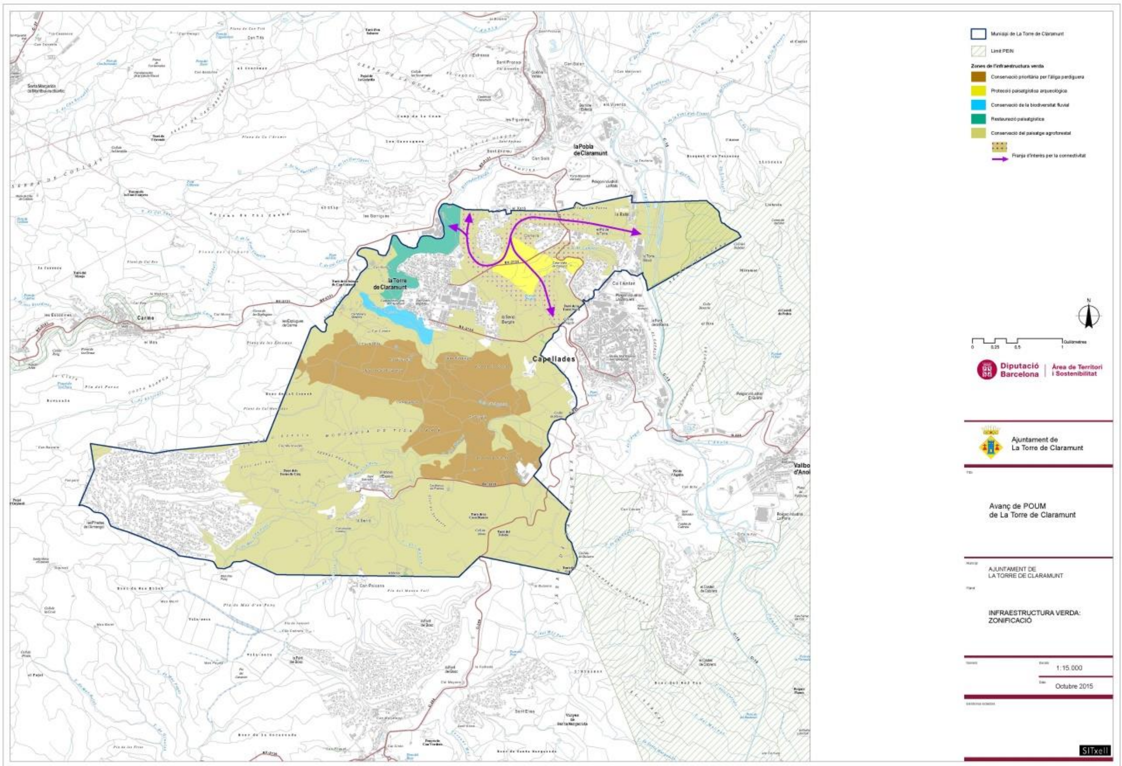


Figure 6. Map of green infrastructure for the municipality of Pobla de Claramunt.

Table 4. Ecosystem services maps currently available in SITxell (classified according to CICES).

CICES Section	CICES Class	Indicator	Unit
Provisioning	Cultivated crops	Average agricultural yield (crops)	kg ha^{-1} year^{-1}
	Plant-based resources	Average aboveground biomass growth (forests)	ton ha^{-1} year^{-1}
Regulating & Maintenance	Global climate regulation by reduction of greenhouse gas concentrations	Aboveground carbon stored (tree layer of forests)	ton ha^{-1} year^{-1} (year 2001 and projection 2013)
	Global climate regulation by reduction of greenhouse gas concentrations	Aboveground carbon sequestered (tree layer of forests)	ton ha^{-1} year^{-1}
	Mass stabilisation and control of erosion rates	Erosion control by ecosystems (based on land cover)	Dimensionless
	Maintaining nursery populations and habitats	Index of botanical interest of habitats	Dimensionless
Cultural	Physical and experiential interactions	Index of potential recreation opportunities	Dimensionless

Source: SITxell, Barcelona Provincial Council and Institute of Environmental Science and Technology (ICTA-UAB).

3.2 Cascais

Cascais is a Portuguese municipality which belongs to Lisbon Metropolitan Area. With 206 479 inhabitants in 2011, the territory occupied by Cascais has an area of 97.40 km^2 and is limited at the north by the municipality of Sintra, south and west by the Atlantic ocean, and east by the municipality of Oeiras. The coastal town was a former fishing village that gained fame as a resort for Portugal's royal family in the late 19th century and early 20th century. Nowadays, it is a popular vacation spot for both Portuguese and foreign tourists. One third of the municipality of Cascais is located in protected areas forming part of the Sintra-Cascais Natural Park (SCNP) and of the Natura 2000 Network. The municipality of Cascais manages directly about 500 ha of natural protected area and 200 ha of urban green space. These areas represent the stepping stones which are key for a major strategy linking the urban areas with the rural and natural ones, promoting the concept of a "*continuum naturale*".

Cascais Green Infrastructure, also known as Cascais Ecological Structure, was presented in 2009 by the Cascais municipality and is a land use planning tool with the fundamental purpose of preserving essential natural areas ensuring the ecological functions on the territory. Together with the protection of natural resources, vital for the sustainability of the municipality, *Cascais Green Infrastructure* defines the possible land uses in natural areas and supports complementary activities in rural and urban areas.

Cascais Green Infrastructure is based on a management model aiming to preserve and valuing the natural and historical-cultural heritage, promoting the environment and the quality of life in the municipality. Enhancing Cascais' green infrastructure implies the creation and management of various urban parks and nature parks and increasing the connectivity between them. The use of the urban parks is mainly oriented towards leisure while the nature parks will contribute to the Sintra-Cascais Natural Park. Their integration in a single articulated network is an initiative of strategic interest for the development of the municipality.

Cascais Green Infrastructure intends to implement concrete measures that allow a sustainable development of the municipality within a time frame of 20 years.

The vision of Cascais Green Infrastructure aims for:

- The maintenance of the ecosystem services like the supply of fresh air, clean water and temperature regulation;
- The protection of areas of high ecological interest;
- The protection of the main streams working as ecological corridors for animals and plants and providing air renewal in the urban centre;
- The promotion of biodiversity through the patchwork of woods, prairies and bushes, protecting the soils and facilitating aquifer recharges;
- The creation of natural spaces, prepared for visitation.
- The landscape system protection by its holistic value, its historical and cultural patrimony and by its representation in the collective memory of the individuals.
- The creation of a network of pathways between the natural and urban space that increases its accessibility and provides sustainable mobility along with a healthy lifestyle.
- The accessibility of parks and gardens to an acceptable distance for the entire population.

- The presence of urban biodiversity at parks and gardens as an indicator of life quality in the urban grid.

3.2.1 Mapping the urban ecosystem

Cascais urban GI was mapped using several GIS layers (Table 5) which were produced based on aerial photography, field trips, and bibliographic research. The task was conducted by a multidisciplinary team and all aspects from natural to cultural elements were characterized. The historical and socio-economic dimension was also taken in consideration.

Table 5. Data produced and used map urban GI in Cascais.

Biophysical Characterization	**Landscape analysis**
Altimetry Hypsometry Slopes Watersheds network Terrain morphology Geology Soil type Land-use capacity Ecological value of soil National agricultural reserve	Landscape units Assessment of landscape units Potential natural vegetation Current natural vegetation Natural and semi-natural habitats Biological value of the current vegetation Interest for the conservation of existing vegetation
Cultural-historical heritage	**Green spaces availability and accessibility**
Traditional urban cores Classified heritage and archaeological heritage Survey of farms in the municipality Farms with cultural interest Cultural-historical heritage Valuation of the historic-cultural heritage Valuation of assets by the parish	Accessibility to public gardens Accessibility to urban parks Accessibility to natural spaces Gardens per capita availability Availability of urban parks per inhabitant

Figure 7 presents four maps used for mapping urban ecosystem in Cascais. The definition of natural and semi-natural vegetation patches is an example of the content of the “Current Natural Vegetation Map”. The “Natural and Semi-Natural Habitat Map” covers the plant communities with conservation interest, which were identified through correspondence with the different habitat types included in the Natura 2000 Management Plan. The “Potential Natural Vegetation Map” was determined based on environmental parameters, integrating climatic information, lithology, pedology and biogeography with field observations and bibliographic research on the vegetation series for the combination of the biophysical characteristics.

The above-described information was fundamental for the creation of Cascais’ Master Plan, in force since 2015, and integrates its execution plan for the next 10 years.

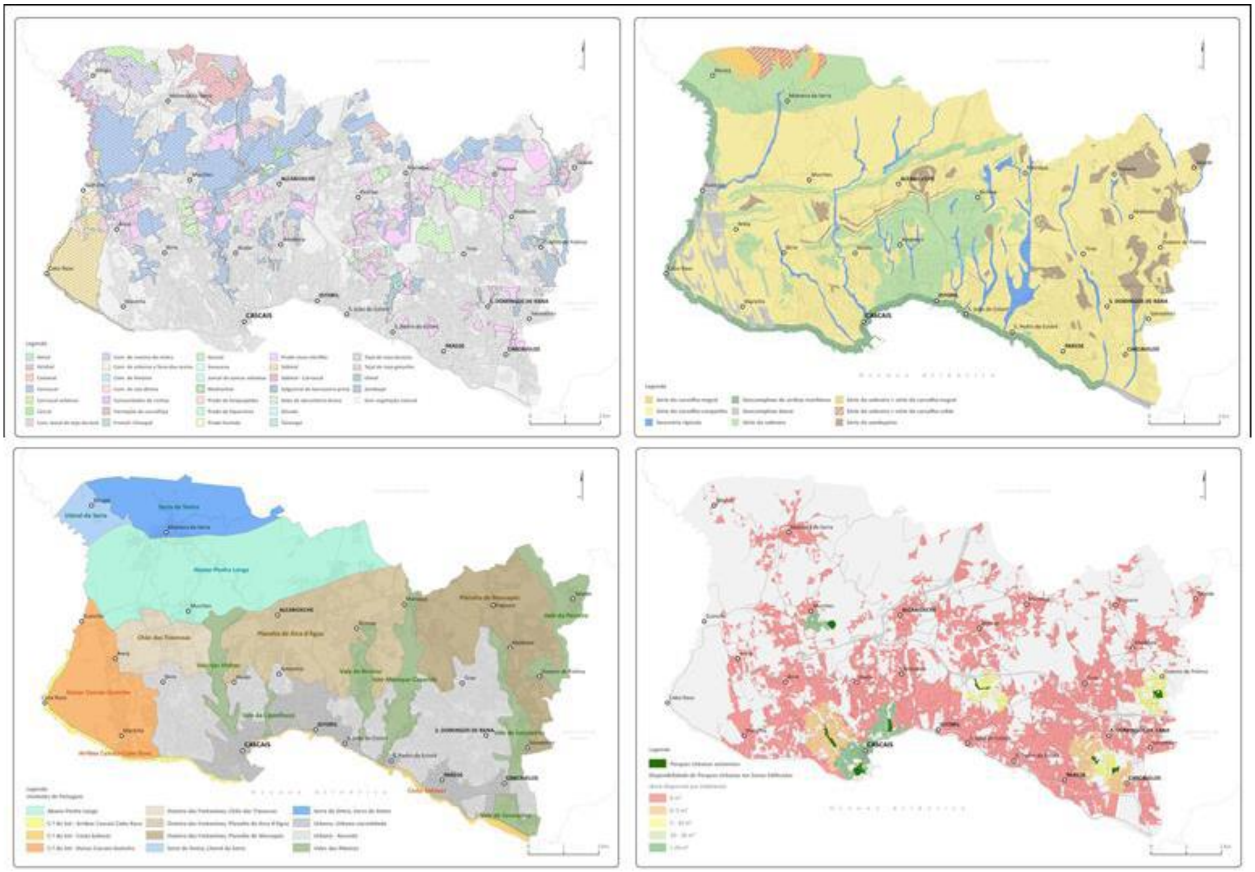


Figure 7. Maps used for mapping urban ecosystem in Cascais. A) Current natural vegetation; B) Potential natural vegetation; C) Landscape units; D) Availability of urban parks

3.2.2 Mapping ecosystem condition

Despite the large volume of data that enables characterizing the urban ecosystem in Cascais, there is still no systematic approach for evaluating the evolution of the ecosystem condition.

3.2.3 Mapping urban ecosystem services

The most important and hence, most valued ecosystem services in Cascais, a touristic city, are leisure and other cultural services, followed by biodiversity, climate regulation and education. The city still needs to continue mapping all these services, although it requires an improvement on data exchange among different areas of expertise.

3.2.4 Conclusions

The mapping of the different ecosystems will provide useful information to implement the municipality's plan on urban GI. The creation of specific indicators to assess the condition and evolution of ecosystems is essential for establishing appropriate policy measures that lead to a sustainable use of the territory. The integration of nature within the urban matrix increases the quality of life and values the territory promoting balance between nature conservation and the needs of a modern society.

3.3 Lisbon

3.3.1 Introducing an urban eco-systemic approach targeting an environmental policy for Lisbon

A city with a good environmental quality is a city that provides a good quality of life for its inhabitants. This is already a competitive issue in the options to be considered while deciding about the location of new investments both for entrepreneurs and citizens. Environmental quality considers aspects of sustainability, lowering various risks, improving biodiversity, fostering the landscape through a land-use planning according to an ecosystemic approach.

Studying pools and flows, biogeochemical cycles, habitats, limiting factors (according to Liebig's law), fragmentation or connectivity, species distributions, or water in the city result in a better knowledge of the urban ecosystem and help the decision making process.

3.3.2 Lisbon's context

Lisbon is over 2000 years old and confined in a small space (8 800 ha). This results in a considerable anthropic pressure on the natural habitats and consequently, in very small areas of pristine biodiversity hotspots, located on the river banks or on abandoned spots in very early stage of ecological succession. However, the influence of man, usually considered as a degradation can also be taken as a positive contribution for biodiversity. One of the best examples is the construction of a peri-urban park in the city in the period 1930-40 which is considered as a natural park[3]. So, in Lisbon, the naturalized areas assume an ecological importance both in terms of the city itself as well as concerning the regional corridors and native biodiversity.

Portugal is located in the border between Euroasiatic and African Biomes while Lisbon is experiencing Atlantic (Northwest) and Mediterranean (Southeast) influence. Biodiversity is thus particularly rich: it has African and European species and it has some perennial broadleaved trees side by side with deciduous trees. Also peculiar species occur which are representative for these two ecotones. Furthermore Portugal in general and Lisbon in particular represent known corridors for migratory fauna.

Lisbon has also a particular approach to exotic biodiversity, because in the past (XV century) Portugal underwent the first globalization process which brought lots of exotic species to Europe. This and the Romanticism following this period led to collections of fauna and flora and resulted in the creation of several botanic gardens (private and public). These newly arrived species have been integrated in the local culture and today it is impossible to understand the city without taking in consideration the oranges (from China), the palm trees (from Canary Islands), the araucarias (from Norfolk islands), the jacaranda (from South America) or the bougainvillea (from the Bougainville Islands).

3.3.3 A strategy for biodiversity in Lisbon

The appealing campaign Countdown 2010, the International Year of Biodiversity 2010 and the United Nations Decade on Biodiversity (2011-20) warranted a response from Lisbon. The articulation

[3] The Forestry Park of Monsanto has been managed following an ecological approach and the human influence has been mainly as a catalyst of the successional process.

with IUCN, UNESCO and CBD with the support of the experiences reported by ICLEI, Curitiba and Singapore showed the importance of defining a Biodiversity Strategy for the city. An important impulse was given by the former mayor (and current prime minister) agreeing with the city council to improve the city's performance on biodiversity targets with 20 % by 2020. This led to the need of an evaluation of the initial frame, especially regarding the availability of biodiversity data which, at that time, were quite dispersed. The city developed a local version of the City Biodiversity Index (CBI, see also Chapter 6) based on earlier examples from Curitiba and Singapore.

This CBI considered three types of indicators: the biodiversity indicators (*sensu strictu*), indicators of ecosystem services and biodiversity governance and management indicators. Indicators were selected based on their relevance for the decision making process, their contribution to the quality of the environment, and their specificity (for example a single species production forest may produce important ecosystem services, but hosts little biodiversity). Preference was given to a small set of indicators to avoid confusion. The CBI was calculated in order to set a baseline for measuring progress to target.

The biodiversity strategy was inspired by the Aichi targets but adapted to the specific local situation of Lisbon. The main topics include (1) causes of biodiversity loss; (2) sustainable use; (3) preservation of genes, species and systems; (4) enhancement of the benefits (ecosystems services); and (5) participatory planning, capacity building and working knowledge (usefulness).

The main axes were directed to:

A. Enlargement of public green areas
B. Connectivity / Discontinuity
C. Ecological management of green infrastructure
D. Improving biodiversity of green infrastructure
E. Classified / Protected Areas (Natura 2000)
F. Retention basins / Infiltration
G. Naturalization of the watersheds
H. Urban agriculture
I. Living beings
J. Citizens awareness about the theme
K. Trails, information about the values
L. Management and local authorities governance

This process was led by the City Council, in collaboration with the Municipal Agency of Energy and Environment, the National Institute for Nature Conservancy and Forests, and the University of Lisbon.

3.3.4 Local action plan for biodiversity in Lisbon

The Strategy to 2020 needed to be put into practice which was done through a Local Action Plan for Biodiversity in Lisbon (PALBL[4]). Three main axes were proposed: Awareness (to act), Improve the Knowledge (for better acting) and Act (on behalf of Biodiversity).

The territorial interventions were already regulated by the environmental component of Lisbon's Master Plan, but new aspects foregoing from the plan were: the establishment of a set of support

[4] Plano de Ação Local para a Biodiversidade em Lisboa 2020 [PT]

regulations, the creation of data bases and networking platforms both to receive data and turn it into publically available and meaningful information, and the improvement of public participation.

Its implementation builds on a multi-sectorial approach (internal and external to the municipality, institutions and civil society) and also with a global impact on different sectors of activity (such as tourism for example).

To improve the performance of the city of Lisbon in terms of biodiversity, there is a need to:

1. Valorize the hotspots of biodiversity, for their importance and their contribution to create more interesting landscape units (Also through national and international publicity);
2. Use them as the substrate of educational and touristic experiences, or activities of partnerships of companies under social responsibility programs;
3. Using biodiversity hotspots as contributing to the improvement of urban environment quality, the citizens' quality of life and as prominent elements regarding the competitiveness of the city in keeping people and important companies for our economy;
4. Promote the consensus of various partners, in the fruition, maintenance, preservation and protection of biodiversity;
5. Prevent the destruction of the results of these collective efforts of conservation and biodiversity maintenance

In the axis Awareness the plan will promote training and communication, the development of thematic trails and the celebration of some events. Concerning Knowledge it will promote conferences, communication networks and the monitoring of species and habitats. The Acting axis will promote GI, sectorial management, regulations and information.

3.3.5 Certification according to Forest Stewardship Council

According to the Metropolitan Master plan of Lisbon[5], the main park of the city has been considered a model forest, not only for its importance but mostly because of the type of management that has been carried out in previous years. The management of Monsanto Park has also required the recognition (Certification) of its performance as a Forest with High Value for Conservation[6] by the Forest Stewardship Council. The process of certification requires monitoring the following indicators

- Protected areas (Natura 2000)
- Threatened or endangered species
- Endemic species
- Critical areas with seasonal use
- Large forest areas with global relevance
- Areas included in rare ecosystems
- Areas that may supply basic environmental services under critical contexts
- Critical areas for the cultural traditional identity of local communities (cultural, ecological, economic or religious relevance)

This work includes the identification of values, the consultation process, the management measures and the monitoring of values (*sensu strictu*).

[5] PROT AML – Plano Regional de Ordenamento do Território da Área Metropolitana de Lisboa [PT]
[6] AAVC – Floresta com Alto Valor para a Conservação [PT]

3.3.6 Monitoring, maintenance, activities

All these approaches to safeguard biodiversity in Lisbon also incur main challenges for the city:

- Update the knowledge we have about our urban ecosystem
- Maintain and improve the quality of the environment for everybody
- Use our CBI as an evaluation tool of our work
- Improve the activities developed on behalf of the urban environment quality: either those promoted by the city council or those promoted by all the others.
- Develop the environmental awareness of all the citizens, in the participatory processes, but also in a volunteer base, co-operating with the city council.

3.4 Oeiras

3.4.1 Policy context and objectives

Oeiras is one of the 18 municipalities of the Metropolitan Area of Lisbon with a surface area of 45,9 km^2 and 172.120 inhabitants. It developed from an early agricultural human settlement to a suburban area during the second half of the 20th century. Its main physical and environmental assets are the proximity to Tagus estuary (Tejo, [PT]) and to Lisbon, a good regional accessibility and positive landscape values. With the first generation of land use plans, this territory evolved to be a predominantly urban area, attracting large national and international service companies, providing good quality residential areas, avoiding illegal settlements, supplying social housing and services leading to more favorable situation as measured by poverty and inclusion indicators than those of neighbouring cities.

