European Commission

JRC TECHNICAL REPORT

BiodiverCities: A roadmap to enhance the biodiversity and green infrastructure of European cities by 2030

Progress report

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Authors

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Abstract

BiodiverCities, a European Parliament pilot, aims to improve civil society participation in planning decision-making with respect to urban biodiversity, the nature in and around cities. The project has two main strands of work. Firstly, BiodiverCities collects practical examples of how to engage citizens in vision building around urban nature, monitoring, and solutions to improve urban biodiversity. Thirteen cities participate to BiodiverCities with local projects on citizen engagement or with case studies on mapping urban biodiversity and ecosystem services. Local activities include enhancing public participation in greening projects, vision building, or citizen science and participatory mapping of urban nature. A second strand of work is the mapping of urban biodiversity and ecosystem services at European scale. Urban biodiversity has been mapped using iNaturalist, a global species observation platform based on citizen science. More than 25,000 species have been observed inside Europe's functional urban areas, of which 130 species, mostly insects, plants and birds, are found in almost every city. Modelling urban temperatures showed that green infrastructure cool European cities by 1.6°C on average, and up to 4°C. Mapping the recreation opportunities in urban green spaces revealed that 44% of citizens did not have enough nature-based daily recreation opportunities. BiodiverCities contributed also to indicator development for the Green City Accord, a movement of European mayors committed to making cities greener and healthier.

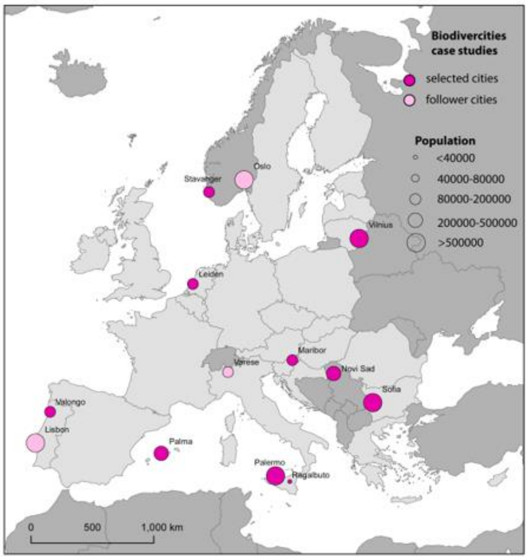
Executive Summary

BiodiverCities is a European Parliament pilot project following up on the EnRoute pilot project[1]. It aims to improve civil society participation in decision-making, leading to building a joint vision of the green city shared among civil society, scientists and policymakers.

The project has two main strands of work. Firstly, BiodiverCities collects practical examples of how to **engage citizens in vision building around urban nature**, monitoring, and solutions to improve urban biodiversity. Secondly, the project assesses **how urban green infrastructure can be used to provide local benefits** for people and nature and how can it contribute to enhancing regional biodiversity.

Engaging citizens in urban biodiversity planning

Thirteen cities participate to BiodiverCities with local projects on citizen engagement or with case studies on mapping urban biodiversity and ecosystem services:



Leiden, Netherlands: how to engage under-privileged, ethnic minorities into participatory processes; co-create and co-maintain with local inhabitants biodiverse urban spaces; explore locals' ideas on nature, biodiversity, and public participation.

Maribor, Slovenia: build green vision around urban nature; map, explore, and learn about local knowledge; develop solutions to improve urban biodiversity.

Novi Sad, Serbia: address the distrust between citizens and the municipality; introduce citizens' needs and matters of concern for planning a greener city; establish a new culture for biodiversity protection and the environment at large.

Palermo, Italy: promote dialogue about the future of schools, to reimagine the school system and the fruition of urban green spaces; connect schools with urban green infrastructure; illustrate the significance of biodiversity and contact with nature for everyday life; promote environmental and outdoor education for children.

Palma de Mallorca, Spain: experiment with co-creation as a planning practice via pilot cases; use incremental approach to change; anchor the activities to the revision of the City Masterplan.

Regalbuto, Italy: reinforce the links and interactions between people and nature; re-conceptualize the relationship between humans and non-humans in a non-utilitarian way; make out of this an asset for a public debate about local development, and for local development; experiment and extend existing participatory dispositives (Simeto River Agreement - SRA) in Regalbuto.

Stavanger, Norway: expand the knowledge base on trees, including both scientific and local knowledge; increase awareness about urban trees among the general public.

Valongo, Portugal: generate a common understanding and vision of a city rich in biodiversity with citizens; expand on the existing participatory projects by experimenting with new methods.

[1] https://publications.jrc.ec.europa.eu/repository/handle/JRC115375

Vilnius, Lithuania: experiment with co-creation as a participatory approach to address conflicts over issues and narratives (also among institutions); empower local citizens and raise awareness about biodiversity; experiment with interventions for biodiversity in post-Soviet neighbourhoods.

Varese, Lisbon: Engaging citizens in a citizen science study on swifts

Sofia, Bulgaria: Participatory mapping of urban trees and the cultural services or green infrastructure

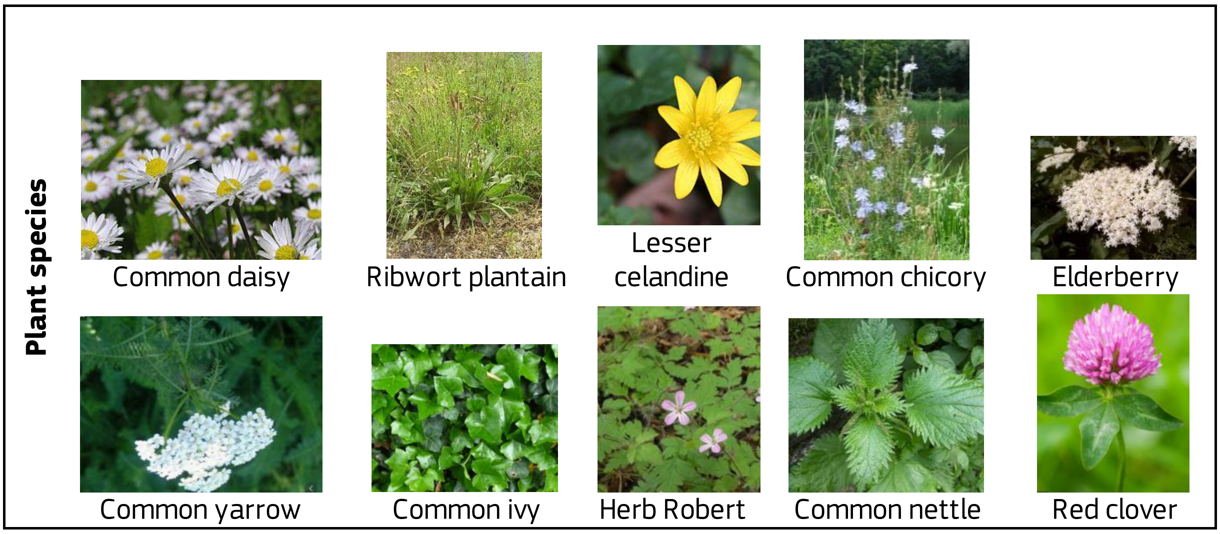
Lisbon, Portugal: Mapping 'saturation maps' and access to green spaces

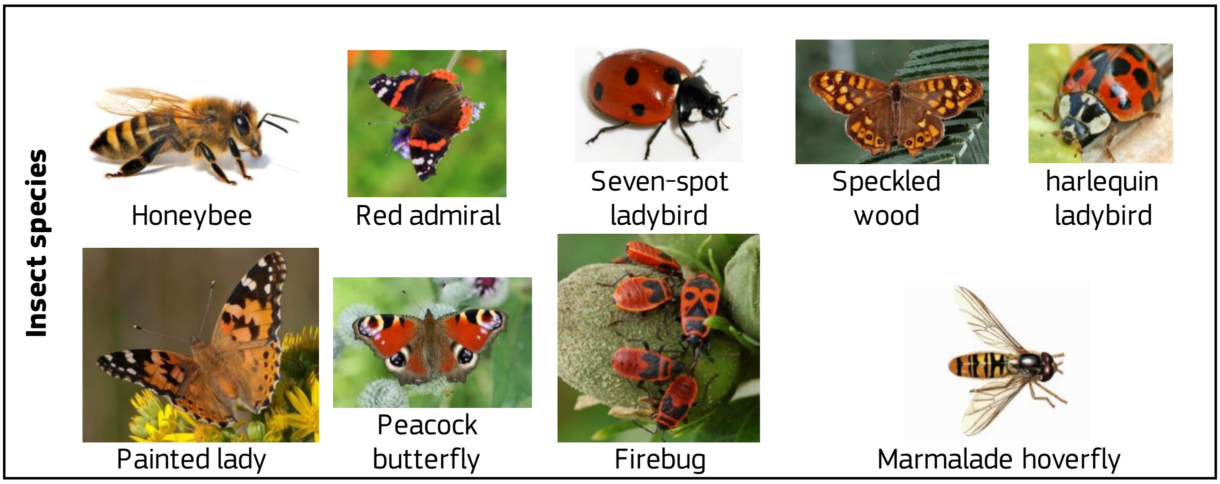
Oslo, Norway: Mapping urban biodiversity

Urban biodiversity

iNaturalist[2] is one of the many citizen science initiatives to record species observations. Here it has been used to make a synthesis of urban biodiversity observed and recorded by registered users of the platform. More than 25,000 species were observed by iNaturalist users inside Europe's functional urban areas. Insects, plants and birds were the most observed taxa.

About 130 species are observed in almost every functional urban area in Europe. Here below follows an inventory with the most observed plant species, animal species, lichen and fungi.





[2] https://www.inaturalist.org/

Bird species


Mallard


Common blackbird


Grey heron


Robin


Eurasian magpie


House sparrow


Great tit

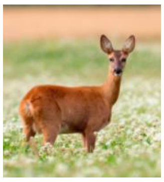

City dove


Common wood pigeon


White wagtail

Mammal species


European hedgehog


Roe deer


Red squirrel

Amphibian species


Common toad


Common frog

Molusk species


Garden snail


Grove snail

Spider species


European garden spider)


Wasp spider


Nursery web spider)

Lichens


Maritime sunburst lichen

Fungi


Shaggy ink cap


Fly amanita)

How urban vegetation cools cities during extreme heat events

Urban heat islands have a detrimental impact on human health and quality of life in cities. If current trends continue unabated urban heat islands may lead to dangerous temperature levels. Vegetation in cities can mitigate the impacts of urban heat island by cooling down cities. A model was applied to estimate the effect of urban and peri-urban vegetation in temperature reduction. Green infrastructure in European cities can cool urban microclimate by 1.6°C on average, and up to 4°C.

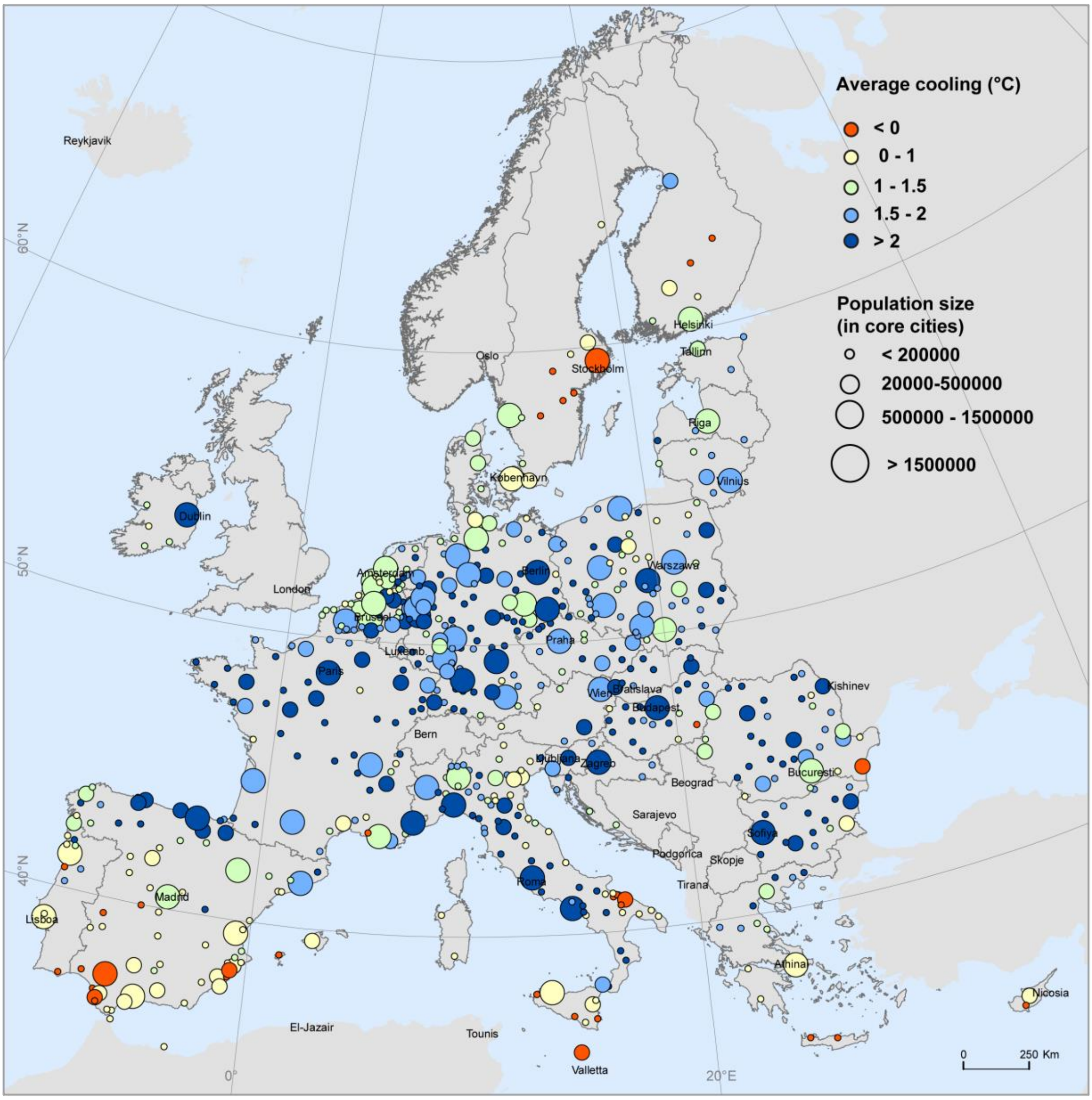


Figure 0.1. Average cooling by vegetation in cities during summer months (°C) in EU27, 2018

A model for assessing the recreation opportunities in urban green spaces

Contact with nature improves physical and mental health and wellbeing. Urban ecosystems provide several opportunities to improve contact with nature through nature-based recreation activities

Parks and urban green spaces represent more than 20 million of hectares of land suitable for recreation. The value represents, in average, 20.5% of the FUAs surface, ranging from a minimum of 0.3% to a maximum of 76.5%.

Opportunities for nature-based recreation increased by 4.4% per decade between 2000 and 2018.

The demand of nature-based recreation increased by 2.6% per decade.

In average citizens have 1.3 possible choices per person for nature-based recreational opportunities available per day. This estimate increased by 1.62% per decade between 2000 and 2018. Nevertheless, in 46% of the FUAs less than 1 possible destination per inhabitant was assigned to citizens in 2018.

In 2018, 44% of citizens did not have enough nature-based daily recreation opportunities. Between 2000 and 2018 the unmet demand decreased by 4.5% per decade. However the pattern is not homogeneous at the FUA level with unmet demand having increased in 28.7% of the cities over the same time period.

Indicators for the green city accord

The Green City Accord is a movement of European mayors committed to making cities greener and healthier. The BiodiverCities project contributed to the selection of indicators for the nature and biodiversity area. These indicators can be used to set a baseline for urban biodiversity and to track changes over time. The indicators are: (1) the share of natural, restored and naturalised areas in the city; (2) the percentage of citizens that live within 300 m of green spaces; (3) the share of urban tree/ canopy cover; (4) the change in vegetation cover inside the urban green infrastructure; (5) the total number of different bird / butterfly species; and (6) the presence of Invasive Alien Species of Union Concern.

Conclusions

Current global challenges, such as climate change, environmental degradation and air pollution, and the Covid19 pandemic, have increased the role and importance of urban green spaces. They provide nature-based solutions to reduce air pollution and flood risk; they increase the resilience of cities against extreme temperatures; they provide opportunities for recreation and stress relief and thus contribute to our physical and mental health and well-being. These benefits are delivered by the biodiversity and ecosystems that underpin the ecological functions of urban green spaces.

BiodiverCities increases the awareness of this underpinning role of urban biodiversity. Thirteen European cities contribute to the BiodiverCities project by setting up citizen engagement activities. The results of these local projects will help us understand better how to involve citizens in making cities greener and more biodiverse.

1 Introduction

1.1 What is BiodiverCities

Urban green infrastructure is now well recognized as a means to make cities healthier, more attractive and more responsive to the needs of citizens while providing habitat for nature. Urban green infrastructure delivers essential ecosystem services such as cooling cities during heat waves, clean air, green recreation spaces, protection against flooding, or enhanced mental and physical health. Urban green infrastructure and the services and benefits it delivers are underpinned by ecosystems and biodiversity. Yet, urban biodiversity and urban ecosystems have been often overlooked in global, European or national biodiversity strategies. Urbanization has been mostly regarded as a threat to biodiversity. However, the trend is changing: the draft post 2020 Global Biodiversity Framework to be adopted at CBD COP15 includes a specific target on urban ecosystems. The potential of cities to help protect biodiversity and ecosystem services is being more and more recognised. Cities are poles of creativity, innovation, and leadership. It follows that also cities can help achieve biodiversity goals and targets. This potential is recognised in key EU policies, notably the European green deal and EU biodiversity strategy to 2030. The strategy includes proposals to green European cities and increase biodiversity in urban spaces. In particular, the Commission will in 2021 set up an urban greening platform, under a new 'Green City Accord' with cities and mayors. Under this accord, cities can commit to make urban areas greener and more biodiverse.

This report summarises the progress made in the BiodiverCities project. BiodiverCities is funded by a grant of the European Parliament. It is implemented by the Joint Research Centre and DG Environment. It is a follow up project of EnRoute[3]. EnRoute tested how better knowledge on urban green infrastructure and ecosystem services can be mainstreamed in urban policymaking processes. Both BiodiverCities and EnRoute contribute to the Commission's initiative on Mapping and Assessment of Ecosystems and their Services (MAES). This initiative asks EU countries to build a knowledge base on ecosystems and use it different policy contexts in order to mainstream biodiversity in policy and decision making.

BiodiverCities aims at enhancing the use of green infrastructure in urban contexts, with a view to contribute solving many challenges cities currently face. A further goal is to increase scientific knowledge and improve knowledge sharing, tools, methods and innovative approaches to enhance biodiversity and the planning and implementing of green infrastructure. **The project aims to improve civil society participation in decision-making, leading to building a joint vision of the green city of tomorrow shared among civil society, scientists and policymakers.**

The project has two main strands of work. Firstly, BiodiverCities collects practical examples of how to engage citizens in vision building around urban nature, monitoring, and solutions to improve urban biodiversity. Secondly, the project assesses how urban green infrastructure can be used to provide local benefits for people and nature and how can it contribute to enhancing regional biodiversity.

2020 will be remembered as the year of the coronacrisis. The pandemic started at a moment when the project staff had launched a call to cities to actively participate in the project. Evidently, the covid19 crisis has considerably impacted the implementation of the project. Meeting with contributing cities and engaging citizens in local workshops or activities could not go on as planned. The pandemic required us to rethink or reschedule the initial working plan. However, the crisis also affected our common view on nature and urban green spaces. European citizens have rediscovered protected areas, nearby ecosystems and urban nature. In times where for many citizens the only form of recreation is outside walking or cycling, we have realised how valuable nature in around cities is for our mental and physical well-being. The level of awareness on the benefits delivered by urban green areas and nature has increased, which, in turn, may be an important incentive for further green Europe's cities.

[3] https://oppla.eu/groups/enroute

1.2 Objective and structure of this report

This **progress report** describes the results of BiodiverCities for 2020 for the two strands of work.

Chapter 2 reports the progress made on the citizens engagement activities. BiodiverCities is centred on co-creation as the fundamental element in urban planning and policymaking for biodiversity. In this spirit, ten participatory experiments across Europe are taking shape. Two mode cities will join. These experiments aim to empower citizens to co-create policies that are fit-for-purpose: designed with citizens and for citizens. This approach places the inhabitants of the city closer to the heart of the decision-making process and has become even more ambitious with the outbreak of the Covid-19 pandemic. As we watch the public spaces become more difficult to access, we try to re-think the ways in which meaningful engagement with each other and the urban environments can still be possible. How do we make sure that public participation is not out of touch with and of relevance to the context? The chapter describe the process that is set up to select cities and gives more details on the planning of cities for 2021.

Chapters 3, 4 and 5 report on a second strand of work in BiodiverCities: the mapping of urban biodiversity and ecosystem services delivered by urban green infrastructure. Urban green and blue infrastructure refers to the network of natural and semi-natural, biodiversity-rich features (e.g. trees, green spaces, parks, rivers, wetlands, forest areas) situated within a city. These high-quality biodiversity-rich areas can help make cities more sustainable and contribute to solve many challenges, such as air pollution, noise, climate change impacts, heat waves, floods and public health concerns. As cities grow and develop, it is vital to improve the availability, quality and accessibility of urban green infrastructure.

The EnRoute project (Maes et al. 2019) has assessed the availability and the condition of urban green infrastructure and the benefits it delivers in Europe's functional urban areas and core cities. The indicators used to assess urban green infrastructure incorporate a variety of data and metrics: anthropogenic pressures, pollution levels, soil sealing, the amount and configuration of urban green space, recreation opportunities and flood mitigation.

Still, there are several important knowledge gaps that are addressed in BiodiverCities. There is little information on urban biodiversity in terms of their habitats and species. Here we addressed this gap by analysis how a dataset based on citizen science can be used to infer urban biodiversity profiles. Secondly, the project focussed on a better understanding of how urban vegetation can mitigate extreme temperatures during heat waves. In addition, an updated method for assessing recreation opportunities in urban parks is presented.

A final report with a synthesis of the results of BiodiverCities will be delivered in 2022.

"We longed for green spaces and cleaner air for our mental health and our physical wellbeing." Ursula von der Leyen, President of the European Commission, State of the European Union 2020.

2 Engaging citizens in urban nature

2.1 Introduction: why engaging citizens on urban nature?

In the past decade or so, the interest in participatory forms in the fields of planning and policymaking for greening urban spaces has been increasing at a rapid pace. The novelty arises primarily from the institutional character of the call for greater environmental participation, rather than being associated with the topic *per se*. Indeed, the theme of invited or uninvited forms of involvement of local publics "with knowledge creation and governance of the environmental process and problems occurring in the place where they live" (Landström, 2020) is not new, and over the last decades it has witnessed an increasing attention and recognition of its significance in scientific and public debates.

Yet, what distinguishes the renewed interest in citizen engagement and deliberative processes is the institutional uptake of such discourses and a sense of urgency that accompanies it. 'The deliberative wave has been building as innovative ways of involving citizens in the policy-making cycle have gained traction with governments and citizens across the globe" (OECD, 2020). A call for different forms of governance in contemporary societies is emerging, in relation to the so-called crisis of representative democracy and increased awareness of the complexity, urgency, and controversial character of environmental and climate change-related issues that demand extended communities to address them (Funtowicz and Ravetz, 1993)[4].

Along these lines, BiodiverCities aims to innovate decision-making and planning at the urban level, leading to a joint vision of the 'green city of tomorrow with citizens, civil society at large, scientists and policymakers collaborating and negotiating its terms.

BiodiverCities contributes to the implementation of the EU Biodiversity Strategy. In the wake of the European Green Deal, this Communication by the European Commission affirms that "the promotion of healthy ecosystems, green infrastructure and nature-based solutions should be systematically integrated into urban planning, including public spaces" (p. 12). The strategy places European cities under the spotlight as key players for greening Europe, it supports **participatory governance at all levels**, and emphasises the role of public spaces in successfully meeting the identified challenges.