Oeiras pursues the Local Agenda 21 sustainability objectives[7] since 2001, and has developed a revised sustainable development strategic plan in 2008, where green infrastructure is the first of ten "driver-projects", followed by the river valleys and coast line protection and fruition. This gives an idea of the importance of green infrastructure from the point of view of public participation in the definition of these priorities for the sustainable development of Oeiras.


Images of Oeiras taken during the 1940's (by António Passaporte) and the 2000's. Copyright: Municipality of Oeiras.

[7] http://www.cm-oeiras.pt/amunicipal/Sustentabilidade/Agendaxii/Paginas/Agenda21+.aspx [PT]

3.4.2 Oeiras land use master plan

The revised land use Master Plan[8] (Plano Diretor Municipal, [PT]) recently approved, outlines the municipal development strategy in five strategic vectors:

a) Concentration and multi-centered urban development;
b) Mobility;
c) Public space qualification;
d) Improvement of the efficiency of the urban services network;
e) Governance efficiency.

The land use model considers green infrastructure, defined according to national legislation - Estrutura Ecológica Municipal [PT]- Municipal *Ecological Structure*, as the frame of urban areas. The municipal ecological infrastructure is built with the areas, values and fundamental natural systems that, together and by reason of its biophysical or cultural characteristics, have as main function to contribute to the ecological balance and for the protection, conservation and environmental enrichment of Oeiras territory.

3.4.3 Green spaces sectorial policy

The green infrastructure set in the master plan is managed according to long term sectorial strategic planning instruments focusing:

- Green corridors establishment (Plano dos Corredores Verdes, [PT]);
- Sustainable water use (Plano da Água , [PT]);
- Afforestation (Plano de Arborização, [PT]);
- Local biodiversity (Plano da Vegetação, [PT]).

The municipality enforces these plans within the competences for urban development approval, green parks and gardens and a vegetable-garden project, and building, tree planting, urban river management, green area irrigation systems, etc.

The population and local actors have been actively involved in the implementation of these plans, either in the framework of a 21 year Environmental Education Plan as well as in the Social Responsibility and volunteering local programs, under slogans like “One citizen, one tree in 2017”.

Historical gardens and farms are of particular concern, as they are part of the historical and cultural heritage of Oeiras.

More recently, a Strategic Plan for River Restoration and Requalification was developed, and has been approved by the Town Council and the Parliament.

3.4.4 Mapping urban ecosystems

The Ecological Network (EN) is a relevant planning feature grounded in national Portuguese law and should be defined in planning practice either at regional or local level. The local administration should define the Municipal Ecological Network (MEN) in their land use Master Plan integrating regional and

[8] http://pdm.cm-oeiras.pt/homepage.aspx [PT]

national environmental policies in articulation with other sectorial policies (housing, transportation, agricultural policies, etc.).

Oeiras has defined the MEN in strict articulation with the regional plan, but also trying to frame the ecological perspective as an added value for landscape development goals. The MEN is implemented in two different levels: Fundamental Ecological Network (FEN) and Complementary Ecological Network (CEN).

The aim of the FEN is to protect the ecological values defined at national and regional scale which in turn are responsible for the main landscape and ecosystem functions, and integrate them into local spatial planning policies and practice. FEN deals not only with ecological and biodiversity resources (e.g. soil, biomass, water, etc.), but also with risk (e.g. flood, soil erosion, tsunami, landslide, etc.). Other values with local relevance for landscape and ecosystem functions and services (e.g. cultural landscape features, local green corridors, public green spaces within the city, etc.) are framed in the CEN.

For the past two decades, other sectorial strategies for ecological and biodiversity improvement have been defined in Oeiras, and most of these strategies were then transformed in several local Plans, which in turns were used in MEN (Table 6, Figure 8). Some examples are the local plan for green corridors, local plan for afforestation, local plan for water management regarding hydrological resources, and recently a plan for river restoration and rehabilitation.

Table 6. Typologies of MEN in Oeiras. Terms in Portuguese and English

Fundamental Ecological Network	
Áreas integradas na Reserva Ecológica Nacional;	National Ecological Reserve;
Áreas integradas na Reserva Agrícola Nacional;	National Agricultural Reserve;
Áreas do domínio público hídrico;	Public Hydrological Areas
Áreas integradas no regime florestal;	Areas under public forestry regime
Áreas de povoamento de sobreiros e azinheiras;	Protected areas of cork and holm oaks
Áreas vitais da Rede Ecológica Metropolitana;	Metropolitan Ecological Network (vital areas)
Áreas afetas a habitats de interesse comunitário	Classified Habitats of European interest
Complementary Ecological Network	
Áreas de salvaguarda do sistema hidrogeológico;	Protected areas of hydrogeological system;
Áreas de produção de biomassa;	Biomass production areas;
Áreas verdes urbanas;	Green urban areas;
Áreas de conetividade e sistema de vistas.	Connectivity areas and system of views

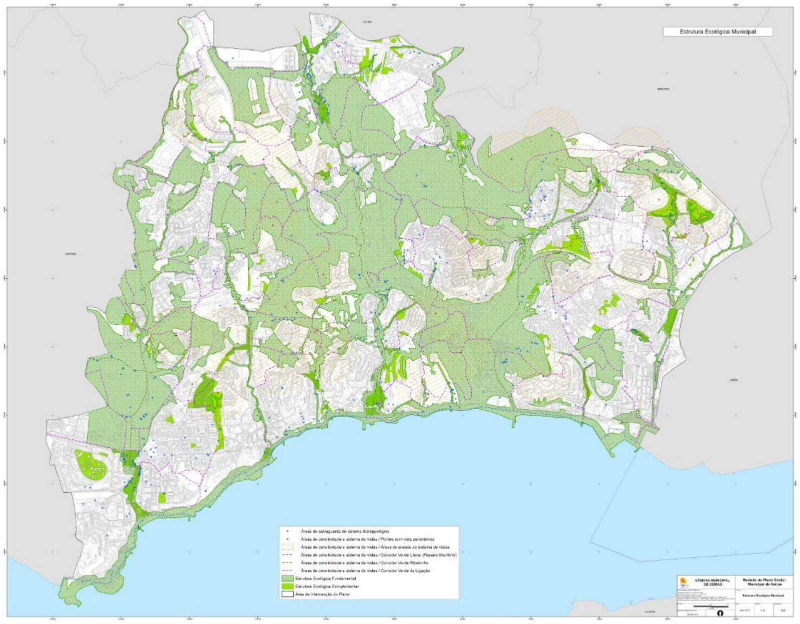


Figure 8. Municipal Ecological Network in Oeiras

3.4.5 Mapping ecosystem condition

Oeiras has developed a Sustainable Development Indicators System – SIDSO – Sistema de Indicadores do Desenvolvimento Sustentável de Oeiras [PT], which to some extent displays the condition of ecosystems, for example in terms of water management and water quality, river ecosystem conditions, air pollution, local cultural assets, human health and outdoor physical activity, environmental awareness, soft mobility, urbanization rates, soil sealing, etc.

The above mentioned Plan for River Restoration and Rehabilitation also defined indicators for monitoring the objectives that were set. Those indicators were articulated with SIDSO and others, although focusing more detail information regarding blue infrastructure.

3.4.6 Mapping ecosystem services

Oeiras has basic information which is necessary to map ecosystem services, but this work is still to be done. The MAES urban pilot will certainly be helpful in setting up European terms of reference and methodologies for this objective.

3.4.7 Conclusions

The territorial, cultural and touristic promotion of Oeiras builds upon several landscape and environmental values, somewhat defined and protected in the land use planning and management mechanisms and in several sectorial strategic plans that give orientation to municipal services actions.

Nevertheless, these assets – which in practical and scientific terms are nothing more than ecosystem services – lack an objective, quantitative and science-supported assessment, which in turn could give support and longer term vision to municipal plans and policies.

Oeiras envisages the further development of the MAES urban ecosystem pilot as the first step to a better ecological management of its territory.

3.5 Padua

Padua (Padova [IT]) is the most densely populated town of north-east Italy (215 000 inhabitants, corresponding to 2 309 inhabitants km^{-2}). Nowadays, only 5.86 % of the urban surface is covered by "public green area" (5.45 km^2 on a total surface of 93.03 km^2). This scarcity of public green areas is mainly due to urban sprawl that characterised the area during the last decades as well as to the lack of land restoration within the urban core itself.

The municipality is responsible for all the activities related to the management of public green areas and trees. To this end the city stores and updates spatially explicit data on trees and green areas within a relational geodatabase which represents the main repository to inform management decisions. This case study focusses on how such information is used in the management of urban green spaces

3.5.1 Tree database of Padua

The tree data collection started in 1999, with the inventory of street trees; from 2013 onwards, the collection also included trees that grow inside public green areas (urban parks and gardens).

Data are collected on the ground by trained and experienced surveyors using mobile devices (Android-based tablets) and paper forms, and all the records are checked for accuracy. Each tree is spatially identified and fully characterised by data on size, health status and maintenance operations needed.

Table 7 shows the type of information collected. Figure 9 shows the relational structure of this information, taking street trees as an example. Next, we focus on the street trees inventory.

Table 7. Type of information collected for each tree in Padua.

Description and health status of trees	
Species name	Tree height class
Planting date	Tree diameter class
Description of the location	Canopy width
Paving	Canopy depth
Tree stake	Canopy configuration
Tree shelter	Condition
Irrigation system	Assessment time frame
Maintenance needs and performance	
Removal	
Pruning (four types)	
Tree stake removal	
Tree shelter positioning	
Visual tree assessment	
Advanced tree assessment	

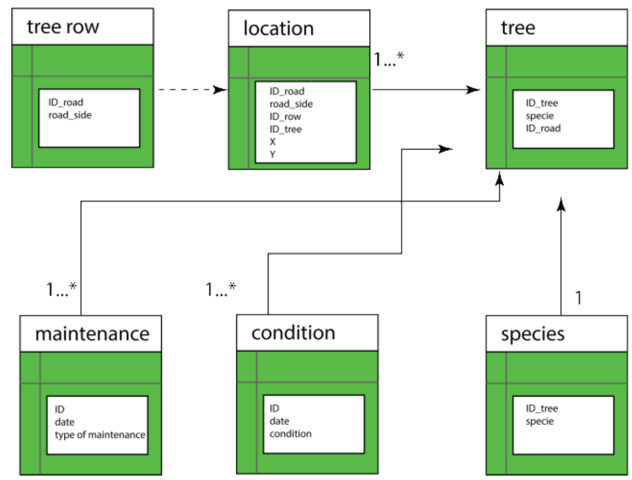


Figure 9. Relational structure of the street tree data.

3.5.2 Street trees: species and ecological traits

Street trees are defined as the trees located on the public right-of-way next to streets and roads. Padua has more than 10 thousand street trees; most of them (61%) are located in residential areas (Table 8). Industrial areas and sport and leisure facilities each hold about 10% of total number of the street trees in Padua. Table 9 and Figure 10 give more details about the ecological traits and species composition of street trees in Padua, respectively. *Tilia x europea*, *Platanus x acerifolia*, *Acer campestre*, and *Cercis siliquastrum* dominate the street tree community in Padua.

Using information about ecological traits (species specific data such as tree height and stem diameter) is a commonly used method for mapping ecosystem services. This information combined with the size of every tree species population delivers sound estimates for services such as air quality regulation and micro-climate regulation. These data are also very useful for validating models based on land cover and land use alone and help thus reduce uncertainty.

Table 8. Street trees by land use type (2016). 'Continuous' and 'Discontinuous' are defined according to Urban Atlas (EEA)

Land Use (Urban Atlas + local data)	Number of trees	%
Agricultural + semi-natural areas + wetlands +river banks	1 778	12.0
Airports -construction sites and industrial areas	1 412	9.6
Land without current use	191	1.3
Continuous Urban Fabric	2 178	14.7
Discontinuous Dense Urban Fabric	5 171	35.0
Discontinuous Low Density Urban Fabric	310	2.1
Discontinuous Medium Density Urban Fabric	1 438	9.7
Discontinuous Very Low Density Urban Fabric	34	0.2
Green urban areas -Sports and leisure facilities	1493	10.1
Parterres-roundabout-hedges along roads or paths	770	5.2

Table 9. Descriptive statistics of street trees in Padua

Characteristics		**Number**	**Characteristics**		**Number**
Total number of street trees		11 289	Tree species		113
Stem diameter	<20cm	5 103	Tree height	<7m	5 121
	20-40cm	2 489		7-18m	4 785
	>40cm	3 692		>18m	1 383
Assessed trees (based on the use of dendrodensimeter, tomograph, and pulling test)		1 267	Assessed trees based on visual inspection		7 564

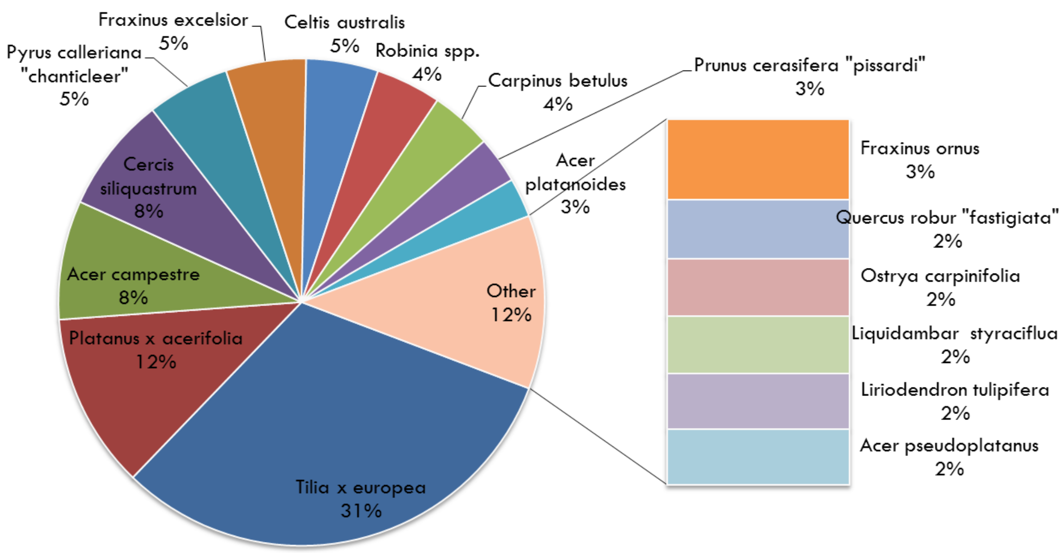


Figure 10. Species composition of street trees in Padua

3.5.3 Applications of the street tree inventory

The street tree inventory is useful to establish baseline information for short and long-term management plans (e.g. planting and maintaining) and for resources and budget allocation. The inventory is a powerful management tool as:

- It provides an overview of the species, number, position and condition of the trees
- It is essential for budget planning
- It allows arborists to set a maintenance schedule
- It aids in setting priorities for pruning, stability assessment, removal, planting (a key element for the formulation of a comprehensive Urban Forestry Management Plan)
- It permits a better hazard reduction

- It helps dealing with citizens requests
- It aids monitoring biodiversity and relative abundance of tree species, as well as age composition in tree population

Urban forests impact the economic and environmental health of citizens. In addition to inform management applications, the Tree Inventory may be also used:

- to quantify the urban forest economic value
- to inform sectoral urban planning
- to map and assess different urban ecosystem services (i.e. carbon storage and sequestration; social-cultural services provided by urban parks, green areas and street trees; cooling effect and noise reduction by vegetation)

3.6 Poznań

3.6.1 Planning urban green spaces

The efforts of Poznań in urban green space planning go back to the 1930s as document analysis shows that a system of green wedges was implemented (see also Figure 11). The current functional and spatial structure of Poznań is shaped by environmental conditions such as valleys of the main river Warta and its tributaries Cybina and Bogdanka. Along these watercourses green wedges in the city of Poznań were formed. The present spatial planning policy is based on the "Study of conditions and directions of spatial development". One of the main goals is the protection of the green wedges system (Figure 11). The study emphasizes that the inhabitants' quality of life and the city's attractiveness are related to the availability of green areas. Therefore the main goals concerning spatial development of green areas in the study are:

- Conservation of the green wedge-ring system;
- Protection of the most environmentally valuable areas from new development by implementing building restrictions on the valuable open spaces;
- Enlargement of the forest area within the city;
- Preservation of the existing parks and greenstones as well as green areas accompanying built-up areas;
- Creation of new parks and areas of sport and recreation.

Mapping and assessment of ecosystem services highlights the linkage between spatial planning and protection of green wedges and distribution of ecosystem services potential.

3.6.2 Mapping urban ecosystem services

Mapping ecosystem services in urban areas in Poland is currently under development. A first study was commissioned by Ministry of the Environment according to agreement no DLP/4/2015, 23rd March 2015. The study "Urban MAES – ecosystem services in urban areas" provides methodological approach for mapping and assessing urban ecosystem services and compares 10 agglomerations in Poland, among which the one of Poznań.

Ecosystem services mapping and assessment in Poznań shows how the city may profit from existing urban green spaces which supply manifold benefits. Examples are the cooling effect and recreational usage (Table 10). Relationships between land use types, their distribution and the potential to provide ecosystem services are presented.

Table 10. Examples of ecosystem services indicators used for mapping in Poznań.

Ecosystem service	ES Indicator	Unit	Data
Cooling effect	Radiation temperature of land surface	°C	LANDSAT image, literature review
Physical use for recreation	Distance to green areas from continuous and dense discontinuous urban fabric	m	Population data, Urban Atlas (see also Chapter 5), literature review

Poznań is a city rich in green areas. A vast land surface within city's administrative borders is dedicated to agriculture land with a mosaic patterns and large semi-natural areas (27%). Forests cover 15% of city area, urban green space comprises 8% of the land and surface water takes 3%. An additional 4.5% of city area is organised as a sport and leisure facilities. Urban fabric with transportation areas and land without current use comprise together 42.5%.

The spatial configuration of land use is an important factor shaping urban climate conditions. The importance of urban green spaces which are well known for their cooling potential is becoming more important to cope with climate change. Based on the Landsat Satellite Image the differences in average radiation temperature between land use types were used to assess their relative cooling effect (Table 11). The results show that highly urbanized areas such as continuous urban fabric, industrial and commercial units constituted temperature hot spots in the area of Poznań. The coolest areas were forests and surface waters. Almost 55% of land in Poznań has a high cooling capacity; 48.5% of urban fabric was found to be outside the reach of the potential cooling effect generated by urban green spaces (Figure 11). The distribution of green spaces in urban structure is another important characteristic related to spatial planning. Distance to green spaces is one of the most frequently used indicators to map physical usage of green space for recreational purposes (Coles and Bussey 2000). A distance of between 300-400m has been recognized as a distance beyond which frequency of visits in green spaces decrease (Grahn and Stigsdotter 2003; Nielsen and Hansen 2007). In Poznań 69% of the continuous and discontinuous dense urban fabric is within 300m from green spaces (size > 2ha); 26% is located within 1km from urban green spaces and only 5% of the built-up areas is more remote (Figure 11).

3.6.3 Conclusion

Although term "Ecosystem Services" is not widely used in practice, spatial planning in Poznań is based on an ecosystem services approach. Urban spatial planning benefits from mapping ecosystems and their services. Of particular relevance is the mapping of supply and demand of ecosystem services to identify mismatches. As such an urban MAES contributes to more precise and target-oriented planning, and thus to the enhancement of urban ecosystem services. This results in an improvement of the quality of life in the city of Poznań.

Table 11. Classification of land use types according to the level of cooling effect

ES level	ES indicator* Average radiation temp. (°C)	Land use types
Priority	20.5-20.8	Water, forest, discontinuous very low density urban fabric (S.L. < 10%)
Significant	22.4-23.9	Agricultural + semi-natural areas + wetlands, green urban areas, isolated structures, discontinuous medium and low density urban fabric (S.L. : 10% -50%)
Insignificant	24.6	Sports and leisure facilities, mineral extraction and dump sites
Lack	25.4-28.2	Airports, construction sites, discontinuous dense urban fabric (50-80%) continuous urban fabric (S.L. > 80%), land without current use (mostly post-industrial), industrial, commercial, public, military and private units, railways and associated land, fast transit roads and associated land, other roads and associated land

* based on Landsat Satellite Image from 17th June 2010, time 9:33
Source: Archive of Department of Integrated Geography, Adam Mickiewicz University in Poznań (unpublished)

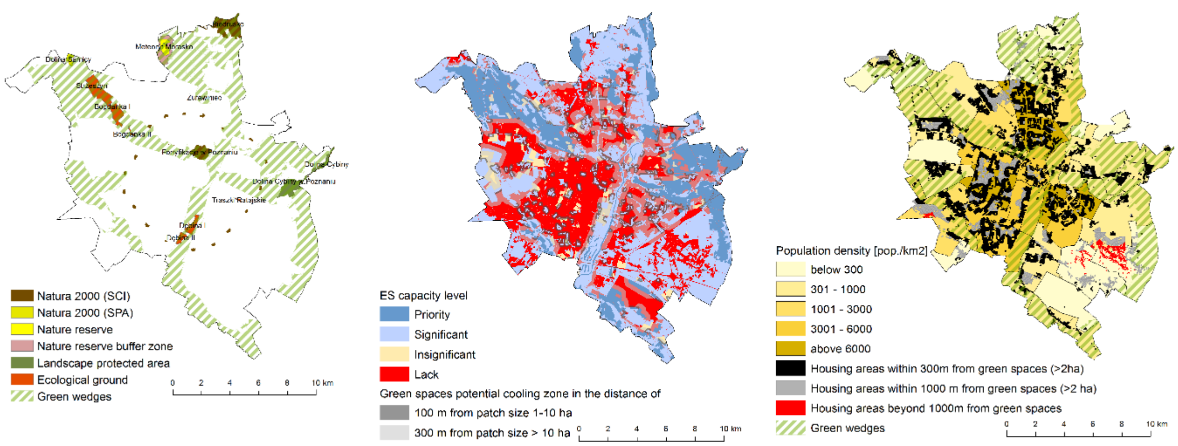


Figure 11. Left: Planning and protection of green wedges; Middle: Potential cooling effect; Right: Distance to urban green space overlaid on population density

3.7 Rome

The Metropolitan City of Rome is located in central Italy, close to the Tyrrhenian coast. It corresponds to the administrative Province, matching the third level of European NUTs, and it embraces 121 municipalities, including the Rome Capital city.

The Greening Rome project is structured into multiple levels from the wider metropolitan area up to the narrower historical center (Figure 12). Such an arrangement allows for a distinctive development of green infrastructure between the rural surrounding landscape, the peri-urban and the urban areas of Rome, that are characterized by different extents and population densities (see Table 1 for the three main levels of the project).

The physical environment of the metropolitan area displays a variety of climatic conditions and physiographic features. The coastal area has a Mediterranean climate, the inland mountain area is temperate, and the intermediary hills have a transitional climate, with a short period of summer aridity and consistent precipitation in spring. The litho-morphology ranges from coastal sandy dunes to pre-volcanic sedimentary hills, volcanic plateaus and reliefs, and carbonate pre-Apennine and alluvial plains along the main river network. Such an environmental heterogeneity, together with a millenary history of human influence, has contributed to shape the variety in typology and spatial configuration of the presently occurring ecosystems.

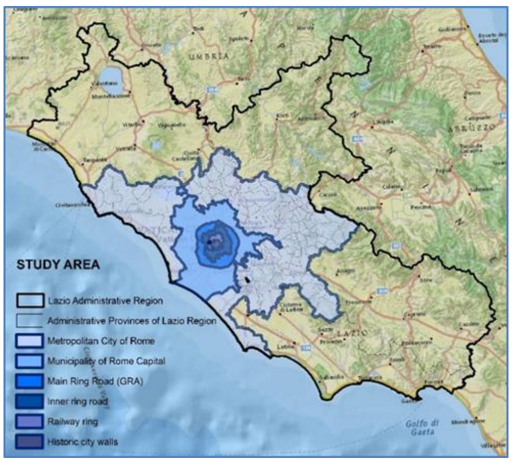


Figure 12. Study area of the Rome case study

Table 12. Different spatial scales for ecosystem assessment in Rome

Main levels of the project	Administrative unit	Extent (km^2)	Inhabitants (number)	Population density (number km^{-2})
Metropolitan level	Metropolitan city of Rome	5 352	4 336 000	810
Peri-urban sector	Municipality of Rome Capital	1 287	2 866 600	2 227
Urban sector	Portions of sub-municipalities inside the main ring way	345	2 067 000	5 991

3.7.1 Policy context

A first important reference point at the national level is the law for the development of green urban areas (National Law 10/2013), which aims at promoting standards for the delivery of ecosystem services (e.g. air quality regulation, hydrological risk, soil protection and cultural values. This law states that all the municipalities must set up a trees register and that the municipality mayors have to produce an account of green areas, which demonstrates their interest in public green (number of trees planted and felled, texture and condition of green areas, etc.). The creation of a Census meets the law terms and expresses the commitment of the administration to environmental issues. In 2014, another national law (56/ 2014) defined the Italian Metropolitan Cities with the aim of a strategic territorial development through the promotion of an integrated management of services, infrastructures and communication networks. This law outlines that the strategic territorial plan is the main tool to achieve these goals. As for the Metropolitan City of Rome, the guidelines for the Strategic Plan have been recently adopted (Deliberation 29/2015). They include the promotion of the natural and cultural capital of Rome and the establishment of synergies among green infrastructure, urban and rural areas.

At the local level, the Greening Rome project is based on two planning instruments:

- the Land Ecological Network (LEN), that has been adopted as a prescriptive document of the General Provincial Territorial Plan of Rome (PTPG Deliberation n.1, 2010) to help balance ecological, social and economic interests in the process of spatial planning. The LEN is composed of core areas, buffer zones and landscape connections each of which has its own management regime[9]
- the Ecological Network of the Municipality, a prescriptive document of the New General Master Plan of Rome (Municipal deliberation n. 18, 2008). It is a legally binding document regulating the relevant physical and functional transformations in the municipality and it includes all its environmental components, such as protected natural areas, public green urban areas and agricultural lands[10].

3.7.2 Ecosystem mapping

A large amount of information is available at the several levels of the project as regards typification and mapping of ecosystems, represented by means of vegetation proxies. In agreement with the methodological approach adopted for the implementation of the MAES process at the national level, the information is based on the re-interpretation of land use/land cover according to homogeneous ecological units. These units arise from a classification of land that integrates bioclimatic, physiographic and biogeographic features in order to define the ecological potential of the environment or, in other terms, the potential natural vegetation and its actual arrangement into mature and successional ecosystems (vegetation series). Moreover, ancillary data on species distribution have been used for ecosystem characterisation. Although the input data and the accuracy of the outputs vary with the extent of study area and with the scale adopted for the representation, the available classifications can be hierarchically adopted across the different levels of the project without inconsistencies. At the metropolitan level, the available map is at 1:25000 scale (http://websit.cittametropolitanaroma.gov.it/BDV2014/Veget_Reale.aspx) and it includes 48 forest, 37 shrubland, 39 herbaceous and 3 pioneer ecosystem types. At the city level, the available map is at 1:10000 scale and it includes 18 forest, 10 shrubland and 24 herbaceous ecosystem types (www.urbanistica.comune.roma.it/prg-vigente-g9b.html). More detailed maps, often supporting the management plans, are also available for specific sites, such as protected areas, portions of main river basins and river corridors.

GIS data (Metropolitan scale/Urban scale) 1:25000/10000:

- Maps of local scale ecoregions
- Maps of Biophysical Land Units
- Maps of Vegetation Cover and Land Use
- Maps of Vegetation Series
- Maps of Potential Natural Vegetation
- Maps of Species Distribution (vascular flora, mammals, birds, amphibian and reptiles)
- Map of Land Use and Land Cover Change 1954-1980-2001

[9] http://ptpg.cittametropolitanaroma.gov.it/UploadDocs/2010/tavole_piano/TP2_1_ReteEcologicaProvinciale100000.jpg [IT]
[10] http://www.urbanistica.comune.roma.it/prg-vigente-4.html [IT]

3.7.3 Mapping ecosystem condition

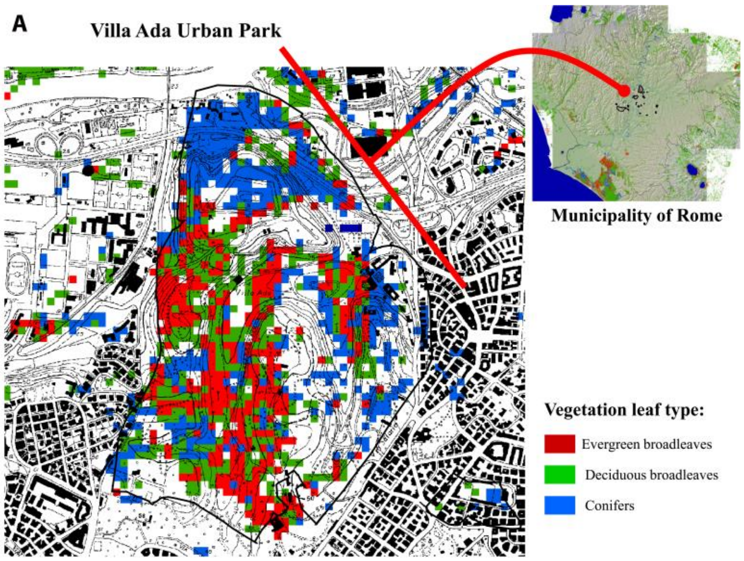
The assessment of ecosystems condition concerns individual ecosystem types and their territorial context. The adopted indicators include the degree of naturalness/hemeroby for each ecosystem type, the occurrence of species and/or habitat of conservation interest, the co-occurrence of historical and cultural elements, the conservation status of land units determined by landscape composition, the quality of spatial configuration in terms of ecosystem fragmentation, the quantity and contrast of edges between different ecosystem types, and the change over time in ecosystem extent.

GIS data (Metropolitan scale/Urban scale) 1:50000/1:25000/1:10000/2x2 km grid cells:

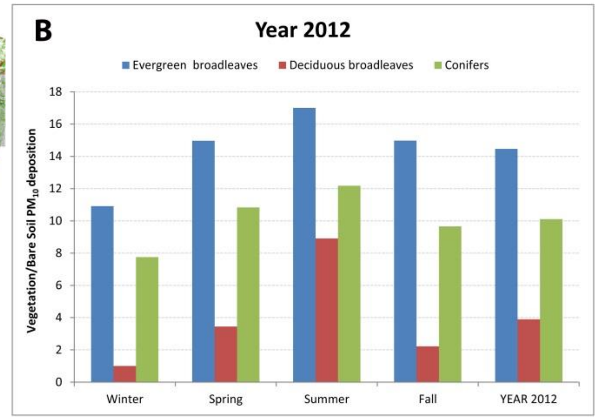
- Maps of Naturalness of ecosystem types
- Maps of Landscape Conservation Status (ILC index) of ecoregions and land units
- Maps of structural conservation status of ecoregions (at the local scale)
- Maps of threatened and rare plant species and target vegetation types for conservation
- Map of richness of species with high conservation value (vascular plants, mammals, birds, amphibian and reptiles)
- Maps of habitat types of Community Interest (Natura 2000)
- Map of positive and negative trajectories of land cover transitions
- Map of sites with outstanding combination of physical, biological and cultural values (core areas for proposal of the Rome Municipality Urban Biosphere Reserve)
- Map of priority areas for the Forestation Plan of Rome Municipality

3.7.4 Mapping urban ecosystem services

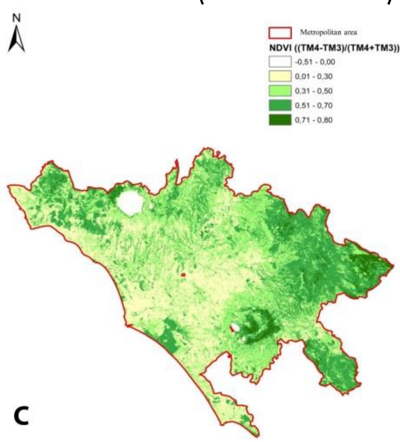
A first exercise to map ecosystem services in the metropolitan area of Rome concerns the air pollution removal provided by urban and peri-urban forests. The particulate matter (PM_{10}) removal has been estimated by a modelling approach, which is based on data acquired at different spatio-temporal scales. Satellite data (Landsat images) were analysed to estimate the Leaf Area Index (LAI) of forest ecosystems, a morpho-functional parameter that affects the amount of removed PM_{10}. Different steps of analysis allowed to obtain a LAI map and, subsequently, the Map of the Regulating Ecosystem Services of PM_{10} removal. In the Villa Ada Urban Park in Rome, the air quality improvement due to vegetation sink capacity for PM_{10} was also simulated (Figure 13). Four seasonal scenarios for the “real case” (actual vegetation cover for evergreen broadleaves, deciduous broadleaves and conifers), and “no vegetation” (bare soil replacing woody vegetation at all locations), are reported. The ratio between vegetation and bare soil deposition was calculated for each vegetation leaf-type. The results show a conspicuous contribution of all the three vegetation types in removing pollutants from the urban atmosphere. The method was adapted to quantify the removal capacity of O_3 in Rome (Manes et al. 2012) and successively it was applied to estimate the removal of PM_{10} and O_3 in ten metropolitan areas in Italy (Manes et al. 2016).



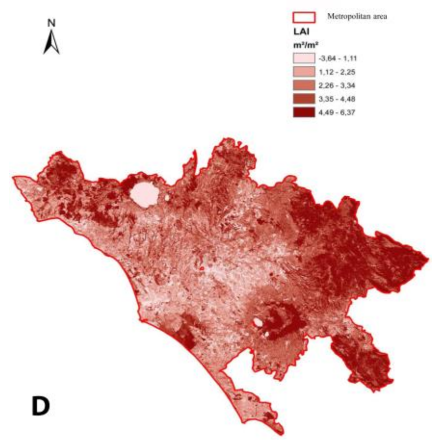
Villa Ada Urban Park: vegetation leaf type derived from a Landsat TM classification (Silli et al. 2015).



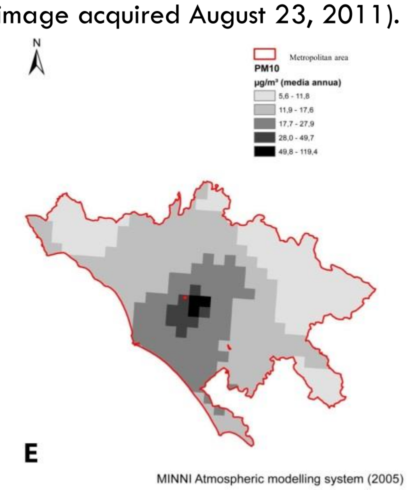
Mitigation role of urban vegetation. Ratio between PM $_{10}$ deposition to each vegetation leaf type ("real case") and PM $_{10}$ deposition to bare soil ("bare soil scenario") in Villa Ada Urban Park.



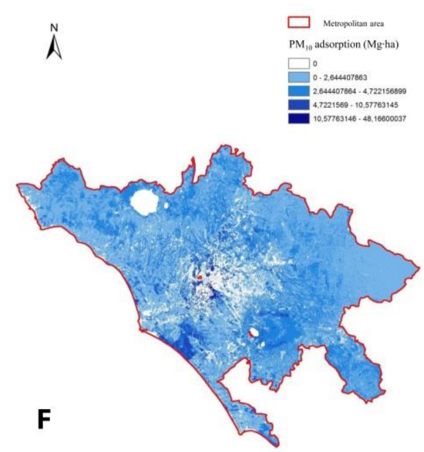
Metropolitan area of Rome: NDVI index, derived from Landsat TM (image acquired August 23, 2011).



Metropolitan area of Rome: Leaf Area Index



Metropolitan area of Rome: PM $_{10}$ (annual average µg/m^{3}), data derived from Mircea et al. 2014



Metropolitan area of Rome: PM $_{10}$ removed by different vegetation types (Manes et al. 2014)

Figure 13. Mapping air quality regulation in Rome. Assessment of the removal of PM10 by urban vegetation.

The "Greening Rome" methodology provides an interesting step towards the assessment and improvement of biodiversity and selected ecosystem services. Moving from the available and new knowledge, the project will develop green infrastructure (GI) projects with the support of the Italian Ministry for the Environment (national implementation of Action 6, Target 2 of the European Biodiversity Strategy). The GI projects will cross the rural, the peri-urban and the urban sectors according to differential demand for ecosystem services in the Metropolitan City of Rome.

3.8 Trento

3.8.1 Policy context

Policies addressing the management and use of green areas in the city of Trento focus on the reduction of the inequality in the access to urban green spaces and the promotion of citizens' involvement and ownership of public green area. The main policy instrument that will directly affect the city's green infrastructures in the next future is the forthcoming revision of the Urban Plan. The municipal planning department has just completed a background study with the aim of assessing the multi-functional value of the green infrastructures outside the most urbanized part of the city, including agricultural fields, forests, pastures and other green areas. Through a process of expert consultation, the study identified and combined a set of spatially-explicit criteria related to five dimensions, namely: (1) ecological-environmental; (2) economic-productive; (3) aesthetic-perceptual; (4) historical-cultural; (5) touristic-recreational. The results will set the basis of a new classification of these green areas and of the regulations for their safeguard to be included in the future planning instruments.

The mapping and assessment of ecosystem services undertaken by the University of Trento focuses on the green infrastructures within the most urbanized part of the city, and aims at complementing this analysis thus providing additional information to support the future planning decisions.

3.8.2 Mapping urban ecosystems

Relatively few data are currently available for mapping urban ecosystems in the city of Trento. Among them, the high-resolution aerial photograph produced in 2015 and the municipal database of public green spaces are the most useful information.

The database includes detailed geo-referenced data about, among others, trees species and dimensions, land cover, boundaries and accesses to public green areas. Unfortunately, these data are incomplete and partially out of date, and cover only a small portion of the city green infrastructures. Researchers from the University of Trento are developing a new purpose-built database, which combines data from different sources and integrates the available information into a complete mapping at the city scale.

The database includes also information about the structure of the urban green space (e.g., size, tree canopy coverage, soil cover), as well as its function and use, which provides input for the mapping and assessment of ecosystem services.

3.8.3 Mapping ecosystem services

The ongoing research activity focuses on priority ecosystem services identified for the city. Trento is located in a narrow valley floor surrounded by mountain landscape rich of natural and protected areas. The urban areas, home to 120 000 inhabitants, has a dense core in the valley floor and several hamlets spread on the hills. These factors determine a marginal role of the urban ecosystems in the overall landscape performances of the region, and a lower demand, compared to other cities, for certain green recreational activities, which can be easily accessed in the surrounding natural landscape. Given these conditions, the analyses focus on four regulating services (microclimate regulation, air filtration, noise mediation, water flow maintenance and flood protection), and on a set of cultural services.

The supply of regulating services is assessed through models tailored to the city scale and based on the biophysical data collected in the new database. The demand is determined with reference to the conditions of both the urban environment and the urban population. Thus, environmental monitoring data (air pollution, noise pollution, soil sealing, etc.) are combined with spatial analysis of population density and service-specific vulnerability indicators.

Table 13 provides an overview of the mapping and assessment approach that is being applied for the selected regulating services. The assessment of cultural services focuses on their contribution to citizens' physical and mental health. The aim is to measure the benefits that different categories of users gain from different types of physical and experiential interactions with urban green spaces. The use of green infrastructures for physical activity and mental restoration will be investigated through the analysis of users' preferences in relation with specific features of the infrastructures themselves, combining a variety of methods (e.g. questionnaires and surveys;, mining of data from social-media geographic information and volunteered geographic information platforms).

Table 13. Mapping and assessment approach for regulating and maintenance services.

Ecosystem service	Supply indicator	Demand indicator (conditions of the urban environment)	Demand indicator (population and vulnerability)
Microclimate regulation	Cooling effect (ΔT)	Urban Heath Island	Density and vulnerability to heat
Air filtration	PM10 captured	Air pollution concentration	Density
Noise mediation	Noise reduced	Noise sources	Density and vulnerability to noise
Water flow maintenance and flood protection	Water retained	Hydraulic and hydrogeological risk	-

A first analysis was completed on microclimate regulation (Geneletti et al. 2016). The cooling capacity of the urban green infrastructures in the most urbanized part of the city and the cooling effect produced on their surroundings have been mapped by applying a method specifically tailored to the urban scale. The method estimates the two main functions involved in cooling, namely shading and evapotranspiration and provides a classification of each portion of the urban green infrastructure according to the type of soil cover, the percentage of canopy cover and the dimension of the area. Each class, depending on the climatic zone, can be linked to a range of temperature differences between the analyzed area and the surroundings. Then, by applying different decay functions depending on the dimension and the shape of the areas, it is possible to map its cooling effect and to assess to what extent the presence of urban green infrastructures influences the microclimate of the city.

Figure 14 shows the two maps of the cooling capacity and of the cooling effect of the urban green infrastructures in the most urbanized part of the city of Trento. The former allows identifying the different components, classified according to their cooling capacity. The latter shows how the ecosystem service is distributed inside the city. A test application has been performed on the current urban plan to demonstrate a potential use of the results in the planning process (Geneletti et al., 2016). Two greening scenarios have been developed for each of the thirteen redevelopment sites - mostly former industrial areas - identified by the plan, and their effects in terms of cooling have been assessed by crossing the cooling effect with detailed data regarding the distribution and vulnerability characteristics of the population. The comparison of the scenarios with the baseline condition produces a quantitative estimate of the number of citizens and vulnerable people that benefit from each intervention, providing a beneficiaries-based indicator to measure the expected impacts of planning alternatives.

From these preliminary results, it is possible to identify four main potential contributions of the ecosystem services assessment to the urban planning process. These correspond to different steps in the drafting of the urban plan and of the associated Strategic Environmental Assessment (SEA):

- Enhancement of the baseline knowledge through the inclusion of data regarding the amount and the spatial distribution of ecosystem services – and of their beneficiaries - in the city.
- Extension of the set of methods and indicators available for the comparison of planning options through the inclusion of innovative, beneficiaries-based metrics.
- Inclusion of nature-based solutions in the plan, fostered by the possibility of analyzing their benefits and effectiveness as well as their co-benefits in terms of other ecosystem services produced.
- Improvement of the follow-up and monitoring activities through a continuous update of the ecosystem services mapping and assessment.