The project will implement the work in partnership with 10 selected cities and 3 follower cities, representing 7 EU Member States plus Norway and Serbia. Experts for each partner city have been contracted to help the JRC achieving the project goals.

The part of the project dedicated to citizen engagement will collect practical cases of:

i) How to engage citizens with regards to different kinds of biodiversity-related issues in urban settings and in diverse politico-institutional and geographical contexts;
ii) Reflect on how diverse knowledge holders are mobilized and how such knowledge is integrated into planning practices and environmental management;
iii) Critically analyse the ways citizens are empowered to influence the decision-making and planning process.

From a scientific and policy perspective, the project will pay particular attention to:

- *Institutional innovation* - by investigating the uptake by different public institutions and levels of government across Europe of citizen engagement tools, framings and methodologies, analysing different 'degrees' of participation (Arnstein, 1969);
- *Local and expert knowledge in planning* - by investigating the ways local and situated knowledge is used and integrated with scientific and expert knowledge in planning and policymaking practices;

[4] At the level of EU institutions, it is noteworthy to mention the European Democracy Action Plan (https://ec.europa.eu/commission/presscorner/detail/en/ip_20_2250).

- *Environmental (in)justices* - by including a 'justice lens' to the analysis of environmental participation, exploring old and emerging forms of environmental injustices, also in relation to 'green interventions'.

The next paragraphs will present a summary of relevant aspects characterizing this project, including the selection process of partners, the contractual elements, the working methodology, the local engagement programs delivered by experts and the next steps.

2.2 Process and workflow to select cities and start up the citizen engagement activities

2.2.1 Selection of cities

A Call for an expression of interest was issued in February 2020 in order to select **ten "cities** that are interested and committed to endorse participatory planning of green infrastructures and urban green". The Call was made publicly available on Oppla (https://oppla.eu/call-expression-interest-collaborate-biodivercities-project) and is included in the present report as 'Annex 1'.

Thirty-nine applications were submitted by an array of actors, including but not limited to public servants representing municipalities, researchers and academics, third sector players (e.g., associations), volunteers of local entities engaging on biodiversity-related topics.

Cities of any size could apply and be represented by different stakeholders or actors, not necessarily corresponding to public authorities or representing public bodies such as the local Municipality.

The quality of the proposals was high, warranting high interest in and commitment to the scope of the Call.

The selection of cities featured a two-steps process. Firstly, a desk-evaluation of proposals was conducted according to the following criteria:

1) **Consistency** with the scope of the project;

2) Identification of an **issue** to address and related drivers of pressures;

3) Clarification of the forms of environmental injustices, if any, possibly related to the issue at stake;

4) Awareness of the **context** in which the engagement process would play out, e.g., from a policy and spatial planning perspectives;

5) **Relatedness** of the citizen engagement process to the policy process;

6) **Potentials** of the engagement process;

7) **Motivation** of the applicant(s).

Secondly, selected cities were invited to a follow-up online interview that allowed for a more detailed understanding of the submitted project (always in relation to the aforementioned criteria).

Moreover, considerations about geographical diversity as well as heterogeneity of issues represented and actors engaged complemented the selection criteria.

2.2.2 Final list of cities

Ten cities were selected, and each officially confirmed their interest: Leiden (Netherlands), Palma de Mallorca (Spain), Valongo (Portugal), Stavanger (Norway), Vilnius (Lithuania), Sofia (Bulgaria), Maribor (Slovenia), Novi Sad (Serbia), Palermo and Regalbuto (Italy).

Selected cities were asked to identify one or two experts who would be responsible for designing and implementing at least three citizen engagement activities in their city, in collaboration with the JRC team. Each expert would receive funds in order to deliver the plan (see 'Terms of reference').

In addition, given the interest raised by their application, three cities were initially selected as 'follower cities'. Follower cities would not receive any funds, but they were invited to participate in official meetings and share their experiences and insights.

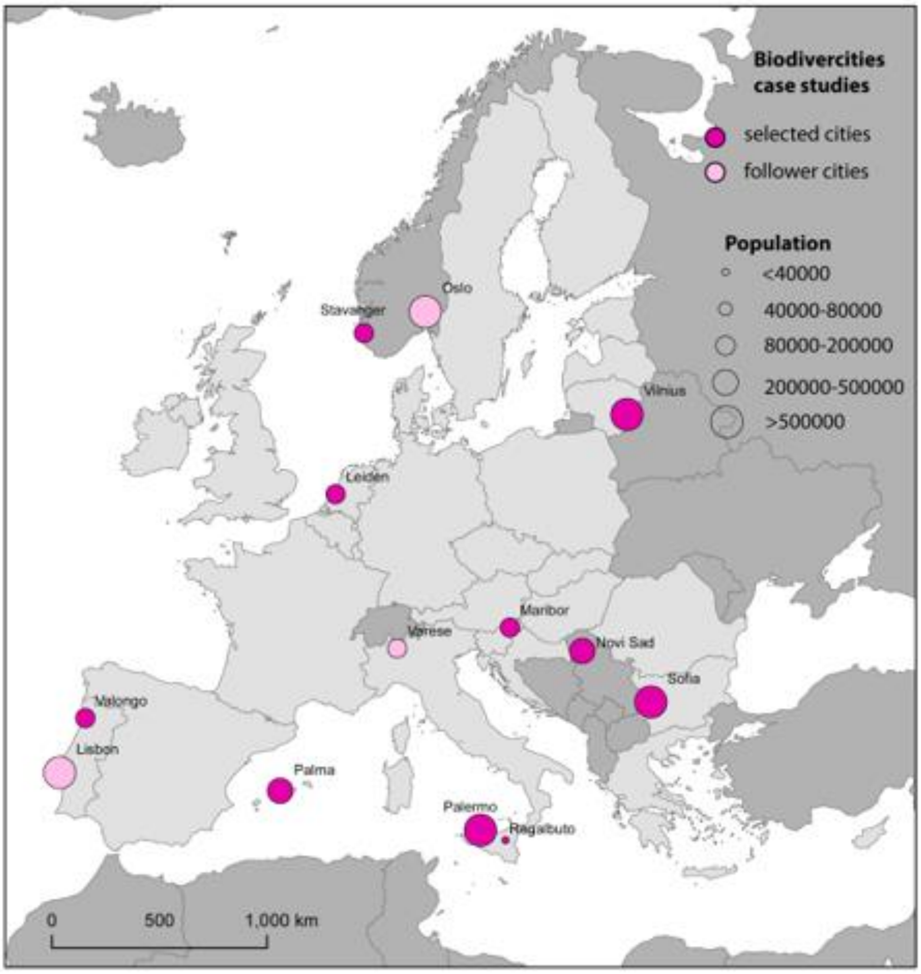


Figure 2.1. Maps of BiodiverCities selected and follower cities (status in July 2020)

In 2021 also Varese (Italy) and Lisbon (Portugal) joined formally the project with an appointed expert. With Sofia, more focus will go to methods for participatory mapping of urban trees and urban green infrastructure in collaboration with citizens.

In April 2021, Stavanger decided to withdraw from the project due to resource limitations.

2.2.3 Contractual part

A Technical Annex was prepared, complementing and justifying the request for a contract for one or two experts per city.

The Technical Annex clarified the purpose, objectives, and scope of the contract, the tasks and deliverables expected from the expert(s), as well as qualified the working approach (including the timeline) and methodology characterising BiodiverCities. More specifically, the contract

- Qualifies the citizen engagement process to be designed and implemented locally in terms of a co-creation process, from issue-framing onwards. Co-creation was defined as "[…] an approach to engaging with citizens on shared matters of concern in specific urban and territorial contexts, implying engagement methods and tools that allow joint creation of outcomes".

- In the spirit of co-creation, sets a co-design phase between the participating cities - represented by the expert(s) and, in some cases, the local extended team - and the JRC. The design phase lasted approximately from July 2020 to December 2020 and consisted in monthly one-to-one meetings ('Engage Corners', see below) dedicated to in-depth discussions about the definition of the local working program (corresponding to 'Deliverable no1').
- Envisages a plan for a set of mandatory to attend project meetings and voluntary to attend workshops, seminars, and talks dedicated to specific topics, held by the JRC scientific officers or external guests.

2.2.4 Warm-up period

Between June and August 2020, the JRC organized a series of online webinars with experts to introduce the objectives of BiodiverCities:

- Two '**Welcome meetings**' held on June 4 and 5, 2020. The two-day interactive event provided space for all participants to introduce themselves and to start creating a common ground to work together. It started with a short introduction by DG ENV on the strategic importance of the project given the Commission priorities and the newly released EU Biodiversity strategy for 2030. During the remaining time, the selected and follower cities presented ideas and views about the engagement activities to be carried out throughout the project, as well as their expectations.
- **1st Citizen Engagement Dialogue** was held on June 16, 2020. The online meeting served as a starting point for the conversation about what citizen engagement means from the perspective of all the participants involved in the project. In the first part of the event, practitioners were asked to choose an object and one or more words that represented public participation in their views and experiences. A collective dialogue followed, where the different layers of meanings associated with such individual choices were debated both in small groups and in the plenary session. In the second part of the meeting, the JRC team presented key aspects of citizen engagement to 'keep in mind' while planning an engagement activity.
- **Three** '**Capacity Building**' workshops, each dedicated to one of the three streams of research and expertise belying the BiodiverCities project: citizen engagement, mapping of green spaces, biodiversity, and ecosystem services, and citizen science. All meetings featured a mix of interventions from experts involved in BiodiverCities and external guests, as well as interactive sessions (i.e. break-out rooms) where participants shared their views, experiences, ideas, and reflections on the issues at stake. More specifically:

The **1st Capacity Building workshop** was held on July 3, 2020. The meeting focused on participatory methods in the fields of planning and policymaking. A series of conversations were held with partner practitioners about past or on-going engagement experiences with reference to the city of Lisbon (Ana Luz, University of Lisbon), the Simeto Valley (Medea Ferrigno and Giusy Pappalardo, Participatory Presidium of the Simeto River Valley Agreement and University of Catania), and Palma de Mallorca (Caterina Amengual Morro, Municipality of Palma de Mallorca). An invited guest, Hagit Keysar (an Israeli researcher and activist, Minerva Stiftung, The Museum of Natural History and Humboldt University, Berlin), also presented her work and activity in Israel-Palestine on and with DYI mapping, named *The Civic View from Above*[5].

The **2nd Capacity Building workshop** was held on July 10, 2020. The meeting focused on how mapping urban green spaces, biodiversity, and ecosystem services could play a role in citizen engagement activities. Two invited guests, Jan Dick (Centre for Ecology and Hydrology, UK) and Iwona Zwierzchowska (Adam Mickiewicz University, Poland), presented their work, respectively on the Cairngorm National Park[6] and a case-study of EnRoute project dedicated to the city of Poznań[7].

[5] See: https://cargocollective.com/hagitkeysar

[6] See: http://www.openness-project.eu/node/62

[7] https://oppla.eu/casestudy/19236

The **3rd Capacity Building workshop** was held on July 17, 2020. The meeting focused on citizen science, providing an overview of tools, methods, and examples, as well as exploring the interests of participants in this regard. Raquel C. Mendes, a PhD candidate from the Faculdade de Ciências da Universidade de Lisboa (FCUL), presented her ideas and research plans on how to use citizen science in school settings to explore biodiversity and enhance green infrastructures in cities.

2.2.5 Engage Corners

From July 2020, meetings with the selected cities ('Engage Corners') took place on a monthly basis. In the first phase of the project, lasting approximately from July 2020 to December 2020, Engage Corners provided space for in-depth and honest conversations between experts and, when applicable, the local extended team, and the JRC. Such endeavour allowed to establish trust between different expert figures and build a more in-depth understanding of the challenges each role comes with.

The agenda points were usually raised by the expert(s) and participating cities. Plans, activities, methods, expectations, difficulties, and even the vocabulary characterizing citizen engagement (e.g., what does 'public participation' mean in *that* context and according to such actors?) were matters of discussion.

Follower cities were also invited to join the Engage Corners, yet with less regularity. The commitment they showcased by actively contributing to the project allowed for considering the investment of extra-funds.

In the next phases of the project, we plan to maintain the series of Engage Corner on a bi-monthly basis.

2.3 Synthesis of the local working plans

The city experts delivered by the end of 2020 a proposal for a local working programme, timeline & agenda for engaging citizens in urban nature". Table 2.1 presents a summary of the citizen engagement activities. A more complete overview of the local working plans is provided in Annex 2. The citizen engagement activities presented in Table 1, Annex 1will take place during 2021, with different timelines depending on each case considered. By the end of 2021, the expert is asked to deliver a report that provides a synthesis of the activities (success, challenges, outcomes, context) and, by February 2022, to follow up with citizens engaged throughout the process.

Each expert and participating cities will be given a feedback on the submitted program by the JRC. The end date for the contract is set for December 31, 2022 in order to allow for adaptation, if needed, of the local working programs on the side of experts and participating cities due to Covid-19 restrictions and limitations in accessing public spaces and setting up gatherings of any kind.

Table 2.1: Brief description of the engagement activities per city.

Leiden, Netherlands: how to engage under-privileged, ethnic minorities into participatory processes; co-create and co-maintain with local inhabitants biodiverse urban spaces; explore locals' ideas on nature, biodiversity, and public participation.
Maribor, Slovenia: build green vision around urban nature; map, explore, and learn about local knowledge; develop solutions to improve urban biodiversity.
Novi Sad, Serbia: address the distrust between citizens and the municipality; introduce citizens' needs and matters of concern for planning a greener city; establish a new culture for biodiversity protection and the environment at large.
Palermo, Italy: promote dialogue about the future of schools, to reimagine the school system and the fruition of urban green spaces; connect schools with urban green infrastructure; illustrate the significance of biodiversity and contact with nature for everyday life; promote environmental and outdoor education for children.
Palma de Mallorca, Spain: experiment with co-creation as a planning practice via pilot cases; use incremental approach to change; anchor the activities to the revision of the City Masterplan.
Regalbuto, Italy: reinforce the links and interactions between people and nature; re-conceptualize the relationship between humans and non-humans in a non-utilitarian way; make out of this an asset for a public debate about local development, and for local development; experiment and extend existing participatory dispositives (Simeto River Agreement - SRA) in Regalbuto.
Stavanger, Norway: expand the knowledge base on trees, including both scientific and local knowledge; increase awareness about urban trees among the general public.
Valongo, Portugal: generate a common understanding and vision of a city rich in biodiversity with citizens; expand on the existing participatory projects by experimenting with new methods.
Vilnius, Lithuania: experiment with co-creation as a participatory approach to address conflicts over issues and narratives (also among institutions); empower local citizens and raise awareness about biodiversity; experiment with interventions for biodiversity in post-Soviet neighbourhoods.
Varese, Lisbon: Engaging citizens in a citizen science study on swifts
Sofia, Bulgaria: Participatory mapping of urban trees and the cultural services from green infrastructure
Lisbon, Portugal: Mapping 'saturation maps' and access to green spaces
Oslo, Norway: Mapping urban biodiversity

2.4 1st Project Meeting

The 1st BiodiverCities Project Meeting took place on 13 November 2020. During the morning and afternoon sessions, the cities had the opportunity to share their progress and present key highlights of their respective projects. Much space was also dedicated to the discussion of concerns and obstacles that the cities have encountered during the recent months – especially those related to Covid-19 restrictions – as well as their needs to confront the challenges.

During the lunch session, the participants met with Wolfgang Petzold, Deputy Director of Communications at the European Committee of the Regions, who presented his ideas on the importance of citizen engagement from the policy perspective.

The 1[st] Project Meeting was associated with the distribution of the 1st Project Digest[8], which contained reflection on the work done so far in the project, summarizing the main issues and themes that were raised during the "Engage Corners": ensuring appropriate level of engagement, justification for participatory activities, communication strategies, and institutional innovation.

2.5 Covid adaptation

The impact of the Covid-19 pandemic on the project has been two-fold. On the one hand, the importance of urban green areas has been highlighted, providing additional visibility and relevance. However, if the recent renewed public interest in green (public) spaces is promising for the scope of BiodiverCities, the ways in which the relationship between green spaces and public life plays out during Covid-19 is still unclear. Moreover, restrictions on mobility, limitations to gatherings, and social distancing rules affect the possibility to meet others in ways that, conversely, affect any public activity – including participatory processes.

On the other hand, the crisis has caused, differently depending on the political and geographical contexts, an upsurge in risk-aversion by public bodies (e.g., municipalities or schools in the case of Italy) as well as by others, including citizens, with regards to engaging in 'beyond necessity' activities.

In most cases, participating cities have been forced to revise their plans for citizen engagement due to the restrictions on group activities and/or difficulties to start out new community engagement activities. As a preliminary consideration to be later confirmed, citizen engagement plans that build upon existing forms of community engagement or that feature as continuations of ongoing participatory processes, seem to emerge as better suited to successfully deliver under the current circumstances.

All the cities managed to arrive with alternative plans for activities. In some cases, this meant change in timing of events, but most commonly, it included a transformation of the activities themselves, moving them partly or wholly online. Such transition is not without consequences for the participatory process, as new forms of and tools for engagement influence, e.g., demographic profile of participants and limit occasions for material deliberation strategies. Moreover, the new culture of social distancing will importantly affect the participatory processes as citizen engagement is, by definition, centred on relationships, collaboration and social learning – social processes that are well-rooted in physical encounters and materiality. Thus, the consequences of Covid-19 and its governance on public life are not reducible to technical matters to be sorted out.

One direction we have been encouraging has been to develop hybrid methods, which mix individual offline activities with digitally supported group engagement and exchange. To support planning online engagement and the use of digital tools in participatory processes, a dedicated workshop has taken place on February 26, 2021 (see 'Next steps')

[8] https://oppla.eu/groups/biodivercities/biodivercities-digest-1

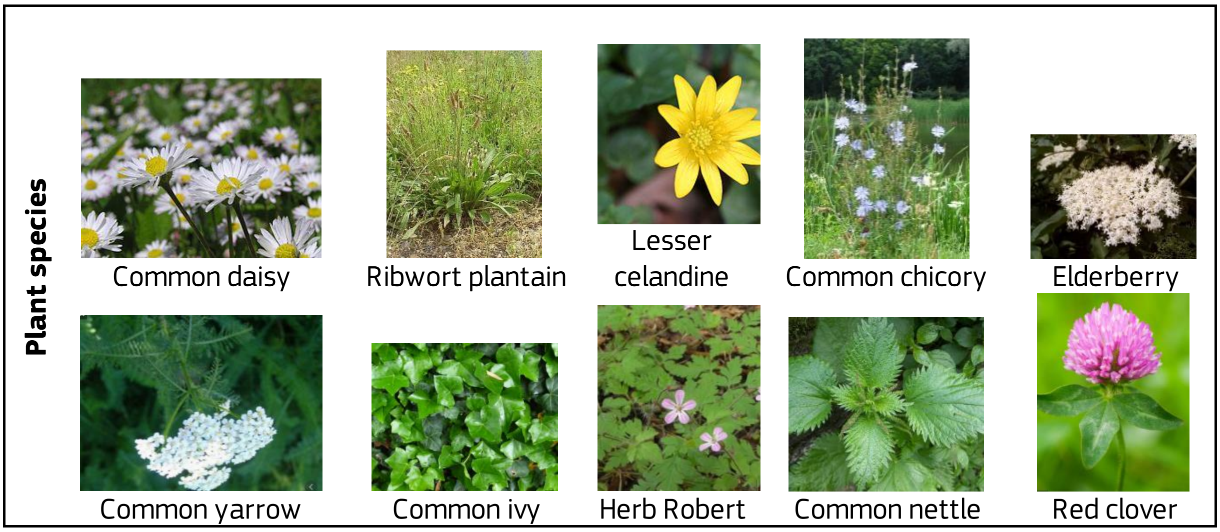
3 Mapping and assessment of urban biodiversity in the EU

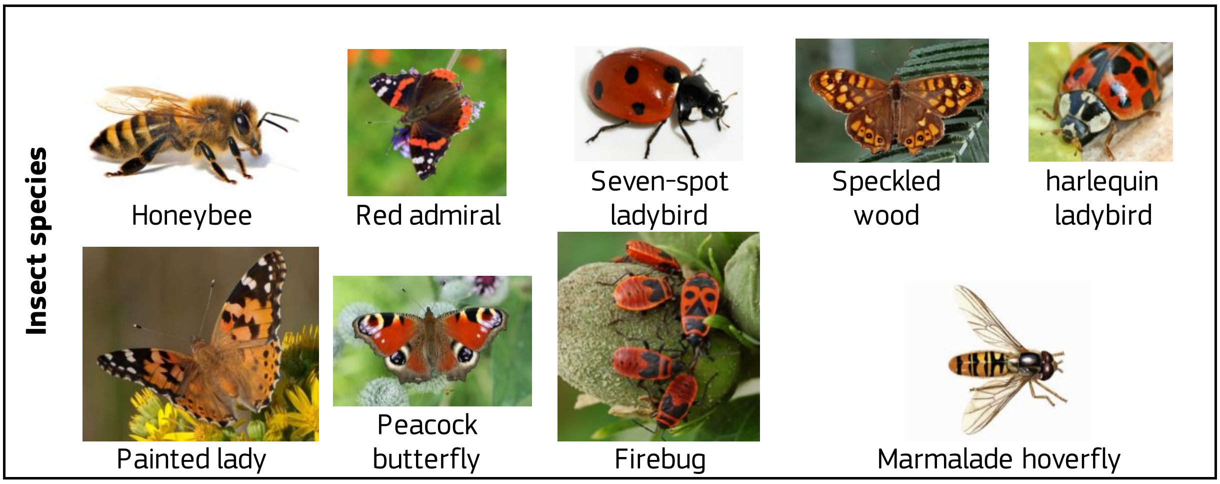
3.1 Key findings

Citizen and science platforms can support the understanding of urban biodiversity. iNaturalist (https://www.inaturalist.org/observations) is one of the globally most used platforms. It counts more than 4 million observations in Europe with 36 136 different species.

Urban ecosystems host a wide variety of species communities: more than 25 000 species were observed by iNaturalist users inside cities. Insects, plants and birds were the most observed taxa both inside and outside Functional Urban Areas (FUAs) (inside FUAs 18.1% were plants, 14.82% insects, 8.11% birds).

Urban biodiversity can be well described by a core set of 130 species that are observed in the majority of Functional Urban Areas (FUAs) in Europe. In fact, about 130 species are observed in almost every functional urban area in Europe. Here below (Figure 3.1) follows an inventory with the most observed plant species, animal species, lichen and fungi.