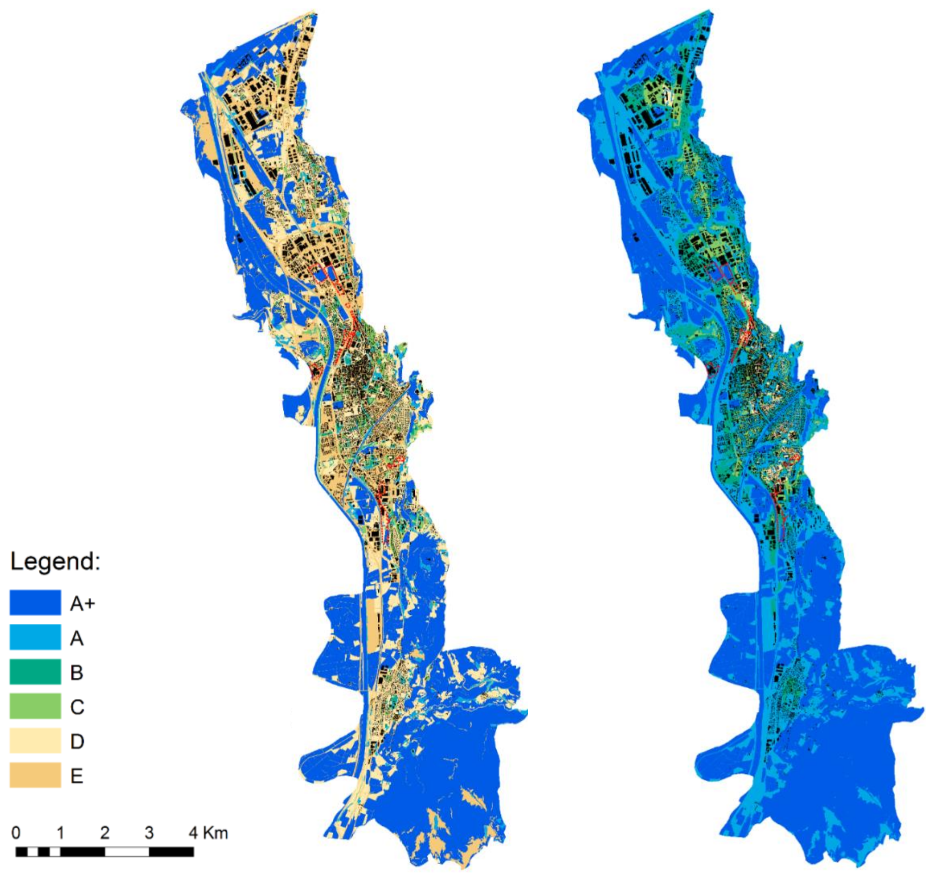


Figure 14. Maps of the cooling capacity (left) and of the cooling effect (right) of the urban green infrastructures in the city of Trento. Cooling capacity is expressed in classes from A+ (highest capacity) to E (lowest capacity). Source: Geneletti et al. (2016)

3.9 Oslo

3.9.1 Policy context and objectives

Oslo is the fastest growing capital in Europe. The Oslo metropolitan region has an explicit policy of densification with the current built area and conservation of agricultural soil and forests outside the built area, maintaining blue-green connectivity. The primary challenge with mapping and assessing urban ecosystem services is compiling indicators at multiple scales and resolutions that address different management levels needs, public and private interests. Stakeholders at private, municipal, regional and national level in the Oslo Region have identified a number of policy opportunities that urban ecosystem services mapping should inform. Notably, very few aspects concern monetary valuation, while the majority of concerns address ecosystem services mapping and classification at various scales and instrument design. The Oslo Environmental Agency has identified 17 ecosystem services as priority areas as expressed in various policy documents (**Table 14**).

Table 14. Ecosystems services identified in policies for the Oslo municipality (second column from left) and the land cover categories to which they apply. Cells shaded in pink indicate where policy documents explicitly address an ecosystem service for a given land cover category, with numbers specifying which policy document. (Barton et al. 2014). Ecosystem service icons developed by Oslo Municipality, Vista Analyse and nxt oslo reklamebyrå [NO].

		PERI-URBAN blue-green infrastructure								BUILT AREA blue-green infrastructure					
		Island	Fjord	Coast-line	Forest area	Agri-culture	Lakes	Parks and sports	Other open space	Forest	Rivers and Streams	Com-munal gardens	Private gardens	City Trees	Green roofs, facade
Category	Ecosystem														
Cultural services	Recreation, physical and	1,2,3,4,5	1,2,3,4,5	1,2,3,4,5	1,2,3,4,5		1,2,3,4,5	1,2,3,4,5	1,2,3,4,5	1,2,3,4,5	1,2,3,4,5	1,2,3,4,5			
	Aesthetics	1,2,3,4,5	1,2,3,4,5	1,2,3,4,5	1,2,3,4,5		1,2,3,4,5	1,2,3,4,5	1,2,3,4,5	1,2,3,4,5	1,2,3,4,5	1,2,3,4,5	3,4	3,4	3
	Education, cognitive	3,4	3,4	3,4	3,4		3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	
	Sense of place, heritage	1,2,3,4,5	1,2,3,4,5	1,2,3,4,5	1,2,3,4,5		1,2,3,4,5	1,2,3,4,5	1,2,3,4,5	1,2,3,4,5	1,2,3,4,5	1,2,3,4,5		1,2,3,4,5	
	Tourism	2	2	2	2		2	2	2	2	2	2		2	
	Art/toys							4				4			
Regulating services	Storm water mangement		7		2,3,4,5		2,3,4,5,7	2,3,4,5	2,3,4,5	2,3,4,5	2,3,4,5,7	2,3,4,7	3,7	3	3,7
	Erosion control				3					3	3	3	3	3	
	Local climate regulation				2					3	2,3	3	3	3	3
	cleaning soil, water or air				2,3	3		3	3	2,3	2,3	2,3	3	2,3	3
	CO2 sequestration														
	Noise reduction				6			6			2, 4, 6	6			6
	Pollination and seed dispersal														
Provisioning services	Food & fiber production		4	4	4		4				4				
	Water provision				4		2,4								
Supporting services	Habitat for biodiversity	1,2,3,4,5	1,2,3,4,5	1,2,3,4,5	1,2,3,4,5		1,2,3,4,5	1,2,3,4	1,3,4	1,2,3,4,5	1,2,3,4,5	1,2,3,4,5	3	2,3,4	

1. Oslo Municipal Master plan (2008): *"Kommuneplan 2008: Oslo mot 2025"* [NO]
2. Oslo Municipal Master Plan (proposed) Smart, Safe and Green: *"Smart, Trygg, Grønn. Kommuneplan for Oslo: Oslo mot 2030 (Høringsutkast)"* [NO]
3. Green Plan for Oslo. Municipal subplan for the green infrastructure (2010): *"Grøntplan for Oslo: Kommunedelplan for den blågrønne strukturen i Oslos byggesone"* [NO]
4. Plan for Sport and Outdoor recreation in Oslo (2013-2016): *"Plan for Idrett og Friluftsliv i Oslo 2013-2016"* [NO]
5. City of Oslo Urban Ecology Programme 2011-2016
6. Action Plan for Noise Reduction 2008-2013: *"Handlingsplan mot støy i Oslo 2008-2013"* [NO]
7. Strategy for Surface water management 2013-2030.

3.9.2 Mapping urban ecosystem services

Oslo municipality has access to a large volume of geographic data describing the city's biophysical attributes that can facilitate mapping of the city's capacity for and supply of ecosystem services. For a complete list of data layers, please see full description of the case study which is available as supplement on CIRCABC. Oslo municipality has conducted its own mapping exercises for recreational potential of peri-urban areas, as a basis for zoning plans for recreational areas in its peri-urban forest. They have also conducted "gap" analysis for access to urban parks.

3.9.3 Value added from ongoing research

Through several ongoing projects (OSLOpenNESS, URBAN-EEA, SIS-URBAN), NINA researchers are mapping both supply and demand for recreational services, aesthetics, sense of place (cultural ecosystem services), storm water management, habitat for biodiversity and pollinator habitat quality (regulating and supporting services). In particular, the projects direct ecosystem services mapping and valuation at answering different kinds of policy questions related to awareness raising, accounting, priority-setting, instrument design and litigation (Barton et al. 2014). A recent consultation exercise carried out within the URBAN-EEA project coordinated by NINA concluded that policy needs for better planning processes are both quite specific and vary across scales. Notably, very few of the policy needs identified monetary valuation:

At property level

- Improvement of the property level indicator Blue-Green Factor (BGF) in terms of (1) better differentiation for selected ecosystem services (water management, pollinator diversity and property amenity values), (2) consideration of adjacent-property and aggregation effects, (3) more cost-effective mapping and calculation of BGF.
- Assessment the implications of BGF indicator methodology and benchmarking for regulation of minimum outdoor areas

At municipal level

- Blue-Green Factor issues similar to those listed above
- Thematic maps of ecosystem service importance of the blue-green infrastructure in both Oslo and its neighbouring municipalities, which can contribute to:
    - 'Mapping and valuation of recreational areas' before 2018
    - Mapping the importance of blue-green infrastructure for climate adaptation in particular **urban flood control**
    - Municipal biodiversity plans
- Municipal level sustainability indicators and infographics for ecosystem service supply and demand that could be included in municipal annual reporting
- The contribution blue-green infrastructure makes to **property values** as a basis for policy design (cost-sharing negotiations, property taxation, ecosystem service user fees).
- Demonstrate more cost-effective, streamlined and quality assured procedures for data-sharing between municipal-level collection of geodata of biodiversity and the mapping products delivered by Naturbase. More effective use of geo data delivered by Digital Norge
- **Training** in tools for participatory mapping of ecosystem services

At county and regional level

- Compilation of municipal zoning and planning maps of blue-green infrastructure, including farmland, for Oslo and neighbouring municipalities
- **Regional indicators** to track implementation of Oslo Region strategy on nature and blue-green structures[11], such as a classification of urban ecosystems for the Oslo metropolitan region, and indicators of blue-green structure fragmentation and connectivity
- Assessment of the relevance of ecosystem service thematic maps for Environmental Impact Assessment of infrastructure projects
- **Training** in participatory mapping with province agency technical staff in regional conservation planning tools

[11] OsloRegionen. Samordnet Areal- og Transportstrategi for Oslo Regionen. Revisjon 2016. (2015) [NO]

At national level

- Make urban ecosystem mapping and assessment part of the planned National Ecosystem Assessment
- Classification methodology for urban ecosystems in the planned "ecological base maps" (Meld.St.14-2015-2016, s.130-133), and **Nature types in Norge**
- Contribute to development of urban sustainability indicators for national level reporting by Statistics Norway (SSB)
- Improve the relevance of ecosystem service mapping for policy instrument design (Vatn et al. 2011), in particular scaling a land use tax (Green Tax Commission NOU 2015:15) and ecological fiscal transfers
- **Updates to Norwegian authorities** on development of methodology in UNSTAT SEEA-EEA, World Bank WAVES and EU Mapping and Assessment of Ecosystems (MAES) and the H2020 project ESMERALDA

3.10 Utrecht

3.10.1 Urban planning context

Utrecht is the fourth largest city of the Netherlands, located in the very centre of the country. Utrecht's specific features challenge its city planners to develop green urban areas. Firstly, Utrecht is the largest transport hub in the country, with highways, rivers and railways passing and transecting the city. Secondly, Utrecht has a historical centre with inner-city canals, wharfs and protected trees. Finally, Utrecht is an attractive location for commuters and students (as home to one of the largest universities of the Netherlands), resulting in a population that is growing faster than other large cities in the Netherlands (Amsterdam, Rotterdam and The Hague).

The 335 000 inhabitants in 2015 are expected to grow to 400.000 in 2030. Consequently, there is a huge demand for housing. Through the new housing development of "Leidsche Rijn", Utrecht is expected to build 30 000 houses, 770 000 m^2 of commercial office space, and 230 ha of business area by 2030. This is the largest scale housing program in the Netherlands over the past few decades.

Space for green infrastructure is therefore often limited due to the presence of paved and built surfaces. At the same time Utrecht has a strong ambition to become a sustainable, green and healthy city and the concept of ecosystem services is seen as key to strengthen the value of green and blue solutions.

Currently, the main instrument for the protection and enhancement of urban green space in Utrecht is the Urban Green Structure Plan of 2007. It is connected with multi-annual green programs that elaborate in greater detail which measures are to be taken in view of the agreed priorities, how these measures will be financed and a planning schedule. The program emphasizes how cooperation with actors such as the province, the municipal land exploitation, the national government and the EU is important for realizing investments in the green structure. The multi-annual green program is updated on a yearly basis.

A second important instrument for the protection and enhancement of green space is the Utrecht Trees policy of 2009. The policy emphasizes that trees have got their own spatial dimension and problems that merit a special policy document including components such as tree structure, instruments, and guidelines for the management and maintenance of trees.

Apart from these instruments there is since 2009 a subsidy regulation for the construction of green roofs. At a neighbourhood level, ten neighbourhood plans were made with green ideas and proposals of inhabitants and budget was provided by the municipality to realize most of the proposals. The project 'green agenda' Maarschalkerweerd started in 2015, aimed at strengthening the green qualities and benefits that ecosystem services deliver at district level. The emphasis lies on a partnership with residents, users and stakeholders to analyse the natural capital in their area and to identify opportunities and threats in terms of implementing the green qualities and ecosystem services of the area. Until now, the assessment of ecosystem services was made qualitatively based on expert judgment, as maps of urban ecosystems services are not yet available.

3.10.2Mapping urban ecosystems services

In a first attempt to map ecosystem services in the city, experts from the Municipality of Utrecht in collaboration with researchers from Alterra (Wageningen University and Research Centre) organised two workshops, as part of OpenNESS and TO2 projects[12]. As a first step, we selected the most relevant ecosystem services for the city: local climate regulation, noise reduction, recreation, and cleaner air. Thereafter, we identified appropriate data sources from those available to do the mapping (**Table 15**).

Table 15. Data sources to map urban ecosystem services in Utrecht

Name	Source	Reference
Green Structure Plan 2030	Utrecht municipality	opendata@utrecht.nl http://www.utrecht.nl/images/DSO/DSOmilieu/groen/GSP.pdf
Trees & Green Management maps	Utrecht municipality	opendata@utrecht.nl http://utrecht.gemgids.nl/bomenkaart/
Trees structure maps	Alterra & Utrecht municipality	Processed at 2.5 m raster level from http://Bomenregister.nl
Neighbourhood green plans (10 districts)	CBS & Kadaster 2016	http://www.cbs.nl/nl-NL/menu/themas/dossiers/nederland-regionaal/links/toelichting-wijk-en-buurtkaart-2013-2015.htm
Air quality maps	RIVM PM10	http://nationaalgeoregister.nl/geonetwork/srv/dut/search?#|b472d8ac-2eb0-4a79-96fc-f0cbc1f717bb
Noise maps	Noise from Road & Train	http://www.utrechtmilieu.nl/geluidskaarten/
Heat stress maps	USGS	Present reflectance temperature [Degrees Celsius] (July 15, 2015), LANDSAT 8 band 10 & 11, converted to °C http://landsat.usgs.gov/best_spectral_bands_to_use.php
Land cover maps	Alterra	TOPNature: Scaleless-enriched 2.5 m raster version of TOP10NL for fast web mapping visualization and ecological applications
Buildings in the Netherlands	Kadaster	Basisregistraties Adressen en Gebouwen (BAG) https://data.overheid.nl/data/dataset/basisregistratie-adressen-en-gebouwen-bag-

[12] TO2 means TO2 Federation which consists of six Dutch institutes for applied research

All data were rasterized at a resolution of 10x10 m and put into the QUICKScan tool (Verweij et al. 2012) with the appropriate legend and classification.

In an interactive and iterative process during the workshops, we developed maps showing the current potential supply of the ecosystem services for each of the city districts. In addition, we also developed maps for different scenarios to make Utrecht greener:

- Creating green buffers around the noisy impervious areas combined with adding green roofs;
- Allowing current trees to age under optimal growing conditions until 2050, to develop more dense crown coverage;
- Adding green areas with a minimum 20% tree crown coverage in restructured areas.

Figure 15 shows the maps and graphs developed for climate regulation and noise reduction. It shows the present reflectance temperature per land use class for a heat event on July 15th 2015. The map shows that buildings, squares and flat roofs are among the hottest areas in the city, with flat roofs clearly topping the scales, followed by road(sides) and other green areas (1-2 °C cooler), grass fields and groups of trees inside the main city area being 3-4 °C cooler than flat roofs. In addition, it shows the average temperature in the different districts under the three scenarios, compared with the present situation. The more agricultural neighbourhood of Vleuten-de Meern shows considerably lower temperatures, and the city centre (“Binnenstad”) on average the highest. The maximum average effect at district level is about 0.5 °C in the given scenarios, locally much larger effects are visible in the maps. Letting the tree crowns grow to 2050 in general give the best reduction. The magnitude of the effect of more trees in the restructuring areas or green roofs and greener noisy areas is depending on the neighbourhood.

Figure 16 shows the maps developed for recreation potential. The starting point was the ‘Green structure plan of Utrecht’, with green nodes connected by green infrastructure. The size of the node was used as proxy for the recreation potential/capacity. Two distances were calculated: 1) Travel distance to any green node; and 2) Only the larger nodes. Recreation potential of land cover in and around Utrecht was based on expert knowledge rules. It showed that the city centre (“Binnenstad”) has a very limited green recreational potential. Neighbourhoods further away from the city centre (“Vleuten”, “Overvecht” and “Oost”) have more potential, this is in line with the areas and major nodes as defined in the Green structure plan of Utrecht. The analysis of the recreation potential considering the Green structure plan of Utrecht, showed that in the plan the travel distance to one of the green nodes is equally distributed over the city. The only exception is for the inhabitants of the city centre (“Binnenstad”) that have to travel more than the rest - 900 m to reach one of the nodes. If considering only the larger nodes, the differences between the districts become much more extreme with distances up to 2 km for people in West. They are (relatively) isolated by the canals and limited amount of bridges, causing extra travel distance to the major recreational nodes.

Figure 17 shows the maps developed for air purification capacity. Since all area in the city has relative high pollution levels but within legal air quality limits, no spatial distinction is made on where to apply the measures. The scenarios developed for temperature reduction were also applied to air purification in order to show the additive effect. The three scenarios result in an improvement of the present situation. The scenario with the highest capacity is ‘increasing tree crown coverage by letting them grow until 2050’. The scenario ‘green roofs & greening noisy impervious areas’ shows the highest overall effect over the study area.