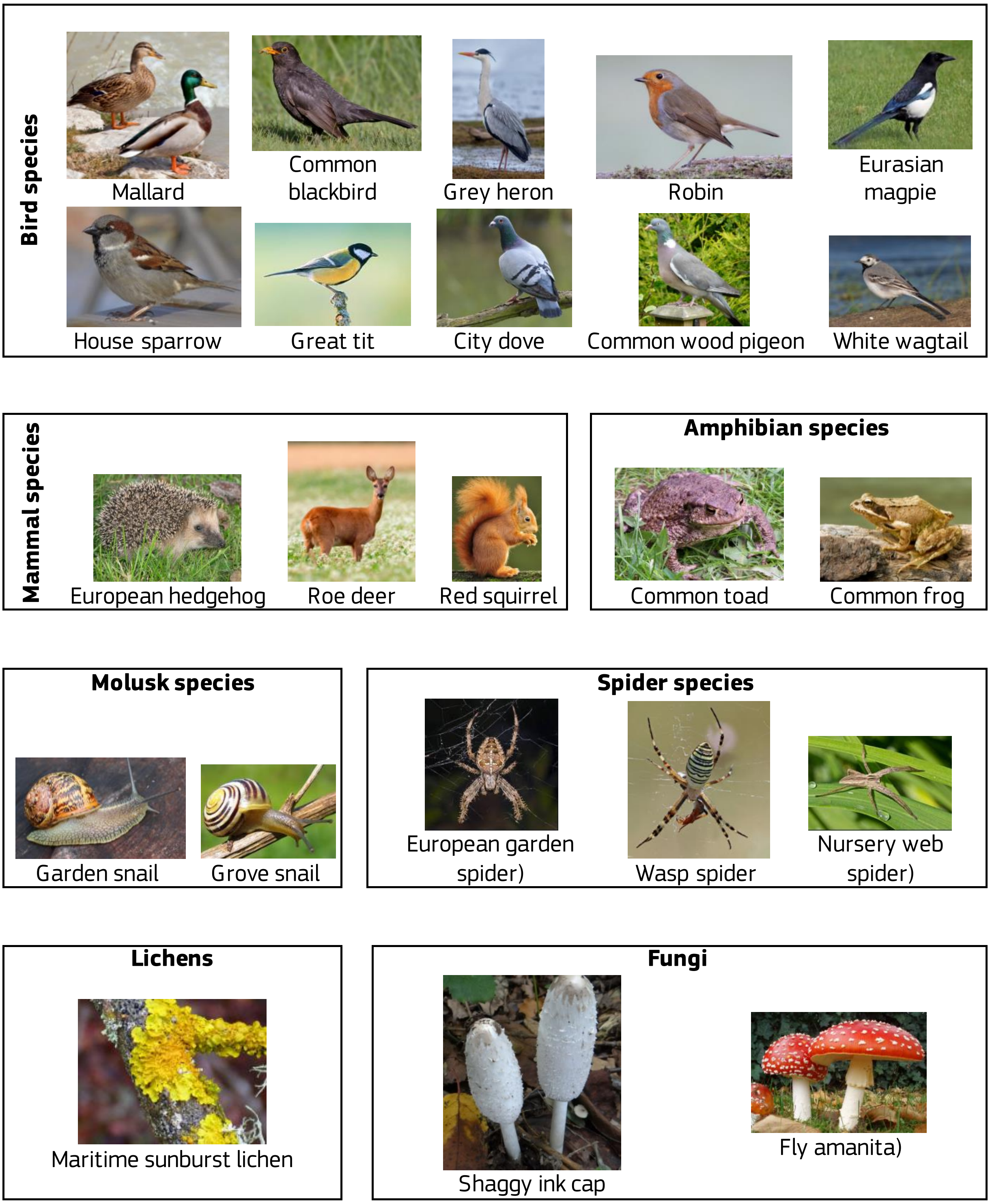


Figure 3.1. Inventory of the most observed plant species, animal species, lichen and fungi.

Among the 31 most common bird species observed in the majority of FUAs, five are classified having a decreasing population trend. One of them is also classified as "Near Threatened" species in the IUCN red list.

Invasive Alien Species (IAS): of the 66 IAS of Union Concern, 35 were observed inside FUAs (10 619 observations). Five IAS are part of the most commonly observed species.

IUCN: 3 863 species under different levels of extinction risk were observed (906 505 observations), of which 517 (12.6% of the IUCN species are observed inside FUA) were classified as exposed to different and more serious levels of vulnerability. One regionally extinct species, the northern bald ibis (hermit ibis) was observed with a total of 163 observations in Europe, 46 (28%) of which inside FUAs.

3.2 Introduction

Why are we interested in urban biodiversity? Urbanisation is a process and a characteristic of the land. As a process it refers to a movement of people: "the gradual increase in the proportion of people living in urban areas" and it implies changes in the way society live and organize the life. As a characteristic of the land, it refers to a combination of dominant proportion of developed areas, buildings and human population density (Moll et al., 2019), which alters the locally dominant natural ecosystems (Beninde et al., 2015). In this second meaning, the term urbanisation can be replaced by "urban-ness" which: "broadly refers to the characteristics associated with cities and their surrounding regions, including abiotic, biotic, socio-economic and structural components" (Moll et al., 2019). Urbanisation as a process and characteristics of land, dominated the 21st century and has strong effects on ecosystems, effects usually stigmatized as negative.

It contributes to increase ecological homogenization, defined as the similarity between even geographically distant suburban systems than to nearby natural ecosystems (Groffman et al., 2014).

Urbanisation is one of the determinants of biotic homogenization – the phenomenon for which spatially distributed biodiversity tends to converge (Leong and Trautwein, 2019). Urbanisation is associated with increased rates of species extinction (Czech et al., 2000), an increased prevalence of invasive and exotic species (Riley et al., 2018) and a growing psychological disconnect between people and nature (Miller, 2005). Nevertheless, as recognised by Beninde et al. (2015) this perspective may distract from the positive effects that urban ecosystems can have on biodiversity, supporting regional biodiversity and native species (Aronson et al., 2014) and on the provision of ecosystem services.

Among the gaps identified by Beninde (2015) there is the need to define a standardized approach for the assessment of urban biodiversity. Broad-scale citizen science data have been recently used for the assessment of urban biodiversity. For example Li et al. (2019) analysed how species occurrences are associated with spatial variation in the physical and anthropogenic environment in Los Angeles Metropolitan area. Leong et. al. (2019) investigated for biotic homogenization on 14 US metropolitan areas. Callaghan et al., 2020 worked on species response to urbanisation in the Boston Metropolitan area. The three studies are based on data extracted from the iNaturalist platform (https://www.inaturalist.org/home).

iNaturalist is a crowd-sourced species identification app powered by Artificial Intelligence (AI). For the casual nature observer, the app allows people to snap photos of such easy targets as backyard plants and bugs and upload images for its AI to provide a match or for members of the community to identify. The platform was launched in 2008, since 2014 iNaturalist became an initiative of the California Academy of Sciences and a joint initiative with National Geographic Society in 2017.

The research questions addressed in this study on urban biodiversity are:

What are the general patterns of urban biodiversity in the EU? How many species are observed on Europe's cities? How many bird species, mammals, plants, other taxa are present? Which species are more widely observed? What type of species can cities support?

More specific questions: Are there any spatial patterns of biodiversity among cities at EU level? Is urban-ness connected with an increased biotic homogenization? What determines intra urban variation in biodiversity? What are the main drivers of intra-urban biodiversity levels? To what extent citizen-science data can contribute to the analysis of urban biodiversity?

3.3 Study area and data sets used in the assessment of urban biodiversity in the EU

3.3.1 Study area

This first exploratory analysis was developed for the Functional urban Areas (FUAs) located in EU27, United Kingdom, Norway, Switzerland and Island (EU-27-Plus in figure 3.2), but excluding the Balkans. Non EU countries were included in order to have the more exhaustive possible coverage of iNaturalist data. FUA are cities and their surroundings, composed of high-density urban centers with at least 50 thousand people plus their surrounding commuting zones (Dijkstra and Poelman, 2012; OECD, 2013). FUAs were chosen because representative of European urbanised areas.

FUAs cover the 20.67% of the study area, 21.3% if considering only EU27. Figure 3.2 shows the distribution of the share of FUAs per country. Luxemburg and Malta are considered as exceptional cases because the entire area of the country forms a FUA. In Belgium, Germany and The Netherlands FUAs cover from 45 up to 60% of the country.

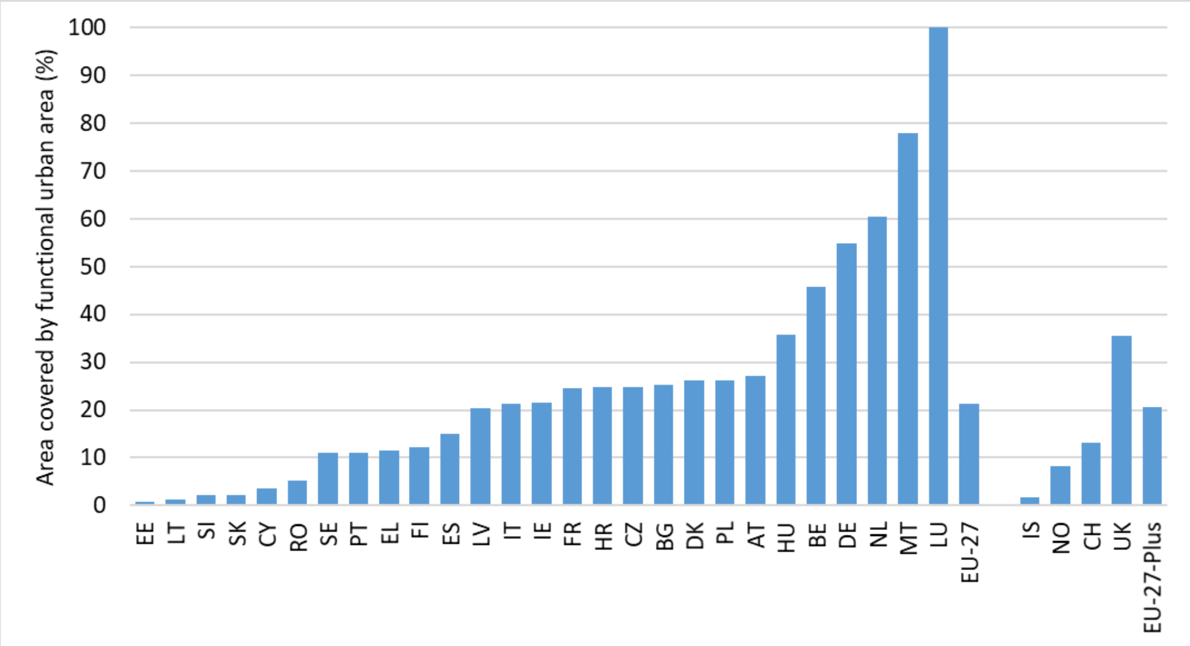


Figure 3.2. Area (%) per country covered by functional urban area (FUA) (EU-27 and EU-27-Plus)

3.3.2 Datasets

To address the questions raised above, the data sets listed in Table 3.1 have been used.

Table 3.1: Data used in the study on urban biodiversity

Variable	Source
Urban species	https://www.inaturalist.org/
IUCN red list species	https://www.iucnredlist.org/search?dl=true&permalink=05f7308f-f3d9-407a-a289-ac2e3e0a97b8
Habitats directive	https://www.eea.europa.eu/data-and-maps/data/article-17-database-habitats-directive-92-43-eec-2/article-17-2020-dataset
Birds directive	https://ec.europa.eu/environment/nature/conservation/wildbirds/eu_species/index_en.htm
Invasive Alien Species	https://easin.jrc.ec.europa.eu/easin
Farmland Birds	https://ebookcentral.proquest.com/lib/europaeu/reader.action?docID=6360414
Local Administrative Units (LAU)	https://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/administrative-units-statistical-units/lau
Urban audit 2020	https://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/administrative-units-statistical-units/urban-audit
Corine Land Cover (CLC)	Corine Land Cover map https://land.copernicus.eu/pan-european/corine-land-cover
NUTS (2021)	https://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/administrative-units-statistical-units/nuts
GHS-SMOD,	https://ghsl.jrc.ec.europa.eu/download.php?ds=smod
GHS-POP,	https://data.jrc.ec.europa.eu/dataset/jrc-ghsl-10007

3.4 Results

3.4.1 Number of observed species

iNaturalist (https://www.inaturalist.org/) was launched in 2008. Figure 3.3 shows the distribution of observations registered per year in Europe (observations included before 2007 display the date when the observation was made in the field. Regarding observations from 1901, they probably come from people uploading historic records that they did not record themselves).

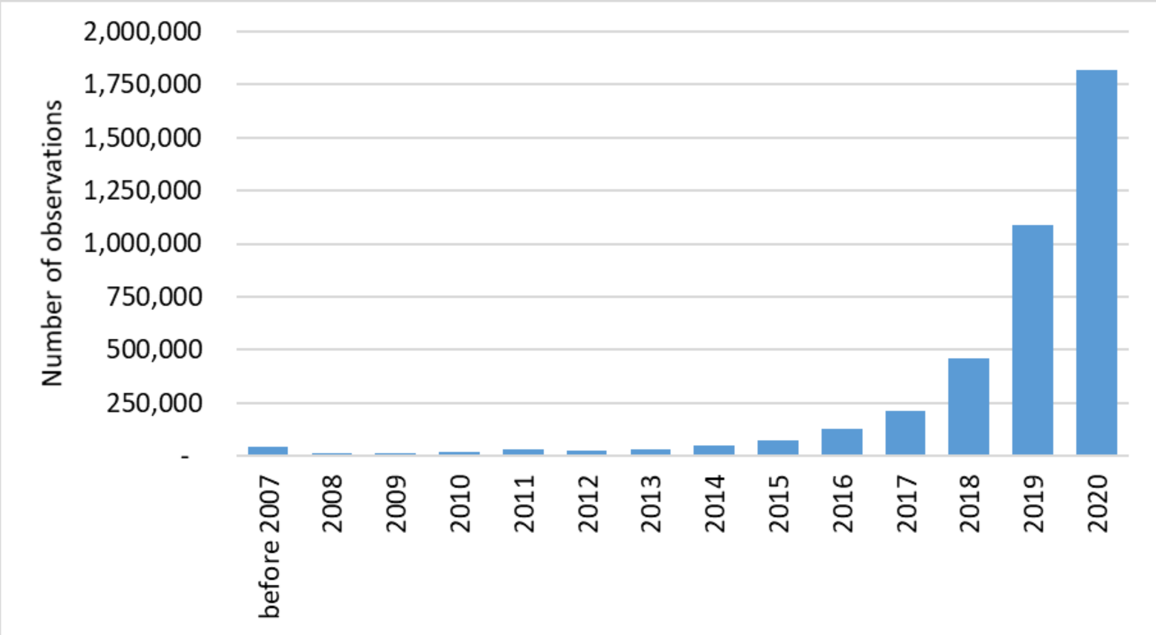


Figure 3.3. Records uploaded in iNaturalist per year in Europe

From the iNaturalist data, 4 011 980 observations were extracted in the EU-27 territory (plus Island - Switzerland - UK – Norway). From the total observations, 36 136 species were recognized. Table 3.2 shows the summary of observations and species per taxon in Europe. Users recorded species both inside and outside FUAs, 56.1 % of observations outside and 46.7 inside FUAs (Table 3.3). So 46.7% of the Inatuarlist data is observed on 20.67% of the study area. Figure 3.4 presents a map with the observations per FUA.

Table 3.2. Observations and species per taxon in Europe.

	Observations		Species	
Taxon	number	%	number	% - species
Plants	1 534 117	38.2	11 676	32.3
Insects	1248 821	31.1	14 571	40.3
Birds	673 625	16.8	1 256	3.5
Fungi	128 271	3.2	3 099	8.6
Mammals	76 208	1.9	299	0.8
Spiders	72 459	1.8	1 102	3
Reptiles	69 675	1.7	338	0.9
Molluscs	69 540	1.7	1 220	3.4
Amphibians	58 084	1.4	130	0.4
Other	53 460	1.3	1 780	4.9
Fishes	27 720	0.7	665	1.8
Total	**4 011 980**		**36 136**	

Table 3.3. Observations (count and percentage) inside and outside functional urban areas in Europe.

		Number observations	**% - observations**	**Number species**	**% - species**
Functional Urban Areas	Outside	2 137 940	53.3	30 955	55.25
	Inside	1 874 040	46.7	25 069	44.74

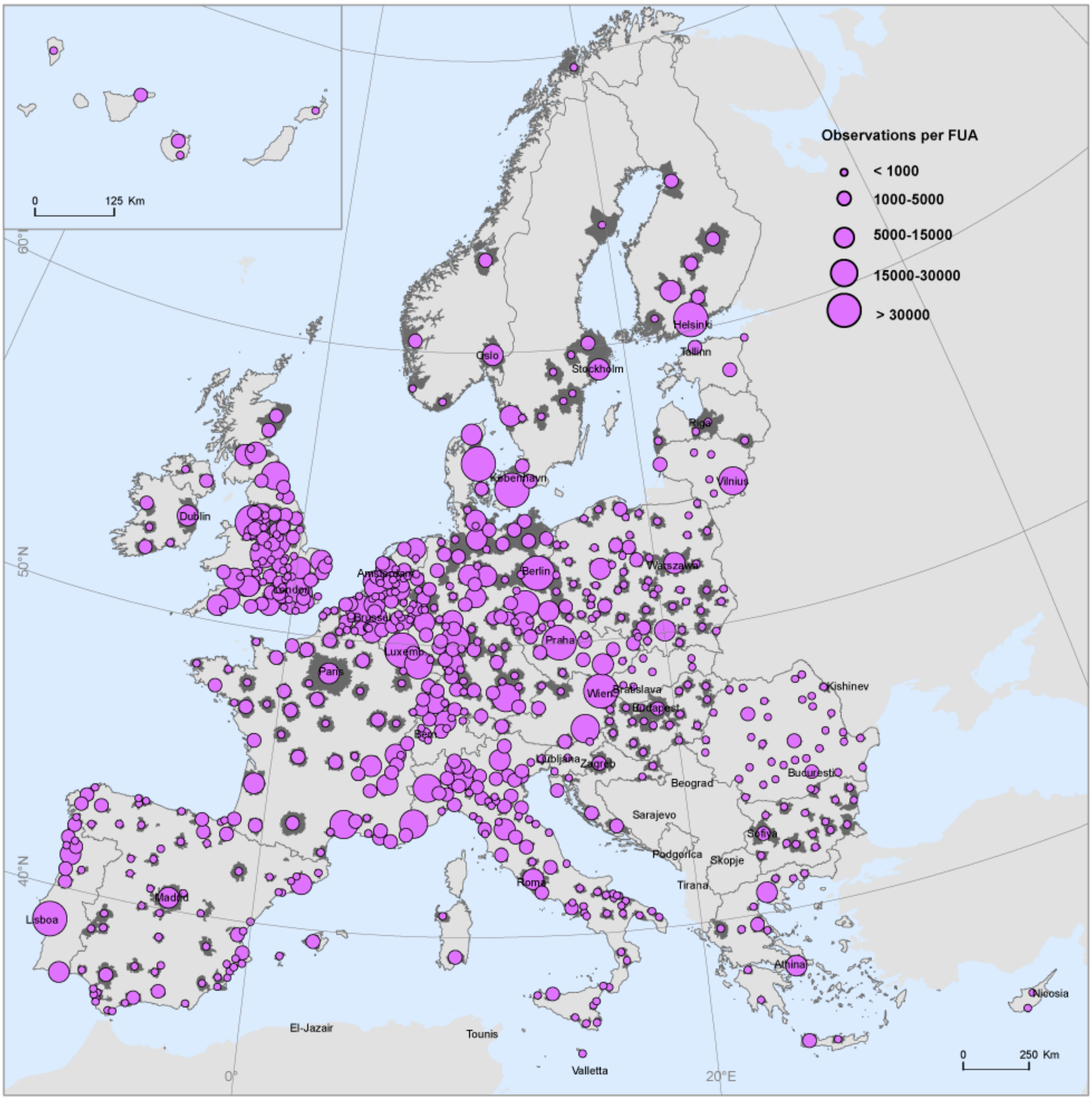


Figure 3.4. Map of observations per functional urban area

Insects, plants and birds were the most observed taxa both inside and outside FUAs (as shown in Table 3.4 and Figure 3.5). Of the total observations inside FUAs **18.1%** were plants, **14.82%** insects, **8.11%** birds.

Table 3.4. Taxonomic coverage of data collection in Europe, inside and outside FUAs (number and percentage of observations per taxa).

		Observations (%)		
Urban	**Taxa**	**Number**	**On total observations**	**On total observations per taxon**
Outside FUA	Fishes	21786	0.54	78.59
	Other	36907	0.92	69.04
	Amphibians	36285	0.90	62.47
	Reptiles	44278	1.10	63.55
	Molluscs	40336	1.01	58.00
	Mammals	46033	1.15	60.40
	Spiders	37128	0.93	51.24
	Fungi	64853	1.62	50.56
	Birds	348241	8.68	51.70
	Insects	654266	16.31	52.39
	Plants	807827	20.14	52.66

		Observations (%)		
Urban	**Taxa**	**Number**	**On total observations**	**On total observations per taxon**
Inside FUA	Fishes	5934	0.15	21.41
	Other	16553	0.41	30.96
	Amphibians	21799	0.54	37.53
	Reptiles	25397	0.63	36.45
	Molluscs	29204	0.73	42.00
	Mammals	30175	0.75	39.60
	Spiders	35331	0.88	48.76
	Fungi	63418	1.58	49.44
	Birds	325384	8.11	48.30
	Insects	594555	14.82	47.61
	Plants	726290	18.10	47.34

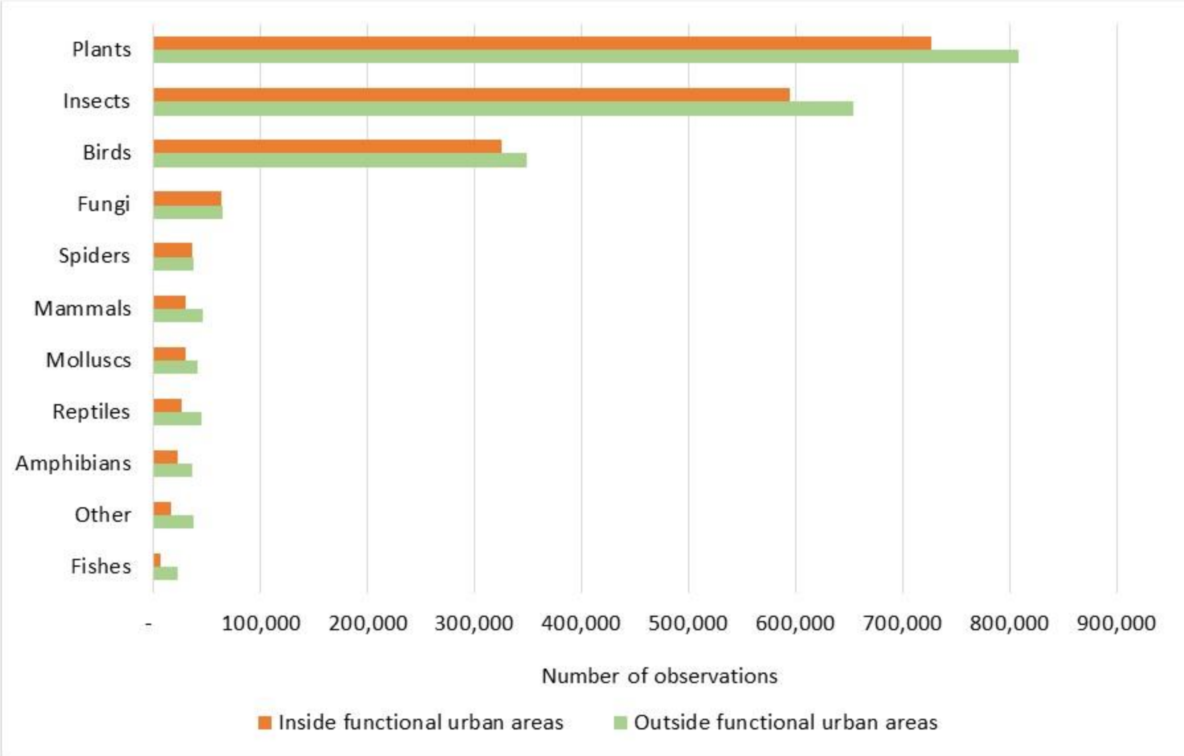


Figure 3.5. Observations per taxon in Europe inside and outside FUAs

3.4.2 Species abundance

In this first exploratory study, abundance is represented by the number of observations per species and analysed using the relative species abundance distribution (SAD) and octave plots.

A SAD is a description of the abundance (number of individuals observed) for each different species encountered within a community. It is one of the most basic descriptions of an ecological community. SADs allow to compare between communities, also if they have few or no species in common and look at the relative proportion of rare, intermediate and common species (Matthews & Whittaker, 2015; McGill et al., 2007). Here the SAD is visually presented using the rank-abundance diagram (RAD). Octave plots are histograms showing the species abundance distribution for one or more samples.