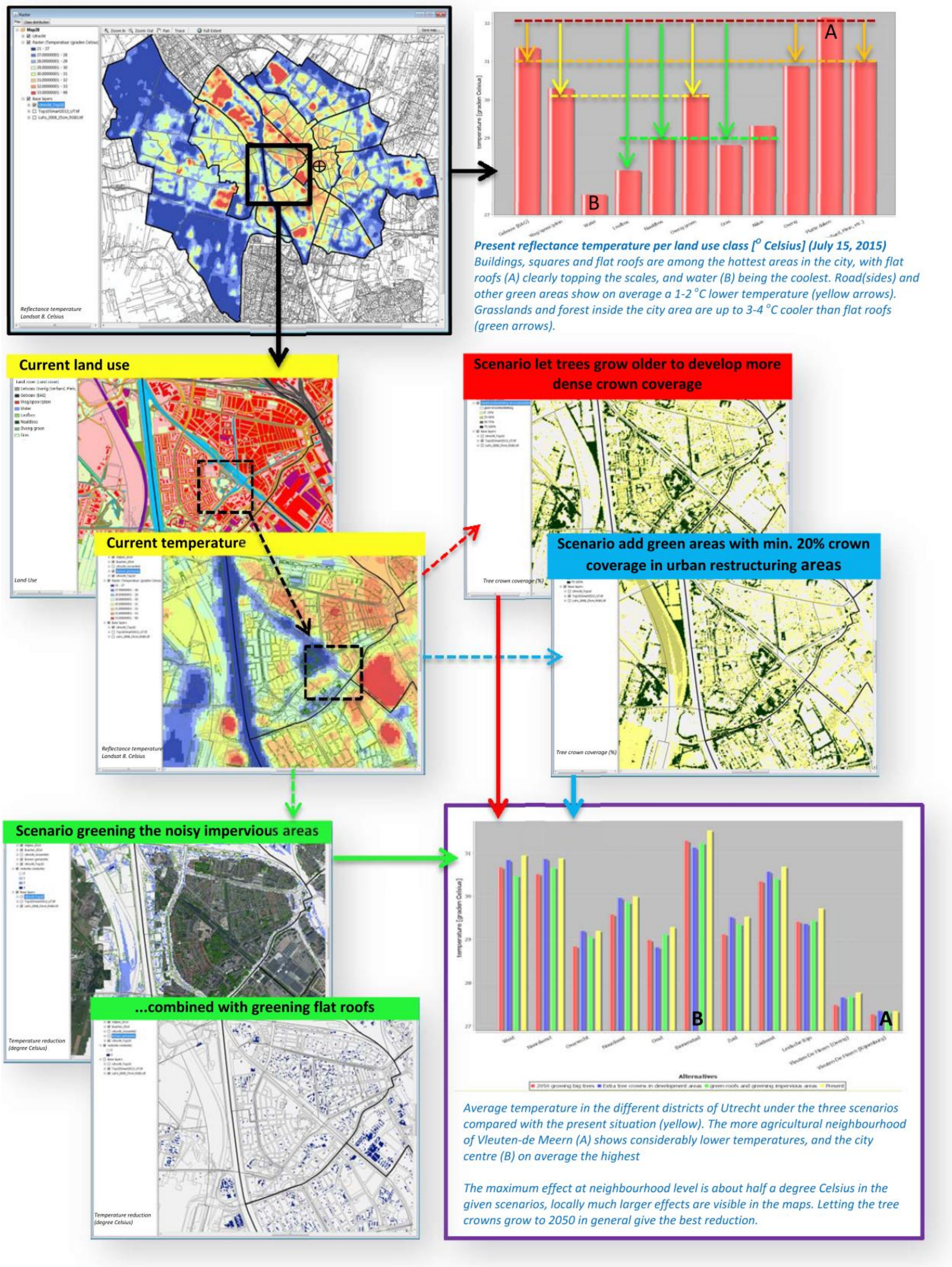
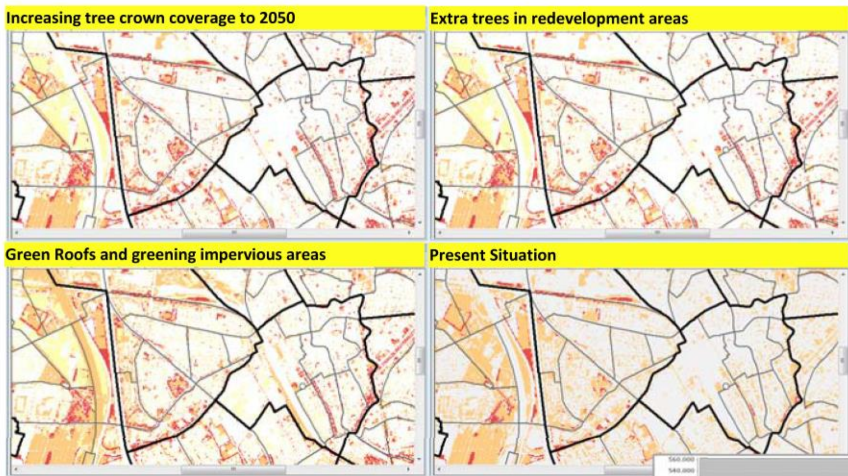


Figure 15. Mapping climate regulation and noise reduction potential under current situation and greening scenarios in Utrecht.

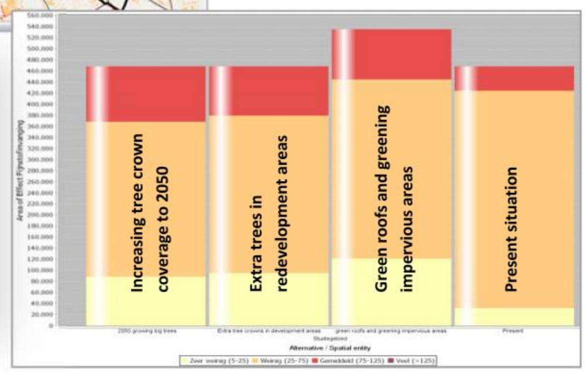
Figure 16. Mapping recreation potential based on accessibility to urban green, using the 'Green structure plan of Utrecht' as basis, with green nodes connected by green infrastructure.



Land cover \ Kroonbedekking : Invanging fijnstof (g/25m2/jaar)

	geen kroonbedekking	0 -25%	25-50%	50-75%	75-100%
Gebouw Overig (Verhard, Plein, etc.)	-	-	-	-	-
Gebouw (BAG)	-	-	-	-	-
Weg/spoor/plein	-	-	-	-	-
Water	-	-	-	-	-
Loofbos **A**	Gemiddeld (75-125)	Gemiddeld (75-125)	Gemiddeld (75-125)	Gemiddeld (75-125)	Gemiddeld (75-125)
Naaldbos **B**	Veel (>125)	Veel (>125)	Veel (>125)	Veel (>125)	Veel (>125)
Overig groen	Zeer weinig (5-25)	Zeer weinig (5-25)	Zeer weinig (5-25)	Weinig (25-75)	Gemiddeld (75-125)
Gras	Weinig (25-75)	Weinig (25-75)	Weinig (25-75)	Gemiddeld (75-125)	Gemiddeld (75-125)
Akker	Zeer weinig (5-25)	Zeer weinig (5-25)	Zeer weinig (5-25)	Weinig (25-75)	Gemiddeld (75-125)
Overig	-	-	-	-	-
Platte daken	-	-	-	-	-
Green Roofs	Zeer weinig (5-25)	Zeer weinig (5-25)	Zeer weinig (5-25)	Weinig (25-75)	Weinig (25-75)

Relation between tree crown coverage percentage and land cover type, the denser the tree crown is the better the purification of the air (PM10 reduction: low (yellow) to high (purple). Deciduous forest (A) purifies less than needle leaved forest (B). Other land cover classes just have a mediocre purifying capacity



Overall differences between the scenarios average effect over the total study area of the Municipality of Utrecht

Figure 17. Mapping air purification potential of urban trees based on the relation between tree crown coverage percentage and land cover type; the denser the tree crown is the better the purification of the air (PM_{10})

3.10.3 Conclusion

The maps and graphs developed for the four ecosystem services with the QUICKScan tool provide a good overview of the green services being present at both district scale and total city scale, and help to compare the impact of different 'greening' management alternatives. For example, as regards potential climate adaptation measures, increasing the tree crown coverage has higher impact than adding green roofs on flat roofs for potential climate adaptation measures. The positive effect of an increase of tree crown density is partly due to planting extra trees and partly due to creating optimal growing conditions for the trees. Overall the maps and quick assessment of these ecosystem services provide a useful starting point to support Utrecht's policy to reach a 'healthy urban living', and its implementation in daily urban practice. According to Utrecht experts, the maps and data will be not only useful for the city planners but also as communication tool to the citizens.

4 POLICY ON URBAN GREEN INFRASTRUCTURE

4.1 Introduction

The pilot aimed to learn what policies on urban GI are currently in place and what challenges cities encounter to enhance the use of green infrastructure and nature-based solutions.

Therefore the online survey involved a number of questions regarding local policies on urban GI. The questions focused on the policy targets, as well as the chances and barriers that researchers and policy makers see to further implement urban GI.

Following the survey the expert workshop in Lisbon included a dedicated session on urban GI policy. The workshop was structured around a series of questions regarding the chances and barriers in the policy arena. The questions were firstly meant to test the outcomes of the survey, and secondly to further build our understanding of urban GI in the local policy arena.

This chapter summarizes the outcomes of the MAES urban pilot policy work.

4.2 Lessons learned from the online survey

The online survey yielded a number of insights in terms of policy on urban green infrastructure in European cities. All the results as well a complete description of the set up are available in a JRC technical report. Here the most important conclusions are summarized.

- Most of the respondents were researchers (44%), followed policy makers (34%) who are involved in the design or the implementation of policy on urban ecosystems or urban green infrastructure.
- Two third of the respondents reported a policy on urban green infrastructure at city level; one third of the replies indicated that such policy is in place at regional level, 32% at national level, 16% beyond the municipality delineation in cooperation with other municipalities (inter-city), 14% reports that there is no policy in place which covered urban green infrastructure in their city. This latter share of respondents called for dedicated policy at all levels, including the EU level.
- Importantly, the presence of a national or regional policy on urban green infrastructure increased the probability that there is a policy at city level from 66% to 80%. This suggests a high coherence in the occurrence of policies at different levels.
- Policy on urban ecosystems and urban GI is sometimes covered by other policies or strategies so that in reality there is a dedicated policy on green urban areas but it is perhaps less visible. Sometimes urban GI is considered in climate planning, in environmental protection or in sustainable development.
- Respondents not surprisingly often mentioned a lack of financial resources or competing claims on available development space as barriers with relation to green infrastructure.

- Respondents appear to have high confidence in the potential of bottom up initiatives (44%) and 'new' initiatives coming from private sector (23%) or a combination of private sector and ngo's (17%) to enhance urban GI.
- Participants who identified themselves as researchers differed with policy-makers and other stakeholders with respect to public awareness and political interest in that policy makers disagree with the statement that awareness and interest are low. But both types of survey participants agree that the main obstacles to a better implementation of urban green infrastructure are competing interest from the development sector and a lack of financial means.

4.3 Conclusions from the workshop

The following questions were asked to MAES urban pilot members at the Lisbon workshop:

1. Which underlying policy goals support green infrastructure in local policymaking?
2. Which policy goals should in your opinion be added? Why? What is the relation?
3. Which of these (potential) policy goals is promising; what makes them promising?
4. What are the main barriers to position urban GI in the light of these policy goals? What would make it easier to convince the political level to do so?
5. On the basis of the answers given to these questions, what should be done to optimally connect urban GI to these policy goals?

By obtaining answers to these questions we aimed to find new ways and strategies to better implement urban GI in the local policy arena. Questions 2 and 3 specifically aimed at making the step from the current 'structure oriented' policies towards more 'supply-oriented' policies. By structure oriented policy we mean a policy that focuses on the establishment and maintenance of (elements of) green infrastructure as such, often single issue policies (e.g., policies on urban trees, butterflies, parks). By a supply-oriented policy we mean a policy that envisages green infrastructure as a means to deliver services that help realising other societal goals (e.g., adaptation to climate change, health issues, water management). This broadening may help enhance the carrying capacity for urban GI within the policy arena. Participants proposed a selection of 'supply-oriented' policy goals and related barriers. The last step, defining new strategies, proved to be the most difficult and did not result in many concrete options. The definition of the barriers however, gives a good insight in the direction to look.

The participants confirmed the current dominance of structure oriented policy goals and indeed also mentioned mainly wellbeing and biodiversity as objectives behind (but not explicitly mentioned) this focus on structure. When asked about other promising policy goals to make the step from 'structure-oriented' towards 'supply-oriented' there was a relative consensus within the group on the following topics:

- Climate adaptation and mitigation. The assumption was that it is easy to explain the advantages of urban GI for this goal to the political level and to the public. Next to that climate change is by now well accepted by most groups in society.

- Health. The reason for favouring this subject was also the increasing focus of policy on health as well as the fact that health directly relates to individuals and therefore attaches to the emotional level.
- Local liveability. One could argue that there is a large overlap here with 'wellbeing', already mentioned in the survey. There was, however, an extra dimension in the discussions that relates to the finding of the survey that there is high confidence in 'new' arrangements such as bottom-up initiatives. Liveability in that perspective may been seen as both recreational, economical and social.

The following barriers were identified as the most important. Most of these barriers are difficult to overcome. If identified by the participants, possible solutions and roles for the MAES urban pilot are also mentioned here:

- Governance. Participants mentioned a lack of interaction, both between higher and lower level of governance as well as between departments of the same organization. They are often vertically organized which hinders communication. The solution mentioned to overcome this barrier is enhanced vertical and horizontal communication.
- Conceptual frameworks. There is a relation with the previous barrier. Participants noticed that the vertical organization is specifically a problem for urban GI as the benefits of urban GI often are situated in synergies with other policy domains and can only be 'cashed' in close cooperation with these domains. However, participants noticed realising this cooperation needs a shared conceptual framework. It is necessary that both departments speak a mutual language, and understand each other's mind-set. The solution mentioned to overcome this barrier is enhanced communication in the sense that GI specialists start talking in the language of the other sectors/policy domains.
- Systemic approach. The added value benefits of spatially or functionally connected GI compared to single-purpose traditional 'grey' solutions will fully realize if it is planned and implemented not as a fragmented, isolated feature, but when nature-based solutions are instead systematically applied across the urban planning and decision making. Conceptual frameworks for each action type need to be brought together to a holistic strategy: Not only the GI (e.g. pocket park) is multifunctional (e.g. for water retention, recreation), but the benefits (for water retention, recreation) are far higher if accompanied by further features in the larger urban area (such as green roofs, open water courses, ecological corridors)
- Short policy cycles. This is a barrier that is often mentioned in discussions on environmental and sustainability issues. It is particularly relevant for investments in urban GI as these will only give benefits over a relatively long period of time. E.g., a city tree may take decades to fully supply its potential benefits. Participants mentioned the possibility of legislation (even a Directive) as a solution.
- Split incentives. These are also barriers that are often mentioned in discussions on sustainability issues. The fact that investments done by one actor often have benefits for another actor. E.g., when a private owner installs a green roof the benefits of this investment in terms of reduced flood risks will be for the entire community. This barrier is closely related to the next barrier.

- Imperfect market (externalities, tragedy of the commons). The idea that natural capital can be used free of costs leads to overexploitation. This is also a barrier mentioned often in discussions on sustainability. New economic definitions were mentioned as a solution.
- Lack of knowledge and calculation models on the positive effects of urban GI. For local policymakers it is often not known what the relation is between urban GI and social benefits. And if it is known, then a local policymaker doesn't know how to measure and calculate them. The solution for this barrier is obviously to develop and make available the required knowledge and models. Participants mentioned that developing a science-policy network that incorporates the city level could be a good next step for the MAES urban pilot.

4.4 Conclusions

The survey results suggested that cities and regions have the capacity to support policy on urban green infrastructure with scientific evidence but we could not conclude in how far such information is actually used in the policy process. Still, we argue that there is a substantial scope for urban ecosystem assessments and for evidence based policy support on urban green infrastructure and nature-based solutions.

Based on the literature and the survey results it may be concluded that local policies are often limited to the maintenance (and enhancement) of urban green spaces without considering sufficiently the functional role of urban GI. So there is a focus on structure rather than on function and ecosystem services. Then again, wellbeing of people or biodiversity goals are mentioned as a reason for maintaining the urban green spaces, but usually they are not framed as ecosystem services.

There is also a number of examples where the ecosystem services provided by urban GI are specifically targeted in other policy domains such as air quality or heat stress. In other words, the concept of making actively use of ecosystem services for the realisation of other policy goals has indeed set foot in the local policy-arena. A systemic approach in using the full potential of ecosystems to provide a set of multiple services to urban citizens is still very rarely implemented.

5 MAPPING URBAN ECOSYSTEMS

5.1 Drawing the line: Delineating urban ecosystems

Cities can be spatially delineated depending on the social and political organisation of a country, the population numbers or density, or they can be mapped using land cover and land use information. In any case, several delineation schemes are possible depending, in essence, on context and purpose. For mapping and assessment of urban ecosystems and their services, the delineation of an urban ecosystem depends on the policy questions of the assessment, the scale of the different socio-ecological processes, and the indicators and data available for the assessment. So instead of drawing a line, the final indicator framework which is proposed in this report includes three scales: the regional scale, the metropolitan scale and urban scale. Figure 18 presents these three scales for Padua, a city in North East Italy and one of the MAES urban pilot case studies. Two boundaries delineate the **regional scale** (NUTS2 and NUTS3, the nomenclature used by Eurostat). The **metropolitan scale** is defined by the functional urban area[13]. In 2011 the OECD and the European Commission developed a new definition of a city and its commuting zone. This new definition is based on the presence of an 'urban centre' a new spatial concept based on high-density population grid cells. The functional urban area (FUA) consists of the city and its commuting zone. The **urban scale** focusses on the core area of the FUA, the city. Further break down is possible over urban districts or even census blocks.

These proposals allow a consistent comparison of urban ecosystem assessments across the EU.

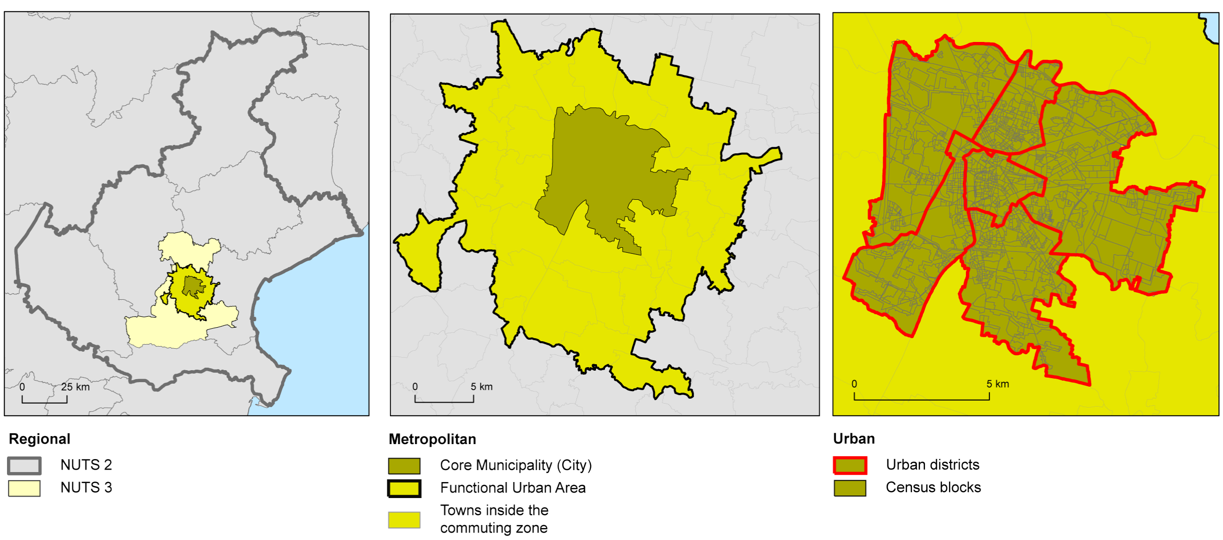


Figure 18. Three scales for mapping and assessment of urban ecosystems based on the example of Padua. Left: Regional scale based on NUTS levels. The city is situated in the region Veneto (NUTS2 level) and is the capital of a province which carries the same name (Provincia di Padova [IT], NUTS3 level). Middle: Metropolitan scale. The functional urban area is subdivided into a core area and a commuting zone. Right: Urban scale. The urban scale consists of the core area and can be subdivided into smaller units such as the urban districts or census blocks.

[13] For detailed definitions and all data: http://ec.europa.eu/eurostat/statistics-explained/index.php/European_cities_%E2%80%93_the_EU-OECD_functional_urban_area_definition

5.2 Typology

This report does not propose an own classification of urban green spaces. For reasons of mapping, we discriminated between single trees or linear elements on the one hand and green surfaces which include among others green open spaces, lawns, patches of woodland, tree canopy or green roofs. This difference was based on the data sources (point or line source information versus data that is organised in polygons or grids).

Different classification systems are available and there is, in general, no consensus, which is perhaps not even necessary. Often, classifications adopt a structural classification approach, a functional approach or both. This is fully in line with the structural notion of urban green space and the functional notion of urban green infrastructure, which was adopted in this report (see Chapter 1).

A structural classification can for instance be based on land cover types or vegetation characteristics (open spaces, single trees, forest). A functional classification can be based on land use types, purpose, or spatial configuration (e.g., recreation grounds, urban parks).

For many cities, it may be important to use a detailed classification of urban green spaces or urban GI for a more detailed assessment of urban ecosystems. Therefore we present in this report two examples which can be used to classify the different components that constitute urban ecosystems. One example stems for a large EU project and should be applicable across Europe. The Green Surge approach uses a predominantly functional classification of urban green spaces.

A second example is drawn from the case studies of the MAES urban pilot and illustrates a local approach fit for purpose. This classification for mapping is based on a structural classification.

Urban atlas can be also used as a typology (see also next section). It is an example of mixed classification based on both functional and structural characteristics. The following GI categories are included: agricultural/semi-natural areas/wetlands, green urban areas, forests, land without current use, sports and leisure facilities, and water bodies. More details of the different urban green space elements that constitute these categories are available in the accompanying report (European Commission 2011).

5.2.1 Example 1: Typology of the Green Surge project

Green Surge is a Horizon 2020 project funded by the European Commission. The acronym stands for Green Infrastructure and Urban Biodiversity for Sustainable Urban Development and the Green Economy. The project aims identify, develop and test ways of linking green spaces, biodiversity, people and the green economy.

The project developed a typology of urban green spaces and linked this typology to ecosystem services and demands. The typology contains 44 urban green space elements which fall into eight categories (Table 16).

Table 16. Table Typology proposed by Green Surge for Urban Green Spaces (UGS)

Category	**Green space element**
Building greens	Balcony green
	Ground based green wall
	Facade-bound green wall
	Extensive green roof
	Intensive green roof
	Atrium
Private, commercial, industrial, institutional UGS and UGS connected to grey infrastructure	Bioswale
	Tree alley and street tree, hedge
	Street green and green verge
	House garden
	Railroad bank
	Green playground, school ground
Riverbank green	Riverbank green
Parks and recreation	Large urban park
	Historical park/garden
	Pocket park
	Botanical garden/arboreta
	Zoological garden
	Neighbourhood green space
	Institutional green space
	Cemetery and churchyard
	Green sport facility
	Camping area
Allotments and community gardens	Allotment
	Community garden
Agricultural land	Arable land
	Grassland
	Tree meadow / orchard
	Biofuel production / agroforestry
	Horticulture
Natural, semi-natural and feral areas	Forest (remnant woodland, managed forests, mixed forms)
	Shrubland
	Abandoned, ruderal and derelict area
	Rocks
	Sand dunes
	Sand pit, quarry, open cast mine
	Wetland, bog, fen, marsh
Blue spaces	Lake, pond
	River, stream
	Dry riverbed, rambla
	Canal
	Estuary
	Delta
	Sea coast

5.2.2 Example 2: Typology used in Trento

To support policy on urban ecosystems in Trento (Italy) (see also case studies in Chapter 3) the University of Trento developed a typology for mapping green infrastructure based on a structural classification. The classification includes nine different types of urban green infrastructure and three types of blue infrastructures (which in this report are also called green infrastructures for simplicity).

Table 17 provides more detail of the legend that is being used for mapping urban green/blue infrastructures.

Table 17. Legend for mapping green/blue infrastructures used in Trento (categories modified after Derkzen et al. 2015; Davies et al. 2011).

Class	**Description**	**Main attributes**	**Geometry**
Green infrastructures			
Woodland	clustered trees and urban forests	typology [coniferous/evergreen broadleaves/deciduous]	polyline
Shrub	areas covered with shrubs (woody plants < 2 m high)		polyline
Herbaceous	non woody plants and grass on soil		polyline
Cultivated land	areas used for growing crops, including fruits and vegetables	typology [arable, orchard, kitchen garden]	polyline
Green roof	grassy cover over a built surface		polyline
Bare soil	other non-vegetated permeable areas		polyline
Tree line	sequences of at least 3 similar trees	typology [coniferous/evergreen broadleaves/deciduous] average dimension [height, diameter of the crown]	line
Hedge	rows of dense shrubs	dimension [height, thickness]	line
Tree	individual trees	typology [coniferous/evergreen broadleaves/deciduous] dimension [height, diameter of the crown]	point
Blue infrastructures			
Water course	permanent water flows		polyline
Water area	permanent water surfaces		polyline
Wetland	frequently flooded lands		polyline

5.3 Mapping

Once the spatial delimitation of the urban ecosystem which is under assessment is clear and a typology for urban GI is set, mapping can start. Depending on the spatial scale different spatial data can be used to map the urban ecosystem and to map the different types of urban green infrastructure. Evidently, the focus of MAES is on mapping urban green infrastructure since urban GI delivers ecosystem services. Furthermore, the total extent and spatial configuration of urban GI are of essential importance when defining the condition of urban ecosystems. Mapping urban green infrastructure, in turn, entails mapping urban green spaces as well as other MAES ecosystem types which are situated within the boundary of the assessment.

This report demonstrates how urban ecosystems can be mapped and illustrates the importance of scale when selecting spatial datasets for mapping. Maps are based on the MAES urban pilot case study of Padua (Padova [IT])

At European scale Urban Atlas[14] is a primary source for mapping urban ecosystems (Figure 19). The Urban Atlas is providing pan-European comparable land use and land cover data for Large Urban Zones with more than 100 000 inhabitants. The atlas allows mapping of several types of built and green infrastructure.

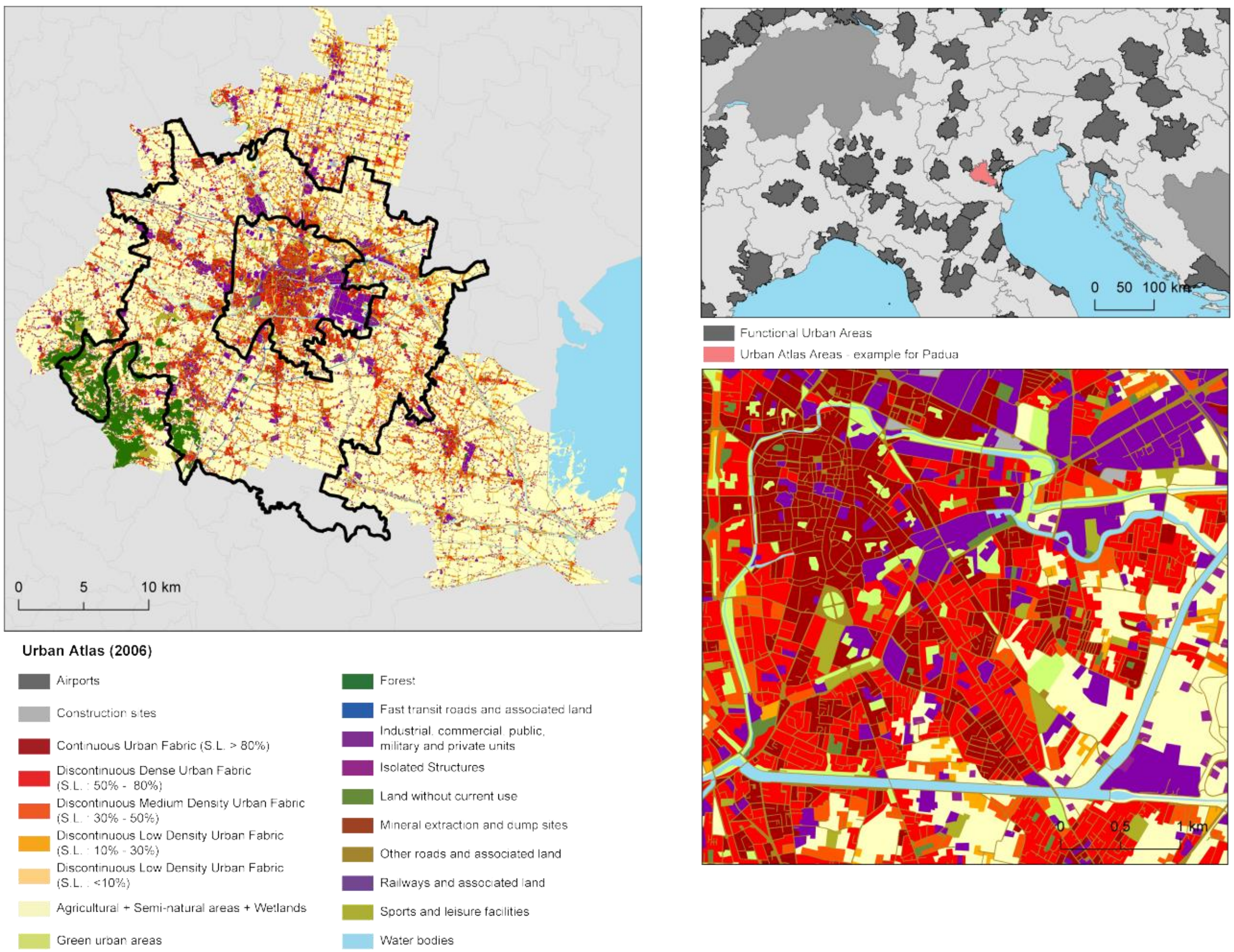


Figure 19. Mapping urban ecosystems using Urban Atlas.

When zooming in at city scale, urban atlas provides a relatively coarse map with mainly urban fabric and roads. Also agricultural/semi-natural/wetland (grouped into one single type) and water bodies are mapped.

A second map (Figure 20) provides more detail since local data are overlaid on the map derived from Urban Atlas. Spatial data for eight types of public green areas is available. These data provide more detail as they describe urban green spaces at a higher spatial resolution. Compare for instance the river banks between both maps.

[14] http://www.eea.europa.eu/data-and-maps/data/urban-atlas

Map section 1 (square) and map section 2 (circle) demonstrate the improvements of using or including different data sets for mapping urban GI. Map section 1 corresponds to an urban park while map section 2 is a residential area with two schools. Providing more detail shows (Figure 20) that the urban atlas type “green urban area” actually consists of a green play ground, an area dedicated for dogs, and urban park. Notice also the more detailed spatial delineation of the park. The residential area has several urban green spaces in and nearby the two schools.

The city of Padua has a tree database. It contains, among others, the species name and the spatial coordinates for every single tree in the city standing on public space. This allows the mapping of trees in the park. Such information is useful since it allows much better quantification of ecosystem services provided by single trees, in particular for the assessment of regulating and maintenance services. Additional information on species, age, and ecological traits (leave size, carbon content, …) improves mapping and assessment of services such air quality and (micro)climate regulation.

Finally Figure 21 compares the combination of urban atlas and local datasets with alternative data sources (the basemap included in the license of ESRI ArcGIS, a GIS software) and Open Street Map, a freely available dataset with spatial information. These datasets offer complementarity or additional detail and can be thus used to offer additional information on key issues such as accessibility of urban green spaces. They are also important to validate maps of urban ecosystems. In this context, also Google Earth and Google Earth Engine (which brings in a time dimension) are expected to become powerful for mapping urban ecosystems at very fine grain.

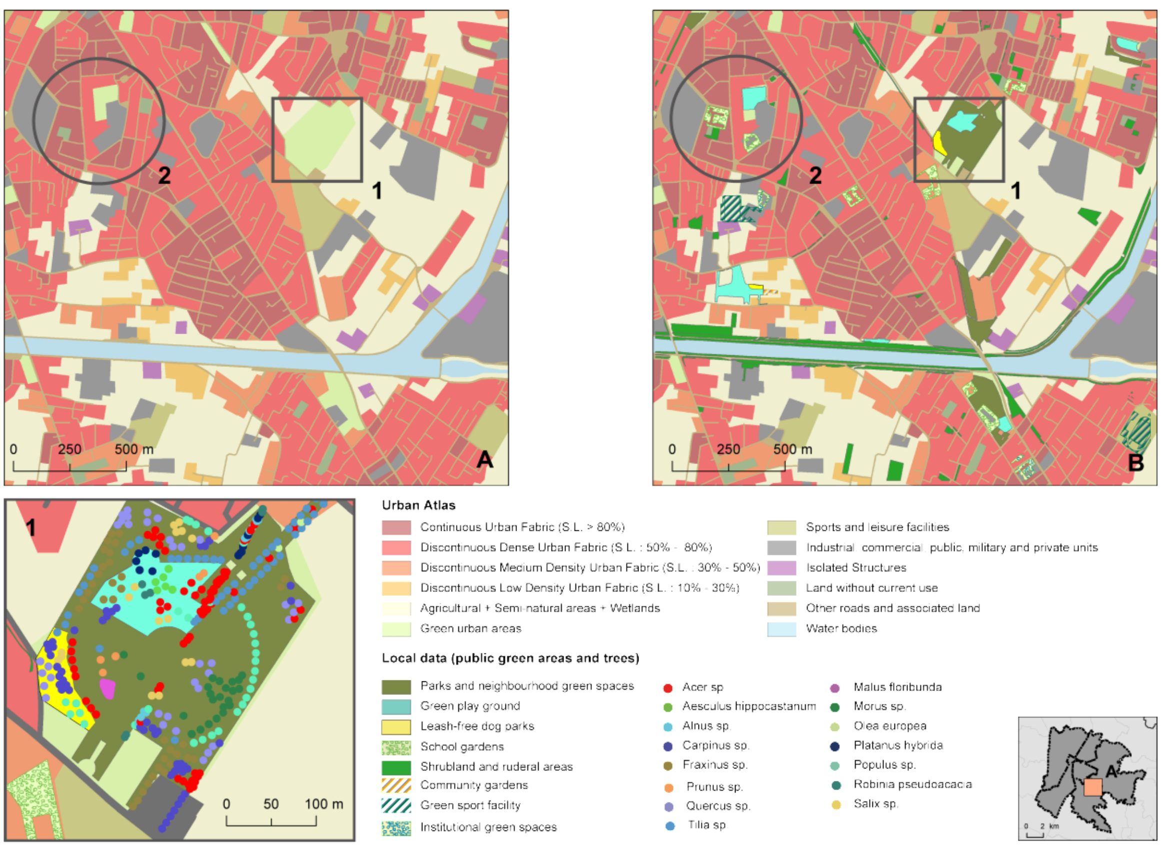


Figure 20. Mapping urban ecosystems based on Urban Atlas and additional locally collected information.

Figure 21. Validation of mapped urban ecosystems (A) with other datasets: ESRI base data (B) and Open Street Map (C).

Besides the data sources used in this section much other useful data are available for mapping. In particular high resolution data are becoming increasingly available and can be used to map urban green space and urban GI.

Special reference is made here to the Pan-European High Resolution Layers (HRL) of the Copernicus program. These layers provide information on specific land cover characteristics, and are complementary to land cover / land use mapping such as in the CORINE land cover (CLC) datasets. The HRLs are produced from 20 m resolution satellite imagery through a combination of automatic processing and interactive rule based classification. Five themes have been identified so far, corresponding with the main themes from CLC, i.e. the level of sealed soil (imperviousness), tree cover density and forest type, (semi-) natural grasslands, wetlands and permanent water bodies. See also Annex 7 on CIRCABC.

In this context also the use of the Natura 2000 data should be considered when mapping urban ecosystem or when assessing their condition (see Box 2).

Box 2. Natura 2000 inside Europe's urban ecosystems

While the importance of urban green infrastructure is increasingly recognized, the potential role of protected areas to support biodiversity in cities is often overlooked. Nevertheless cities have their role in the efforts to protect and manage vulnerable ecosystems and biodiversity.

The Natura 2000 network is a key instrument to protect biodiversity in the EU. Some Natura 2000 sites are located in remote areas but most of them are part of the surrounding landscape. So far only few analyses on the type and distribution of Natura 2000 sites within the city limits have been done at the EU scale. In 2006 Sundseth and Raeymaekers provided a valuable overview of the role of the network the major European cities.

By overlaying spatial data of the extent of functional urban areas (FUAs) in the EU with the extent of the Natura 2000 network we estimated that 9 878 (of the 27 308) sites are at least partially within FUAs. Showcases are presented for Cyprus, Germany and Luxembourg as well while the bar diagram contains aggregated data per country on the total share of FUA per country and to total proportion of each national Natura 2000 network inside FAUs.

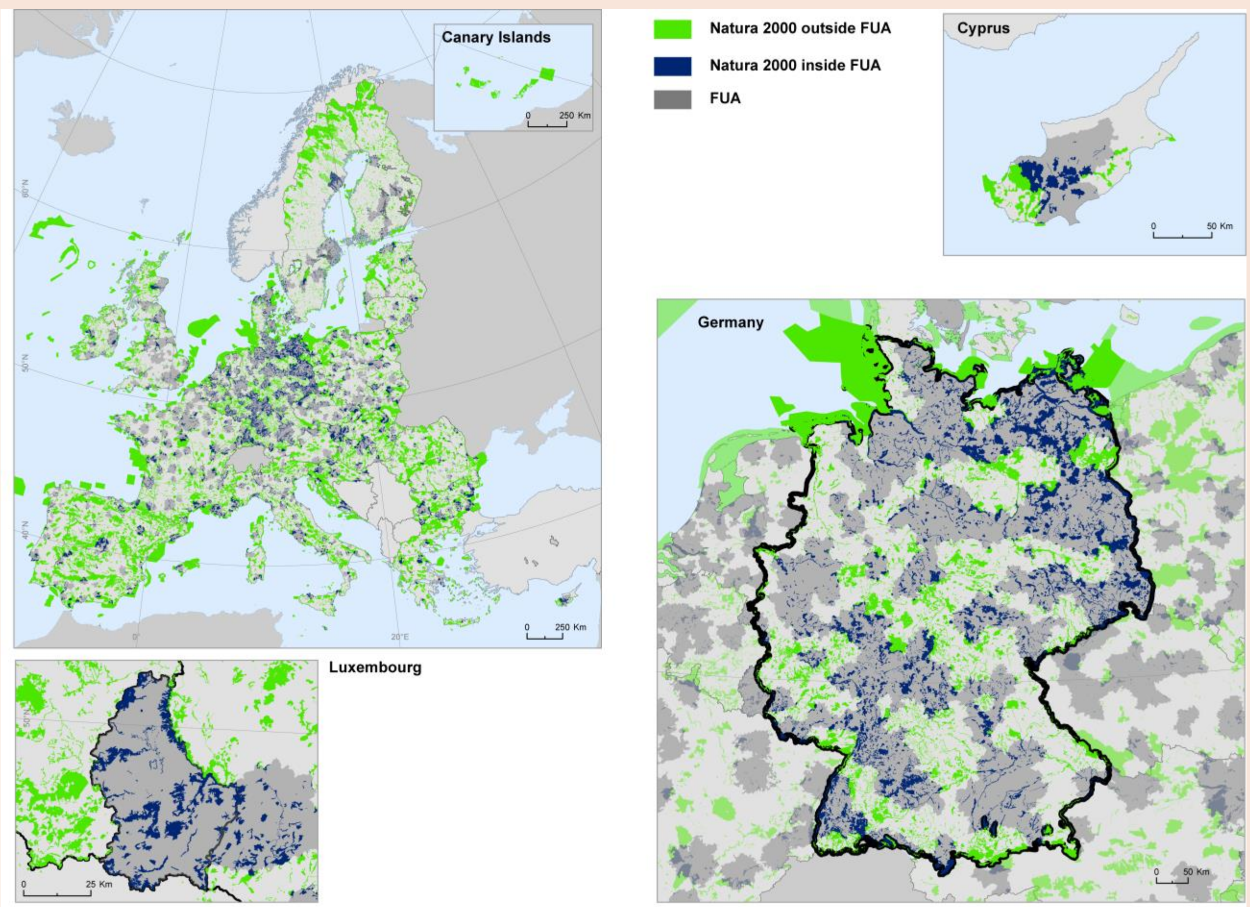


Figure. Overlap between functional urban areas and the Natura 2000 network in the EU.

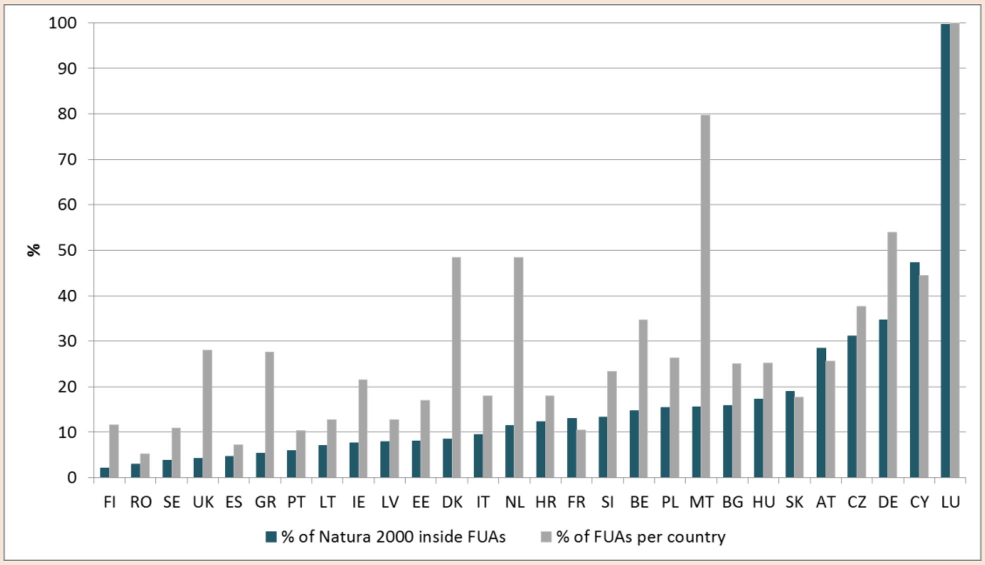


Figure. The percentage of FUA per country and the percentage of Natura 2000 inside FUAs.

6 URBAN ECOSYSTEM CONDITION

6.1 Indicator framework

A common approach to measure ecosystem condition is based on its similarity to a least-impacted, reference, or historical state. This is for instance the approach used to assess ecological status as required for the Water Framework Directive. However, the concept of a "pristine urban ecosystem" against which the present state can be compared is not really credible nor does it provide an appropriate frame. So how do we then define the condition of urban ecosystems, let alone measure it. How do we know if urban ecosystems are in poor or good condition?

The pilot members discussed the concept of urban ecosystem condition during the MAES urban pilot workshop in Lisbon in February 2016. Urban ecosystems are considered in "good condition" if the living conditions for humans and urban biodiversity are good. This means, among others, good quality of air and water, a sustainable supply of ecosystem services, species and habitats of Community interest in good conservation status and a high level of urban species diversity. Several participants of the workshop framed urban ecosystem condition by referring to the balance inside the socio-ecological system between built and green infrastructure. Built infrastructure and green infrastructure constitute together the urban ecosystem and deliver a wide range of social, economic and ecological services. Therefore, this report proposes that urban ecosystem condition could be assessed along the gradient from built infrastructure to green infrastructure.

Table 18 contains a set of key indicators to measure urban ecosystem condition. This selection is based on the results of the survey and a literature survey reported in a report of the Joint Research Centre (Rocha et al. 2016). This report contains more detailed lists of indicators. Also the partners of the pilot were consulted to make a final selection (see also methods section in Chapter 2).