Figure 3.6 shows the SAD of all species observed inside FUAs. The distribution presents few common, or most observed species and many rare or less observed. Considering all the taxa, 21369 species were observed up to 64 times (7121 only once); 2401 were observed between 128 and 512 times and 703 species had more than 1024 observations.

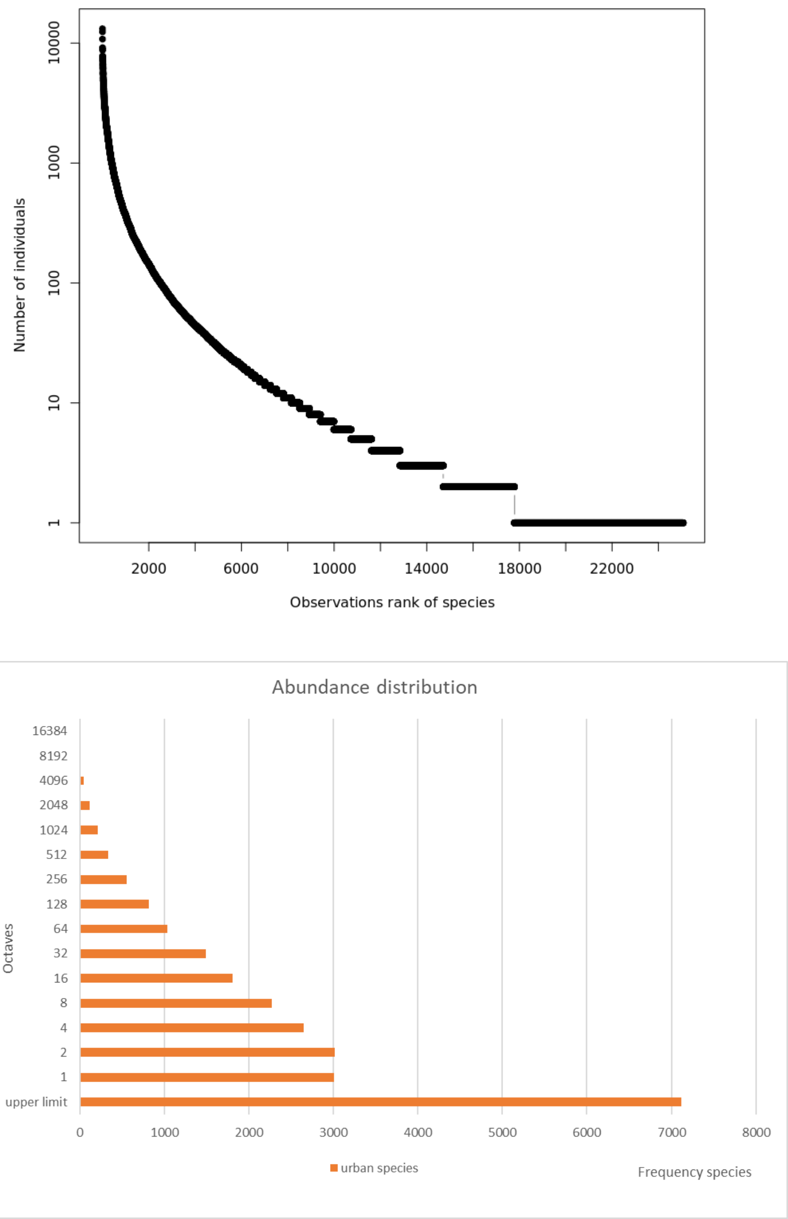


Figure 3.6. SAD inside FUAs, represented using RAD (left) and Octave plots (right).

Annex 2 shows the Species Abundance Distributions of groups of species observed inside FUAs.

Table 3.5. Observations per species grouped by taxa, reported in absolute and relative terms.

A

observations	insects	plants	fungi	birds	spiders
1-8	5765	3908	1397	347	449
16-64	2878	2156	577	254	224
128-512	1402	1175	222	202	99
1024-8192	402	517	45	147	27
16384-32768	13	15	0	18	0

B

observations	insects	plants	fungi	birds	spiders
1-8	55.10	50.29	62.34	35.74	56.20
16-64	27.51	27.74	25.75	26.16	28.04
128-512	13.40	15.12	9.91	20.80	12.39
1024-8192	3.84	6.65	2.01	15.14	3.38
16384-32768	0.12	0.19	0.00	1.85	0.00

The analysis allows to explore which taxon has the higher proportion of rare species.

In absolute numbers, insects (5765 rare species), plants (3908) and fungi (1397) are the taxa with the higher number of rare species (see table Table 3.5. A) Relatively to each taxon, the share of rare species observed is higher in fungi (62.3%), spiders (56.20), insects (55.1%) and plants (50.29%) (see Table 3.5. B). The different order of magnitude among observations per species is presented in figure 3.6, 3.7., and 3.8.

Of the 25069 observed species, 130 species were observed in the majority of cities (more than 300), see Table 3.6 and Figure 3.7; which, following Leong and Trautwein 2019, who analysed iNaturalist data in 14 cities in the US, we define as “cosmopolitan species”.

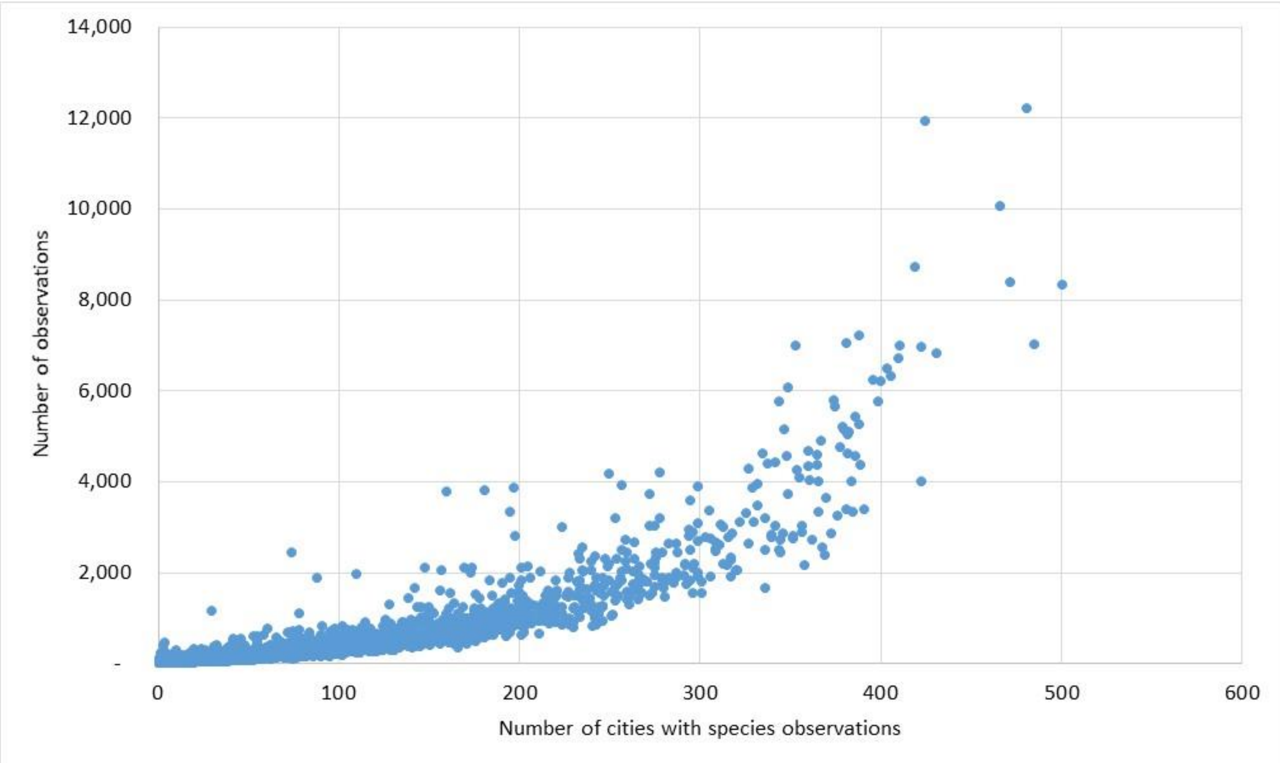


Figure 3.7. Distribution of observations per number of cities.

Table 3.6. Cosmopolitan species per classes of cities rank

Number of cities	Number of species	Total number of observations
>300	130	536346
300-200	232	380183
200-100	621	404054
<100	24086	553457

Plants, insects and birds represented, all together, 92.2% of the species (with 494575 observations).

Table 3.7. Distribution of the 130 cosmopolitan species, per taxa ordered per number of species, classified according to the population trend reported from the IUCN red-list.

	Number of species					
	Population trend (IUCN)					
Taxa	**Decreasing**	**Increasing**	**Stable**	**Unknown**	**Not in the list**	**Total**
Plants	1		28	2	16	47
Insects		1	20	1	17	39
Birds	5	13	9	1	3	31
Fungi					3	3
Mammals		1	2			3
Spiders					3	3
Amphibian			2			2
Mollusks			2			2
Total	6	15	63	4	42	130

Table 3.7 shows the distribution of the species classified according to the population trend reported in the IUCN –red list. 63 species (48.5%) are classified as stable (but 42 of them (32.%) are not included in the IUCN-red list). Birds show the higher variability, with 5 species with a decreasing population trend (16% among birds species), 13 species with a decreasing population trend (41%. among birds species) and 9 declared having a stable population trend (30% among birds species).

Table 3.8. The top 10 plant species selected from the cosmopolitan species list. * species not included in the IUCN-red list for Europe.

Name	Number of cities (observations)	IUCN category	Population trend	Suitable for pollinators
Bellis perennis (common daisy)	461 (7225)	*	*	yes
Plantago lanceolata (ribwort plantain)	411 (4879)	Least Concern	Stable	
Ficaria verna (lesser celandine)	410 (5669)	Least Concern	Stable	
Cichorium intybus (common chicory)	408 (3407)	Least Concern	Stable	
Sambucus nigra (elderberry)	407 (4923)	Least Concern	Stable	
Achillea millefolium (common yarrow)	405 (5564)	Least Concern	Stable	yes
Hedera helix (common ivy)	404 (5217)	Least Concern	Stable	
Geranium robertianum (herb-Robert)	401 (6150)	*	*	yes
Urtica dioica (common nettle)	398 (6289)	Least Concern	Stable	
Trifolium pratense (red clover)	396 (3955)	Least Concern	Stable	yes

Among plants, see table 3.8, the population trend of the first 10 observed cosmopolitan species are stable. All species are classified as very low level threat (Least Concern). Four out of ten species are plants suitable for pollinators. Three species are commonly used for their officinal properties (ribwort plantain, common chicory, common nettle). The common nettle, as an example, has a long history of use as a source for traditional medicine and provides an important habitat for beneficial insects and may have a role to play in enhancing conservation biological control in agricultural crops.

Table 3.9. The top 9 insect species selected from the cosmopolitan species list. * species not included in the IUCN-red list for Europe.

Name	Number of cities (observations)	IUCN category	Population trend	Suitable for pollinators
Apis mellifera (honey bee)	527 (8732)	Data Deficient	Unknown	yes
Vanessa atalanta (red admirals)	512 (7332)	Least Concern	Stable	yes
Coccinella septempunctata (seven-spot ladybird)	503 (8983)	*	*	no
Pararge aegeria (speckled wood)	450 (7426)	Least Concern	Stable	yes
Harmonia axyridis (harlequin ladybird)	448 (12432)	*	*	not
Vanessa cardui (painted lady)	448 (4148)	Least Concern	Stable	yes
Aglais io (peacock butterfly)	435 (7187)	Least Concern	Stable	yes
Pyrrhocoris apterus (firebug)	426 (6582)	*	*	no
Episyrphus balteatus (marmalade hoverfly)	410 (4635)	*	*	yes

Among insects, the population trend for the first 10 observed cosmopolitan species are stable, see table 3.9. All species are classified as very low level threat (Least Concern). 6 out 10 insect cosmopolitan species are pollinators and 2 are ladybirds. Ladybirds are also used for crop pest control: *Coccinella septempunctata* (seven-spot ladybird) and *Harmonia axyridis* (harlequin ladybird). The seven-spot ladybird, is a widespread species originally native from Europe, Asia and Northern Africa. The harlequin ladybird is a species of Asian origin, has been used as a biological control agent against aphids worldwide. This latter is a habitat generalist that might reduce native biodiversity by competing and monopolizing resources (https://www.cabi.org/).