Mapping and assessment of ecosystem condition has followed the DPSIR approach (the Drivers, Pressures, State, Impact and Response model). While this model has been applied to assess ecosystem condition for natural and semi-natural ecosystems in Europe (e.g., 3rd MAES report on ecosystem condition, Erhard et al. 2016), there are some limitations to apply it in the context of urban ecosystems. As already outlined above, there are no pristine urban ecosystems or historical reference conditions to compare with. Secondly, several indicators which are typically used to measure trends of drivers pressures on natural ecosystems lose their significance when used in an urban context. Examples are population density, the density of the road network, or the intensity of land use. Wherever they reach high levels, ecosystems are considered under pressure. In cities, however, these indicators reach evidently high values. Using these indicators as pressures on urban ecosystems is inconsistent with the concept of urban ecosystems as socio-ecological systems, which is advanced in this report. Therefore, our proposal is to use indicators which relate to population and land use (intensity) to describe the state of urban ecosystems, and in particular, to characterize built infrastructure. High population density and intensive use of built infrastructure can indeed indicate a more efficient use of resources and energy than would be possible in rural areas, and this would lower the pressure on rural ecosystems.

Table 18 contains four headline categories to classify indicators which can be used to help determine the condition of urban ecosystems: pressure indicators, state indicators for built and green infrastructures, state indicators which are related to the ratio between green and built infrastructure, and finally, indicators for measuring urban biodiversity. Indicators are grouped into different classes. For every indicator the relevant spatial scale is also included (Regional, Metropolitan, Urban).

The list of indicators in Table 18 is not exhaustive. A complete list of indicators which was provided through the different collection channels is available in the JRC technical report and on CIRCABC. Besides this source of information, much scientific literature is available reporting on local case studies and experiences. However, Table 18 aims to ensure a coherent mapping and assessment of condition of urban ecosystems across the EU and several of these are used by the European Environment Agency for reporting on the state of urban ecosystems in the EU.

Pressures on urban ecosystems can be assessed by considering urban sprawl and air pollution. Air pollution is of main concern in cities and specific legislation is put in place to minimize exposure of citizens to harmful substances such as NO_2, particular matter and ozone. Indicators linked to this legal framework are preferentially used to map and assess pressures on urban ecosystems.

Table 18 makes a difference between indicators which measure the condition of urban green infrastructure (without considering built infrastructure) and indicators which can be used to monitor the urban ecosystems as a whole (so including built infrastructure). Urban GI indicators are typically grounded in forest connectivity research and are used in or adapted to urban ecosystems. Indicators for measuring condition of the whole urban ecosystem use the proportion of green versus built infrastructure. Depending on the purpose and the context, different proportions can be assessed.

Finally, urban biodiversity can be monitored by targeting specific taxa. Birds are commonly monitored in cities. In Sheffield (UK) for instance, a study counted based on a 500 m x 500 m grid covering the city counted 77 bird species. For every citizen, there is 1.18 bird in the city (Fuller et al. 2009). Also lichens are proposed given their relation to air quality. Following increased global attention (e.g., IPBES), also pollinator insects are used as indicators for urban biodiversity. In this context, the potential role of citizen science is worth mentioning as tool for monitoring urban biodiversity. In cities, several species are introduced, often for cultural reasons (in Botanic gardens or zoos) so they are not necessarily viewed as a pressure but as part of the cultural heritage.

Box 3. The City Biodiversity Index also known as the Singapore index on cities

At the Tenth Meeting of the Conference of the Parties to the Convention on Biological Diversity (CBD COP-10) in 2010, Parties adopted Decision X/22 on the Plan of Action on Subnational Governments, Cities and Other Local Authorities for Biodiversity. The Plan of Action supports the implementation of the Strategic Plan for Biodiversity 2011-2020 at the national and local levels by providing recommendations to national governments on how they can engage local authorities and translate national strategies to the local context. It also encourages the use of the City Biodiversity Index (CBI) as a monitoring tool to assist local authorities to evaluate their progress in urban biodiversity conservation, which can be further included in national reports. In recognition of Singapore's leadership and contributions in the development of the Index, the CBI was renamed the Singapore Index on Cities' Biodiversity, or Singapore Index. It is a composite index which was developed by the Singapore National Parks Department with support from ICLEI, the CBD and others researchers (Kohsaka et al. 2013).

The CBI is a tool for cities to benchmark and monitor the progress of their biodiversity conservation efforts against their own individual baselines. It comprises two parts: first, the "Profile of the City" provides background information on the city; and second, 23 indicators that measure native biodiversity in the city, ecosystem services provided by biodiversity, and governance and management of biodiversity. Each indicator is assigned a scoring range between zero and four points, with a total possible maximum score of 92 points.

One of the case studies, Lisbon, has developed an own version of the CBI including more metrics to measure biodiversity, ecosystem services provided by biodiversity and policy performance. This extension of the CBI serves also as an example of how to map and asses in a more detailed way the supporting role of urban green infrastructure for daily leisure and recreation.

The annex of this report contains the Lisbon version of the CBI.

Table 18. Indicator framework for measuring the condition of urban ecosystems

Pressures indicators of urban ecosystems

Class	*Indicator*	*Scale* R	M	U
Urban Sprawl	Percent of built-up area (%)	●	●	
	e.g., Weighted Urban Proliferation (Urban Permeation Units m^{-2}) (Jaeger and Schwick 2014)	●	●	
Air pollution	Concentration of NO_2, PM10, PM2.5, O_3 ($\mu g\ m^{-3}$)	●	●	●
	Number of annual occurrences of maximum daily 8 hour mean of O_3 > 120 $\mu g\ m^{-3}$	●	●	●
	Number of annual occurrences of 24 hour mean of PM10 > 50 $\mu g\ m^{-3}$	●	●	●
	Number of annual occurrences of hourly mean of NO_2> 200 $\mu g\ m^{-3}$	●	●	●

State indicators of urban ecosystems

Built infrastructure *Class*	*Indicator*	*Scale* R	M	U	**Green infrastructure** *Class*	*Indicator*	*Scale* R	M	U
Population density	Number of inhabitants per area (number ha^{-1})	●	●	●	Urban forest pattern	Canopy coverage (ha)		●	●
Land use and land use intensity	Artificial area per inhabitant (m^2 $person^{-1}$)	●	●	●		e.g., different indicators based on forest pattern and fragmentation including SEBI 13		●	●
	Land annually taken for built-up areas per person (m^2 $person^{-1}$)	●	●	●	Tree health and damage	e.g. foliage damage crown dieback; measurements based on visual inspection of trees		●	●
Road density	Length of the road network per area (km ha^{-1})		●	●	Connectivity of urban green infrastructure	Connectivity of GI (%)		●	●
						Fragmentation of GI (Mesh density per pixel)		●	●
						Fragmentation by artificial areas (Mesh density per pixel)		●	●

State indicators related to the ratio between green and built infrastructure

Class	*Indicator*	*Scale* R	M	U
Land use	Proportion of urban green space (%)	●	●	●
	Proportion of impervious surface (%)	●	●	●
	Proportion of natural area (%)	●	●	●
	Proportion of protected area (%)	●	●	●
	Proportion of agricultural area (%)	●	●	●
	Proportion of abandoned area (%)	●	●	●

Indicators of urban biodiversity

Class	*Indicator*	*Scale* R	M	U
Species diversity	Number and abundance (number ha^{-1}) of bird species	●	●	●
	e.g., number of lichen species	●	●	●
Conservation	Number and abundance (number ha^{-1}) of species of conservation interest	●	●	●
Introductions	Number of alien species	●	●	●

R: Regional scale; M: Metropolitan scale; U: Urban scale

6.2 Reference conditions

Table 18 does not define a reference condition nor does it set a baseline or target situation. Clearly, the next step in the MAES urban pilot is to achieve a better understanding of urban ecosystem condition and to define baseline and reference conditions to measure progress to target but also to help policy makers with setting realistic targets for urban GI and urban biodiversity in order to improve urban ecosystem condition.

Recognising that the two functional components of urban ecosystems (built and green infrastructure) are essential to understand urban ecosystem condition is helpful to further define a reference against which condition can be assessed. Several proposals were made during the workshop to define a reference or baseline for urban ecosystem condition. In Table 19 they are presented according to a functional framework and a structural framework.

Reference conditions can be defined or agreed based on existing policy targets or new policy targets or ambitions. A third approach is based on a scientific analysis of indicators and their associated data to define empirically derived thresholds and reference levels. Note that the Millennium Ecosystem Assessment defined ecosystem condition as the capacity to provide ecosystem services. However, this concept assumes a positive relation between ecosystem condition and ecosystem services which still needs more scientific underpinning.

Table 19 uses both a structural and functional framing: A structural framing aims to measure ecosystem condition using with point-in time measurements of for example canopy cover, water quality, or land use (Palmer & Febria 2012). All the indicators listed in Table 18 are structural indicators. They do not capture the dynamic properties of an ecosystem and cannot monitor its performance. A functional framing tries to capture system dynamics through repeated measurements by quantifying key biophysical processes (such as energy and material flows but also ecosystem service flows).

The concept of Ecological Integrity, which has been at the basis for developing indicators which measure ecological status of water bodies under the Water Framework Directive (e.g. fish based indices) may offer useful and new ideas for assessment of urban ecosystems (and of other ecosystems as well). Ecosystem integrity refers to the self-organizing capacity of ecological systems as well as their resistance against non-specific ecological risks (Müller, 2005), which varies depending on the system’s developmental stage and due to occurring disturbances, caused for example by human land use activities or land cover change The key components to represent EI are ecosystem structures (such as biodiversity, abiotic heterogeneity) and ecosystem processes related to energy balance (exergy capture, entropy production, metabolic efficiency), water balance (water flows) and matter balance (storage capacity, nutrient loss) (Müller 2005).

Table 19. Approaches for defining a reference condition of urban ecosystems

Approaches based on:	Examples of a functional framing	Examples of a structural framing
Existing policy targets	Targets related to energy efficiency (2030 EU energy and climate targets-20-20 targets), or climate change mitigation policies (e.g. achieving climate neutral cities)	Targets related to air and water quality, and biodiversity.
New policy targets	Targets based on objectives or visions (for instance a target to decrease the average summer temperature in cities to mitigate the urban heath island effect)	Targets based objectives or visions (e.g. the ratio of green infrastructure versus grey infrastructure, public access to urban green space for every citizen with 10 minutes walking distance)
Indicators (maximum potential)	Empirically derived targets based on an upper percentile of indicator data: e.g., good urban ecosystem condition defined as a condition at which an indicator value reach a certain agreed value.	Empirically derived targets based on an upper percentile of indicator data: e.g., good urban ecosystem condition defined as a condition at which an indicator value reach a certain agreed value. Approach used to maximum ecological potential of heavily modified water bodies under the water framework directive
Capacity to provide ecosystem services	This is how the Millennium Ecosystem Assessment defined ecosystem condition. Targets based on agreed levels of ecosystem services delivery assessed through agreed methodologies.	
Ecosystem integrity	Joint assessment of structural and functional components of ecosystems	

6.3 Conclusions and next steps

The "good condition" of a city reflects a "good" or "desired" balance between green and built infrastructure, which can be measured by a selection of indicators. Both functional and structural metrics necessary to assess urban ecosystem condition and urban biodiversity.

During the next phase the MAES urban pilot will look at how a desired state or condition of urban ecosystems can be described and how new policy targets could help defining reference conditions. The concepts of ecological integrity offer an interesting approach to understand ecosystem condition, also in urban contexts.

7 URBAN ECOSYSTEM SERVICES

7.1 Indicator framework

The MAES indicator framework for urban ecosystem services includes a set of key indicators which can be used for mapping and assessment regional, metropolitan and urban scales. The framework does not include all CICES ecosystem services, but only services which are relevant and important in cities. Cities depend also on ecosystems beyond the city limits, in this case we refer to the collection of indicators proposed in the 2nd MAES report (Maes et al. 2014).

Table 20 shows the shortlist of key urban ecosystem services organized by CICES section and CICES class; CICES is a hierarchical classification system and allows thus further subdivide classes into class types which is useful for some urban ecosystem services. So where relevant, more detail is added through the CICES class type. CICES version 4.3 only provides examples of class types so the types inserted in Table 4 are based the pilot.

Food and water are the most provisioning services in cities; other provisioning services including biomass and energy from timber are not retained but as already mentioned, if such services are relevant for a city, suitable indicators may be found in the second report of the MAES working group. Key regulating ecosystem services in cities are the regulation of air quality, noise, temperature, and water flows including also flood regulation. Also pollination is considered relevant while cities may also contribute to global climate regulation. The most important cultural ecosystem services are Nature based recreation and education, and cultural heritage (as far as this concerns the natural environment).

Table 20 also includes for each service the main Service Providing Unit (SPU) and the expression of demand for urban ecosystem services. The SPU refers to the "smallest distinct physical unit that generates a particular ecosystem service" (Andersson et al. 2014). The expression of demand is adopted from Wolff et al. (2015) who proposed three categories of demand indicators: risk or exposure (for regulating ecosystem services); consumption (for provisioning ecosystem services); preference and potential or direct use (for cultural ecosystem services). Tables 21-22 go into more detail and include the indicators. Also in these tables, the indicators are organised using the CICES classification. Each indicator is marked as a supply indicator (●) or a demand indicator (●). If possible the unit of measure is provided; if the indicator is the result of a complex model also the scientific reference is included. Similar as for condition, the relevant scale is given as well.

Table 20. Key urban ecosystem services organized by CICES section, class and class type, and by type of service provision unit and expression of demand.

CICES Section	CICES Class	Class type (urban ecosystem services)	Service providing unit (SPU)	Demand
Provisioning	Cultivated crops	Vegetables produced by urban allotments and in and the commuting zone	Crop fields, fruit trees, private and public gardens	Consumption
	Surface water for drinking		Watershed	
	Ground water for drinking			
	Surface water for non-drinking purposes			
	Ground water for non-drinking purposes			
Regulating	Filtration/sequestration/storage/accumulation by ecosystems	Regulation of air quality by urban trees and forests	Forest, trees, shrubs	Risk of exposure to pollutant concentration beyond thresholds
	Global climate regulation by reduction of greenhouse gas concentration	Climate regulation by reduction of CO_2	Vegetation, soil	
	Micro and regional climate regulation	Urban temperature regulation	Forest, trees, shrub, herbs, lawns, wetlands, water bodies	Risk of exposure to high temperatures
	Mediation of smell/noise/visual impacts	Noise mitigated by urban vegetation	Forest, trees, shrubs, vegetated surfaces	Risk of exposure to noise
	Hydrological cycle and water flow maintenance	Water flow regulation and run off mitigation	Trees, shrubs, vegetated and permeable surfaces	Risk for flood sensitive areas or land use
	Flood control		Wetlands	Exposure to flooding
	Pollination and seed dispersal	Insect pollination	Crop fields, fruit trees, private and public gardens	Dependency on insect pollination
Cultural	Physical use of land-/seascapes in different environmental settings	Nature based recreation	Parks, gardens, forest, trees, agricultural areas in the commuting zone, wetlands, water bodies, waterways, Natura 2000 sites	Preferences; Potential and direct use
	Scientific	Nature based education		
	Educational			
	Heritage, cultural			

7.1.1 Provisioning ecosystem services

Table 21 presents the final selection of indicators for provisioning services in cities. Food and water are the most important provisioning services.

Vegetables are often produced in urban allotments and in the rural-urban fringe (Gómez-Baggethun et al., 2013). Indicators in table 5 include thus surface area and production statistics. Urban agriculture and community gardening (a single piece of land gardened collectively by a group of people) potentially decrease food miles measured as the distance between production and consumption, thus lowering fossil fuel use and transportation costs. At the same time urban food production can strengthen a sense of community, reconnect consumers with farmers, raise awareness on the environment and human health (McPhearson et al. 2014), and keep money circulating locally (McClintock, 2010). Important providers are crop fields, fruit trees, and private and public gardens.

Water supply is a critical ecosystem service to cities. Several statistics on water production and consumption are available and can be used. Table 21 includes indicators on supply (at the scale of a watershed) and use or demand expressed by consumption of drinking water or water for other, non drinking purposes. Ground water and surface water are put together for convenience but note that in CICES they are considered as separate classes (see also Table 21).

Table 21. Indicator frame for provisioning services. Each indicator is marked as a capacity indicator (●) or demand indicator (●). R (Regional), M (Metropolitan), U (Urban).

CICES Division - Group					
Nutrition - Biomass					
Class	**Class type (urban ecosystem service)**	**Indicator (unit)**	**Relevant spatial extent**		
			R	**M**	**U**
Cultivated crops	Vegetables produced by urban allotments and in and the commuting zone	● Production of food (ton ha^{-1} $year^{-1}$)	●	●	
		● Surface of community gardens /small plots for self-consumption (ha)		●	●
Nutrition - Water					
Surface/ground water for drinking		● Drinking water provision (m^3 $ha^{-1}year^{-1}$)	●	●	
		● Drinking water consumption (m^3 $year^{-1}$)	●	●	●
Materials - Water					
Surface/ground water for non-drinking		● Water provision (m^3 $ha^{-1}year^{-1}$)	●	●	
		● Water consumption per sector (m^3 $year^{-1}$)	●	●	●

7.1.2 Regulating and maintenance ecosystem services

In terms of impact regulating and maintenance ecosystem services are very important to support urban ecosystems. Demand for these services comes from exposure to several environmental risks (e.g., poor air quality, noise, flooding).

Table 22 proposes a final selection of indicators for mapping and assessment of regulating and maintenance ecosystem services in cities. Well known regulating services are the regulation of air quality, the regulating of temperature (cooling), water flow regulation and flood protection, contribution to global climate regulation and pollination.

Urban forest, trees and shrubs, and vegetated surfaces can improve the air quality by removing or intercepting pollutants. The most important pollutants, which result in serious risks to health are particulates ($PM_{2.5}$ and PM_{10}), ozone (O_3), nitrogen dioxide (NO_2) and sulfur dioxide (SO_2). Air pollution in cities is well studied and various indicators are available to assess the role of vegetation in reducing air pollution. Table 21 mentions the amount of pollutants removed by vegetation (in leaves, stems and roots), the dry deposition velocity and the (share of the) population exposed to high concentrations of pollutants. In general, the effect of vegetation on the average pollutant concentrations is not so high but a proper design of urban green infrastructure can locally lead to significantly lower exposure.

Besides air pollution, also noise mainly caused by all forms of traffic is an important stressor in cities. Key factors related to the noise are the distance to the source and the character of the soil or surface (Bolund & Hunhammar, 1999). Urban soil and plants can reduce noise pollution through absorption, deviation, reflection and refraction of sounds (Derkzen, van Teeffelen, & Verburg, 2015; Gómez-Baggethun & Barton, 2013; Gómez-Baggethun et al., 2013). Planting "noise buffers" (close to the noise source, rather than close to the area to be protected) made of trees and shrubs can reduce noise to the human ear.

Built-up infrastructure and impermeable surfaces result in alteration of water flow in that a higher proportion of the rainfall joins the surface-water run-off and results in increased peak flood discharges and degraded water quality through the pick-up of e.g. urban street pollutants. Flood control is therefore an important urban ecosystem service as vegetated areas contribute to prevent and mitigate negative effects in several ways by intercepting water or through percolation (Armson et al. 2013; (Armson, Stringer, & Ennos, 2013; Bolund & Hunhammar, 1999; Gómez-Baggethun et al., 2013). Table 21 includes eight indicators to map and assess the regulation of water flows and the protection against floods in cities.

Urban ecosystems can provide a valuable role in bee conservation (Baldock et al. 2015) so indicators on pollinators and pollination in urban ecosystems are very useful. This corroborates findings that cities can be hotspots for biodiversity (see Knapp et al.) and that is worthwhile accounting for urban biodiversity and the services which are directly derived from them. Besides, given the increasing attention for urban farming initiatives, (McClintock, 2010); pollination is becoming important in cities and rural-urban fringe for small scale urban agriculture and private gardens where wild pollinators maintain pollination services. Table 21 includes therefore two indicators to assess pollination.

Many cities and regions have the ambition to become climate neutral. Climate neutrality refers to net zero carbon emissions. Urban green infrastructure can play a role in achieving this objective by contributing to carbon storage or by reducing energy use (see next section). Therefore it is relevant to include carbon related indicators in the framework.

Table 22. Indicator frame for regulating services. Each indicator is marked as a capacity indicator (🟢) or demand indicator (🟠). R (Regional), M (Metropolitan), U (Urban).

CICES Division - Group					
Mediation of waste, toxics and other nuisances - Mediation by ecosystems					
Class	**Class type (urban ecosystem service)**	**Indicator (unit)**	**Relevant spatial extent**		
			R	**M**	**U**
Filtration/ sequestration/storage/ accumulation by ecosystems	Regulation of air quality by urban trees and forests	🟢 Pollutants removed by vegetation (in leaves, stems and roots) (kg ha^{-1} year-1)		●	●
		🟢 Dry deposition velocity (mm s^{-1})		●	●
		🟠 Population exposed to high concentrations of pollutants (% on surface area)		●	●
Mediation of smell/noise/visual	Noise mitigated by urban vegetation	🟢 Leaf Area Index + distance to roads (m)		●	●
		🟢 Noise reduction rates applied to UGI within a defined road buffer dB(A) m^{-2} vegetation unit (Derkzen et al. 2015)		●	●
Mediation flows-Liquid flows					
Hydrological cycle and water flow maintenance	Water flow regulation and run off mitigation	🟢 Soil water storage capacity (mm)	●	●	●
		🟢 Soil water infiltration capacity (cm)	●	●	●
		🟢 Water retention capacity by vegetation and soil (ton km^{-2})	●	●	●
		🟢 Intercepted rainfall (m^3 $year^{-1}$)	●	●	●
		🟢 Surface runoff (mm)	●	●	●
Flood protection	Flood protection by appropriate land coverage	🟢 Share of green areas in zones in danger of floods (%)		●	●
		🟠 Population exposed to flood risk (% per unit area)		●	●
		🟠 Areas exposed to flooding (ha)		●	●
Maintenance of physical chemical biological conditions - Lifecycle maintenance, habitat and gene pool protection					
Pollination and seed dispersal	Insect pollination	🟢 Capacity of ecosystems to sustain insect pollinators activity (dimensionless) (Zulian et al. 2013)	●	●	
		🟢 Relative abundance (number over area or over a length)	●	●	
Maintenance of physical, chemical, biological conditions - Atmospheric composition and climate regulation					
Global climate regulation by reduction of greenhouse gas concentrations	Climate regulation by reduction of CO_2	🟢 Carbon storage in soil (ton C ha^{-1})	●	●	
		🟢 Carbon sequestration (ton ha^{-1} $year^{-1}$)	●	●	

Micro and regional climate regulation	Urban temperature regulation	● Leaf Area Index		●	●
		● Temperature decrease by tree cover (°C m^{-2})		●	●
		● Cooling capacity of UGI (Zardo et al.)		●	●
		● Cooling capacity of UGI (Derkzen et al. 2015)		●	●
		● Cooling capacity of UGI (Grêt-Regamey et al. 2014)		●	●
		● Population exposed to high temperatures (% per unit area)		●	●

Urban GI can not only contribute to global climate regulation but also regulates the local climate and is an effective means to mitigate the urban heath island effect (the atmospheric temperature rise in cities during summer). The heath island phenomenon has been commonly associated to cities, because their surfaces are characterized by low albedo, high impermeability and favorable thermal properties for the energy storage and heat release. Climate change is increasing the frequency and intensity of environmental extremes, and cities and their surroundings experience different degrees of warming. Urban heat waves combined with an extensive urban heat island effect can cause additional hot days in urban regions compared to rural locales, increasing health risks for vulnerable population (Gasparrini & Armstrong, 2011; Tan et al., 2009). Urban blue and green infrastructure can contribute to the regulation of local temperatures. Water areas and large water bodies regulate the temperature. Vegetation and trees can help through: 1) evapotranspiration 2) shading 3) reducing wind speed (Skelhorn et al. 2014).

7.1.3 Cultural ecosystem services

Urban ecosystems offer a wide range of cultural ecosystem services to urban inhabitants. Urban parks are popular places for physical exercise, to pick-nick or to relax. Table 23 presents the final selection of indicators for cultural ecosystem services in cities.

Cultural ecosystem services are defined as material and non-material benefits that people obtain from the contact with nature. Access to adequate environmental amenities is fundamental for the sustainability and quality of life, health and well-being (Gelormino et al. 2015). For people living in urban areas, this means that the daily interaction with nature will come from their everyday urban places, including urban green infrastructures and the rural-urban fringe. The main activities related to cultural ecosystem services in cities are recreation – physical, social, spiritual and mental well-being, nature exploration, contemplation, living in an attractive and healthy environment, and nature education.

Important providers of cultural ecosystem services in cities are urban forests, crop fields, fruit trees, private and public gardens, parks and playgrounds, fresh water bodies, and coastal and marine ecosystems. Also protected areas (Natura 2000) sites should be considered in this context.

Table 23. Indicator frame for cultural services. Each indicator is marked as a capacity indicator (●) or demand indicator (●).R (Regional), M (Metropolitan), U (Urban).

<table>
<tr><th colspan="6">CICES Division - Group</th></tr>
<tr><th colspan="6">Physical and intellectual interactions with ecosystems and land-/seascapes [environmental settings] – Physical and experiential interactions</th></tr>
<tr><th rowspan="2">Class</th><th rowspan="2">Class type (urban ecosystem service)</th><th rowspan="2">Indicator (unit)</th><th colspan="3">Relevant spatial extent</th></tr>
<tr><th>R</th><th>M</th><th>U</th></tr>
<tr><td rowspan="9">Physical use of land-/seascapes in different environmental settings</td><td rowspan="9">Nature-based recreation</td><td>● Accessibility[15] to public parks, gardens and play-grounds (more than 50 ha) - (inhabitants within 10 km from a park)</td><td>●</td><td>●</td><td>●</td></tr>
<tr><td>● Accessibility to public parks gardens and play-grounds (between 10 ha and 50 ha) - (inhabitants within 1 km from a park)</td><td>●</td><td>●</td><td>●</td></tr>
<tr><td>● Accessibility to public parks gardens and play-grounds (between 2.5 ha and 10 ha) - (inhabitants within 500 m from a park)</td><td></td><td>●</td><td>●</td></tr>
<tr><td>● Accessibility to public parks gardens and play-ground (between 0.75 ha and 2.5 ha or smaller but important green spaces) - (inhabitants within 250 m from a park).</td><td></td><td></td><td>●</td></tr>
<tr><td>● Weighted recreation opportunities provided by Urban Green Infrastructure (Derkzen et al. 2015)</td><td></td><td></td><td>●</td></tr>
<tr><td>● Nature based recreation opportunities (includes Natura 2000; includes bathing water quality) (dimensionless) (Zulian et al. 2013)</td><td>●</td><td>●</td><td></td></tr>
<tr><td>● Proximity of green infrastructure to green travel routes (km)</td><td>●</td><td>●</td><td>●</td></tr>
<tr><td>● Green related social service provided to population (dimensionless) (Secco and Zulian 2008)</td><td></td><td></td><td>●</td></tr>
<tr><td>● Regression models on georeferenced data (i.e. pictures or geo tagged locations) (Tenerelli et al. 2016)</td><td>●</td><td></td><td></td></tr>
<tr><th colspan="6">Physical and intellectual interactions with ecosystems and land-/seascapes [environmental settings] – Intellectual and representative interactions</th></tr>
<tr><td>Educational</td><td rowspan="2">Nature-based education</td><td rowspan="2">● Accessibility of parks from schools (number of public parks and gardens within a defined distance from a school)</td><td rowspan="2"></td><td rowspan="2">●</td><td rowspan="2">●</td></tr>
<tr><td>Scientific</td></tr>
<tr><td>Heritage, cultural</td><td></td><td>● Cultural and natural heritage sites[16] (e.g., UNESCO world heritage sites) (number per unit area, % per unit area)</td><td>●</td><td>●</td><td>●</td></tr>
</table>

[15] See Poelman et al. (2016). http://ec.europa.eu/regional_policy/en/information/publications/working-papers/2016/a-walk-to-the-park-assessing-access-to-green-urban-areas-in-europe-s-cities

[16] We suggest to make use of the definitions of cultural and natural heritage derived from the Convention Concerning the Protection of the World Cultural and Natural Heritage (UNESCO http://whc.unesco.org/en/conventiontext/).

8 CONCLUSIONS AND NEXT STEPS

8.1 Conclusions

The MAES urban pilot extends the MAES common assessment framework to urban ecosystems by proposing guidelines for mapping urban ecosystems and by providing an indicator framework for consistent assessment of urban ecosystem condition and ecosystem services in cities across the EU.

This study has shown that there is a large scope for urban ecosystem assessments. Firstly, urban policies increasingly use urban green infrastructure and nature-based solutions in their planning process. Secondly, an increasing amount of data at multiple spatial scales is becoming available to support these policies, to provide a baseline, and to compare or benchmark cities with respect to the extent and management of the urban ecosystem.

The survey as well as the expert workshop resulted in increasing evidence of new societal arrangements in cities: the livability of a neighborhood and a city can be increased through local implementation of urban green infrastructure, in particular if these are based on bottom up initiatives which increase local ownership.

More work is necessary to understand how the condition of urban ecosystems has an impact on human wellbeing. Only few indicators are available and can be applied. This pilot contributed to defining better the concept of urban ecosystem condition along the continuum from built to green infrastructure. It will be important to continue with this work, in particular in the context of natural capital accounting and measuring and assessing nature-based solutions, but also in the discussions on how to make cities more resilient to various challenges including climate change.

Ecosystem services are increasingly used in urban planning but there is a difference in application between research and policy. This was clear from the case studies. The research community is better informed and has more in-depth knowledge of ecosystem services. This knowledge is effectively used to support policy. Researchers give content to the functional role of urban green infrastructure by making the link to, in particular, regulating and maintenance ecosystem services.

In contrast, case studies led by urban planners or city administrations base their conclusions on mapping urban green infrastructure in combination with data of urban biodiversity. Urban green infrastructure is seen from a structural point of view. The concept of ecosystem services is not yet fully introduced in the city's planning offices. Recreation (in urban parks) is an exception to this.

Therefore it is relevant to focus future assessments on a set of key urban ecosystem services which can be clearly coupled to the achievement of other policy targets in policy domains such as health, security, climate, urban microclimate (heath island mitigation), air quality, social wellbeing, and energy use/efficiency.

Operationalization of urban ecosystem services needs dedicated tools, which consider the specific conditions of urban ecosystems. In particular high resolution data are essential for mapping and assessment.

8.2 Next steps

The MAES urban pilot will continue with work on the interface between research and policy. The framework which is presented in this report needs to be tested across Europe. The next phase of the MAES urban pilot aims at building further on the many positive experiences collected during the first year and which are reflected in this report. It will promote the application of urban GI at local level and will deliver guidance on the creation, management and governance of GI. It will also test whether the MAES urban pilot framework is usable to capture whether and how nature-based solutions answer societal challenges in cities.

In this context EU added value comes from different sources: collaboration across scales and disciplines (community of practice), upscaling and contributing to the MAES knowledge base.

The MAES urban pilot illustrates that collaboration on a voluntary basis can deliver positive outcomes. Different city administrations from different countries worked together with scientific experts and policy across different scales along the science-policy interface. Such collaborations are important in the context of the EU Urban Agenda: they illustrate how joint work between and across different policy levels can lead to concrete green infrastructure policy setting, respecting the subsidiarity principle. An important next step in the MAES urban pilot is thus to enhance 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

Besides enhancing collaboration, application of the knowledge base on ecosystems remains an important objective of MAES. The current framework needs further testing and validation. Therefore the MAES urban pilot will actively solicit cities to partake in urban ecosystem assessments, which will focus on collaboration with local and regional stakeholders from policy and civil society. Several ongoing EU research projects such as ESMERALDA can contribute in this testing and validation phase.

It will be important to operationalize the MAES knowledge base on urban ecosystems for the Green Infrastructure Strategy and the EU's ambitious research policy on nature-based solutions, with the first set of projects on nature-based solutions funded under Horizon 2020 will be operational in late 2016 (Maes & Jacobs 2015).

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ABBREVIATIONS

CBD: Convention on Biological Diversity

CBI: City Biodiversity Index

CICES: Common International Classification of Ecosystem Services

CIRCABC: A collaborative platform of the European Commission for distribution and management of documents

COP: Conference of the Parties

EC: European Commission

EEA: European Environment Agency

ESMERALDA: Acronym of a research project: Enhancing ecosystem services mapping for policy and decision making

FUA: Functional Urban Area

GI: Green Infrastructure

GIS: Geographic Information System

GreenInUrbs: Acronym of a research project: Green Infrastructure approach: linking environmental with social aspects in studying and managing urban forests

GreenSurge: Acronym of a research project: Green infrastructure and urban biodiversity for sustainable urban development and the green economy

H2020: Horizon 2020, the EU's program on research and innovation

HRL: High Resolution Layer, a term used for earth observation datasets

ICLEI: Local Governments for Sustainability is the world's leading network of over 1,000 cities, towns and metropolises committed to building a sustainable future

IUCN: International Union for Conservation of Nature

JRC: Joint Research Centre

MAES: Mapping and Assessment of Ecosystems and their Services

NUTS: Nomenclature of territorial units for statistics, a geographical nomenclature subdividing the economic territory of the European Union into regions at three different levels

OECD: Organisation for Economic Co-operation and Development

OpenNESS: Acronym of a research project: Operationalisation of natural capital and ecosystem services

OPERAs: Acronym of a research project: Ecosystem science for policy & practice

SEBI: Streamlining European Biodiversity Indicators

SEEA-EEA: the System of Environmental-Economic Accounting (SEEA) Experimental Ecosystem Accounting (EEA) proposed by United Nations Statistical Division

SPU: The Service Providing Unit refers to the "smallest distinct physical unit that generates a particular ecosystem service.

URBES: Acronym of a research project: Urban biodiversity and ecosystem services

WAVES: Wealth Accounting and the Valuation of Ecosystem Services, a project of the World Bank

GLOSSARY OF TERMS

City: A city is a local administrative unit where the majority of the population lives in an urban centre of at least 50 000 inhabitants (definition by the European Commission and the OECD on functional urban areas).

City Biodiversity Index (CBI) also known as Singapore index on cities: A monitoring tool to assist local authorities to evaluate their progress in urban biodiversity conservation.

Commuting zone: A commuting zone contains the surrounding travel-to-work areas of a city where at least 15 % of their employed residents are working in this city (definition by the European Commission and the OECD on functional urban areas).

Ecosystem service: The benefits that people obtain from ecosystems (definition by the millennium ecosystem assessment). The direct and indirect contributions of ecosystems to human well-being (definition by The Economics of Ecosystems and Biodiversity, TEEB). The concept 'ecosystem goods and services' is synonymous with ecosystem services. The service flow in MAES conceptual framework refers to the actually used service.

Functional urban area (FUA): The functional urban area consists of a city plus its commuting zone. This is defined in the EU-OECD FUA definition. This was formerly known as LUZ (larger urban zone).

Green infrastructure: 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 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 (definition from the Green Infrastructure Strategy).

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. This term is preferred over grey (or other coloured) infrastructure.

Urban ecosystem condition: Urban ecosystems are in good condition if the living conditions for humans and urban biodiversity are good. This means, among others, good quality of air and water, a sustainable supply of ecosystem services, species and habitats of Community interest in good conservation status and a high level of urban species diversity.

Urban ecosystem service: Ecosystem service delivered by an urban ecosystem.

Urban ecosystem: Socio-ecological system composed of green infrastructure and built infrastructure. This definition of urban ecosystems is a further development of the definition used in the 2nd MAES report (Urban ecosystems are areas where most of the human population lives and it is also class significantly affecting other ecosystem types).

Urban green infrastructure: The multifunctional network of urban green spaces situated within the boundary of the urban ecosystems. Urban green parks are structural components of urban green infrastructure.

Urban green space: Urban space which is partly or completely covered with vegetation.

ANNEX. THE CITY BIODIVERSITY INDEX OF LISBON

Table. City Biodiversity Index (CBI) applied in Lisbon. In bold indicators derived from the original CBI list. In Italic indicators specific for the application in Lisbon.

Biodiversity indicators		
CBI Lisbon	INDICATORS	MEASUREMENT CRITERIA
1	**natural areas**	**percentage of natural, semi-natural and naturalized (for abandonment and management) areas**
1.1	naturalness degree - natural areas	ha
1.2	naturalness degree - semi-natural areas	ha
1.3	naturalness degree - areas naturalized by abandonment	ha
1.4	naturalness degree - areas naturalized by management	ha
1.5	relevant ecotopes	number of habitats/ecosystems (EUNIS 2003)
2	**connectivity measures**	
2.1	at ground level	ha
2.2	at canopy level	ha
3	**native biodiversity in built areas**	number of bird species in built areas
4	**variation of total vascular plant species (autochthonous, exotic and cultivars)**	**number of species**
4.1	variation of autochthonous vascular plant species	number of species
5	**variation of the number of bird species**	number of species
5.1	variation of the number of mammals species	number of species
6	**variation of the number of butterflies species**	number of species
7	**variation of the number of reptiles species**	number of species
	variation of the number of amphibians species	number of species
	variation of other groups of plants and animals (f.exp. estuarine macroinvertebrates)	number of species
9	**protected and classified areas**	areas subject to a protection status at local, national or international levels
9.1	forest regime	ha
9.2	fito - monuments and buffer protected areas	ha
9.3	geo -monuments and buffer protected areas	ha
9.4	natural phyto - monuments relevant for biodiversity	ha
10	**variation of invasive exotic species**	**number of invasive exotic species**
10.1	invasive flora	number of species
10.2	mammals invaders	number of species
10.3	invasive birds	number of species
10.4	reptilian invaders	number of species
10.5	amphibians invaders	number of species
10.6	invasive fish	number of species
Ecosystem Services provided by biodiversity		
CBI Lisbon	INDICATORS	MEASUREMENT CRITERIA
11	**area permeable city**	**set of permeable areas excluding water plans (in ha)**
11.1	agriculture and urban horticulture	ha
11.2	central green spaces or smaller than 50 ha	ha
11.3	local council green spaces over 50 ha	ha
11.4	peri-urban parks	ha
11.5	Forest Park Monsanto	ha

11.6	permeable small urban spaces	ha
11.7	mudflats and salt marshes	ha
11.8	intervened meadows (dry lawns and others)	ha
11.9	ruderal meadows (abandoned)	ha
12	**CO_2 sequestration and climate regulation**	**area x CO_2 sequestration /ha/year**
12.1	Acacia stands in Monsanto Forest Park	ha
12.2	Oak woods in Monsanto Forest Park	ha
12.3	Cupressus stands in Monsanto Forest Park	ha
12.4	Eucalyptus in Monsanto Forest Park	ha
12.5	Pinewoods in Monsanto Forest Park	ha
12.6	meadows in Monsanto Forest Park	ha
12.7	Olea stands in Monsanto Forest Park	ha
12.8	mixed stands in Monsanto Forest Park	ha
12.9	arboreal areas of the city (spots)	ha
12.10	arboreal areas of the city (alignments)	ha
12.11	intervened dry meadows and ruderal meadows	ha
12.12	lawns	ha
12.13	other grassland	ha
13	**area of public green spaces - leisure services and recreation**	**ha**
13.1	green areas per inhabitant	m^2
13.2	people served by peri-urban parks over 50 ha	number of inhabitants
13.3	people served by Forest Park Monsanto	number of inhabitants
13.4	people served by local council green spaces	number of inhabitants
13.5	people served by central parks (10-50 ha)	number of inhabitants
13.6	people served by urban parks (2.5 - 10 ha)	number of inhabitants
13.7	people served by local green spaces (2 - 10 ha)	number of inhabitants
13.8	people served by neighborhood parks (0.75 - 2.5 ha)	number of inhabitants
13.9	people served by proximity green spaces (0.75 - 2 ha)	number of inhabitants
13.10	people served by all types of green spaces over 0,75 ha	number of inhabitants
14	**visits to green spaces**	**number of visits and number of students**
indicators of diversity management and governance		
CBI Lisbon	INDICATORS	MEASUREMENT CRITERIA
15	**municipal budget for biodiversity**	**in EUR million**
16	**number of projects related to biodiversity**	**number of projects running**
17	**regulations and policy**	**number**
18	**institutional capacity - number of entities with functions essential for biodiversity**	**number of entities**
19	**institutional capacity - number of local agencies involved in actions and interdepartmental cooperation projects related to biodiversity**	**number of entities**
20	**participation and partners - existence of public consultations for projects related to biodiversity**	**existence**
21	**participation and partners - number of agents, academic institutions, NGOs, private companies, international institutions**	**number of entities**
22	**education and awareness (awareness) - inclusion of biodiversity in school curricula**	**existence**
23	**education and awareness (awareness) - number of awareness events made**	**number of events**

ANNEX. DOCUMENTS AVAILABLE IN CIRCABC

Supporting documents from the Pilots' work can be found at https://circabc.europa.eu/w/browse/b3aa2f63-9ef8-4f23-b6b5-c7ac17ddc202

Annex	Description	File
Annex 1	Description of the workshop questions	1_Annex_Workshop.pdf
Annex 2	Indicators scored by the experts for Step 3 of the process	2_Annex_Indicators.xlsx
Annex 3	Contributions of the case studies	3_1_Annex_Barcelona.pdf 3_2_Annex_Oslo.pdf 3_3_Annex_Poznan.pdf 3_4_Annex_Oeiras .pdf 3_5_Annex_Cascais.pdf 3_6_Annex_Lisbon.pdf 3_7_Annex_Trento.pdf 3_8_Annex_Padua.pdf 3_9_Annex_Rome .pdf 3_10_Annex_Utrecht.pdf
Annex 4	Case study summary table	4_Annex _CS_summary.pdf
Annex 5	List of data layers used for Oslo case study	5_Annex _Oslodata.pdf
Annex 6	Description of the relevant urban ecosystem services	6_Annex _description.pdf
Annex 7	Available data (European Environment Agency)	7_Annex _EEA_data.pdf

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