The painted lady (*pieris rapae*), observed in 448 cities, is a very serious pest of crucifers in Europe, North America, Japan, China, Australia and New Zealand. Unless controlled, damage from painted lady larvae can result in total crop loss (https://www.cabi.org/).

Table 3.10. The top 10 bird species selected from the cosmopolitan species list. * species not included in the IUCN-red list for Europe.

Name	Number of cities (observations)	IUCN category	Population trend	Water bird
Anas platyrhynchos (mallard)	511 (13194)	Least Concern	Stable	yes
Turdus merula (common blackbird)	497 (10804)	Least Concern	Increasing	
Ardea cinerea (grey heron)	444 (9168)	Least Concern	Decreasing	yes
Erithacus rubecula (robin redbreast)	436 (7549)	Least Concern	Increasing	
Pica pica (Eurasian magpie)	432 (6963)	Least Concern	Stable	
Passer domesticus (house sparrow)	427 (7176)	*	**	
Parus major (great tit)	421 (6659)	Least Concern	Increasing	
Columba livia domestica (Feral pigeon)	418 (6123)	*	*	
Columba palumbus (common wood pigeon)	415 (7804)	Least Concern	Increasing	
Motacilla alba (white wagtail)	412 (3772)	Least Concern	Unknown	yes

** decreasing population trend in the past.

Among birds, all species are classified as very low level threat (Least Concern). The population trend for 2 out of 10 observed cosmopolitan birds are stable. The population trend of 3 out of 10 is increasing and one (the grey heron) is decreasing, see table 3.10. Three out of ten species live close to water (the mallard, the grey heron and the white wagtail).

Among the 31 birds observed in the majority of FUAs, 5 are classified having a decreasing population trend: the *Ardea cinerea, Sturnus vulgaris, Hirundo rustica, Fulica atra, Falco tinnunculus*. A part for the *Fulica atra* that is considered a “Near Threatened” species the others are not in danger. They were observed in more than 350 cities with 27825 observations.

Table 3.11. Highest ranking species for mammals, molluscs, amphibian, spiders, and fungi selected from the cosmopolitan species list. * species not included in the IUCN-red list for Europe.

Taxa	Name	Number of cities (observations)	IUCN category	Population trend
Mammals	*Erinaceus europaeus* (European hedgehog)	365 (2909)	Least Concern	Stable
	Capreolus capreolus (roe deer)	332 (2936)	Least Concern	Increasing
	Sciurus vulgaris (red squirrel)	305 (3774)	Least Concern	Stable
Mollusks	*Cornu aspersum* (garden snail)	353 (3724)	Least Concern	Stable
	Cepaea nemoralis (grove snail)	321 (2856)	Least Concern	Stable
Amphibians	*Bufo bufo* (common toad)	384 (5079)	Least Concern	Stable
	Rana temporaria (common frog)	321 (3621)	Least Concern	Stable
Spiders	*Araneus diadematus* (european garden spider)	404 (3563)	*	*
	Argiope bruennichi (wasp spider)	379 (2405)	*	*
	Pisaura mirabilis (nursery web spider)	323 (1996)	*	*
Lichens and fungi	*Xanthoria parietina* (maritime sunburst lichen)	350 (3540)	*	*
	Coprinus comatus (shaggy ink cap)	340 (2187)	*	*
	Amanita muscaria (fly amanita)	322 (3181)	*	*

3.4.3 Targeted species

Targeted species are groups of species of particular interest. They allow a first understanding of what type of biodiversity can cities host, as an example, from a conservation point of view the maintenance of threatened species in a city is more valuable than the occurrence of non-native invasive species.

For this purpose, four groups of species were selected: Invasive Alien Species (IAS) of Union concern; species listed in the IUCN red list; species protected by the Habitat Directive and by the Birds directive.

3.4.3.1 Invasive Alien Species of Union Concern.

IAS are species that are introduced into a natural environment where they are not normally found, with potentially serious negative consequences for their new environment. The European Parliament and the Council adopted the EU Regulation no. 1143/2014 on the prevention and management of the introduction and spread of IAS, which entered into force on 1 January 2015. The IAS Regulation gives priority at European level to a subset of IAS, named as IAS of Union concern (Art. 4 "the Union list", hereinafter IAS of Union concern). Species are included in this list because they can cause such a significant damage in Member States (MS) justifying the adoption of dedicated measures at Union level (Tsiamis et al. 2017).

Previous European level analyses pointed out the impact by IAS on urban ecosystems (Maes et al. 2019; Maes et al. 2020). One of the key messages of the EU wide ecosystems assessment, published in 2020, is that IAS are observed across all ecosystems, but they have spread mostly in urban areas and grasslands with 69% of invaded areas represented by urban ecosystem type.

Of the 66 IAS of Union Concern, 35 were observed inside FUAs, with 9623 observations. Table 3.11 shows the species ranked by number of cities where they were observed and number of total observations. Table 3.12 presents a short description of the first 5 ranked species, 4 of which are also part of the cosmopolitan species group.

Table 3.11. IAS of union concern observed inside FUAs.

Type (plant/animal)	Realm	Name	Number of FUAs (observations)
Animal	Freshwaters	*Trachemys scripta* (Red-eared terrapin)	159 (751)
Animal	Terrestrial	*Myocastor coypus* (Coypu)	132 (1300)
Animal	Freshwaters	*Procambarus clarkii* (Red swamp crayfish)	101 (490)
Animal	Terrestrial	*Sciurus carolinensis* (American grey squirrel)	85 (2732)
Animal	Freshwaters	*Lepomis gibbosus* (Pumpkinseed)	59 (163)
Animal	Freshwaters	*Pacifastacus leniusculus* (Signal crayfish)	54 (139)
Animal	Terrestrial	*Ondatra zibethicus* (Muskrat)	48 (140)
Animal	Terrestrial-Freshwaters	*Procyon lotor* (Raccoon)	29 (189)
Animal	Marine, Freshwaters	*Eriocheir sinensis* (Chinese mitten crab)	25 (68)
Animal	Terrestrial-Freshwaters	*Threskiornis aethiopicus* (Sacred ibis)	23 (114)
Animal	Terrestrial	*Muntiacus reevesi* (Muntjac deer)	19 (132)
Animal	Freshwaters	*Pseudorasbora parva* (Stone moroko)	17 (32)
Animal	Terrestrial-Freshwaters	*Nyctereutes procyonoides* (Raccoon dog)	13 (26)
Animal	Terrestrial-Freshwaters	*Oxyura jamaicensis* (Ruddy duck)	11 (26)
Animal	Terrestrial	*Vespa velutina nigrithorax* (Yellow-legged hornet)	7 (10)
Animal	Freshwaters	*Lithobates catesbeianus* (North American bullfrog)	6 (37)
Animal	Freshwaters	*Perccottus glenii* (Amur sleeper)	2 (2)
Animal	Terrestrial	*Callosciurus erythraeus* (Pallas's squirrel)	1 (12)
Animal	Terrestrial	*Corvus splendens* (House crow)	1 (6)
Plant	Terrestrial	*Impatiens glandulifera* (Himalayan balsam)	276 (3205)
Plant	Terrestrial	*Heracleum mantegazzianum* (Giant hogweed)	111 (571)
Plant	Terrestrial	*Lygodium japonicum* (Vine-like fern)	37 (68)
Plant	Terrestrial	*Ailanthus altissima* (Tree of heaven)	34 (73)
Plant	Freshwaters	*Myriophyllum aquaticum* (Parrot's feather)	27 (53)
Plant	Freshwaters	*Elodea nuttallii* (Nuttall’s pondweed)	25 (30)

Plant	Freshwaters	*Hydrocotyle ranunculoides* (Floating pennywort)	13 (99)
Plant	Terrestrial	*Gunnera tinctoria* (Giant rhubarb)	12 (42)
Plant	Terrestrial	*Acacia saligna* (Golden wreath wattle)	12 (36)
Plant	Terrestrial	*Heracleum sosnowskyi* (Sosnowski's hogweed)	9 (34)
Plant	Freshwaters	*Lagarosiphon major* (African elodea)	7 (20)
Plant	Freshwaters	*Ludwigia peploides* (Floating primrose-willow)	5 (8)
Plant	Freshwaters	*Ludwigia grandiflora* (Water primrose)	3 (3)
Plant	Freshwaters	*Myriophyllum heterophyllum* (Broadleaf watermilfoil)	3 (3)
Plant	Terrestrial	*Cardiospermum grandiflorum* (Balloon vine)	2 (4)
Plant	Terrestrial	*Heracleum persicum* (Persian hogweed)	1 (1)

Table 3.12. Detailed description of the 4 species that were observed the most inside FUAs. (source: "Invasive Alien Species of Union concern", EU 2017

https://ec.europa.eu/environment/nature/pdf/IAS_brochure_species.pdf).

Species	**Description** **Pict origin reason of introduction and reason of danger**	
Impatiens glandulifera		The Himalayan balsam is native to the foothills of the Himalayas from north-west Pakistan to northern India. A tall, attractive, annual herb, it was first introduced as a garden plant in the early 19th century and has since escaped in the wild. The species spreads rapidly by means of explosive seed heads and out-competes native species, particularly along river banks, floodplain forests and wet meadows
Trachemys scripta		The slider is a large freshwater turtle, native to Eastern and Central US. In the past, over 50 million individuals have been imported into Europe for the pet trade. Many have since escaped or been deliberately released into the wild. The species is now present in 22 Member States. The slider is a serious threat to endangered populations of indigenous turtle species, such as the European pond turtle *Emys orbicularis* or the Mediterranean turtle, *Mauremys leprosa* because it competes for basking and nesting sites. With its voracious appetite, It disturbs aquatic habitats and poses

		a human health risk, being a possible reservoir for salmonella.
Myocastor coypus (coypu)		The coypu or nutria is a large rodent from South America. It was first introduced into Europe in the 19th century for fur farming. While farming has been abandoned in the meantime, the species has since colonised coastal marshes, swamps and other wetland areas in no less than 19 Member. Considered a major pest across much of the EU, the coypu is estimated to cost over 65 million euros a year in economic damage and management costs. Because of its voracious appetite, it severely disrupts the natural habitats and alters the composition of local plant communities. Additionally, it degrades river banks and irrigation systems through its extensive burrowing activities and has a major impact on agriculture.
Heracleum mantegazzianum		The giant hogweed is a more than 2 meters high flowering plant native to the Western Greater Caucasus. It was first introduced into Europe as an ornamental plant but has since spread rapidly via wind and water to a wide range of semi-natural or degraded habitats. The species' appearance and environmental impacts are similar to those of the Persian hogweed and the Sonowski's hogweed. It is now well established in 20 Member States. In these countries, it has become a major pest capable of invading and completely transforming the landscape. The plant is highly phototoxic: contact with its juice can cause major skin inflammations and even severe burns upon exposure to sunlight.
Procambarus clarkii		The red swamp crayfish is a highly adaptable freshwater crayfish, native to South-Eastern USA. Originally introduced into Europe for aquaculture, it has since escaped into the wild and is now present in 10 Member States. Along with other invasive alien crayfish, the red swamp crayfish is responsible for the dramatic decline of the native crayfish *Austropotamobius pallipes* to which it transmits a lethal fungal disease. In addition, it is known to change the structure of entire wetland habitats by disrupting the native species composition and it causes significant damage to drainage and irrigation systems, especially in rice-growing areas.

3.4.3.2 IUCN red list species

The IUCN Red List Categories and Criteria are a system for classifying species at high risk of global extinction.

They are objective, can be applied consistently by different people and provide a clear guidance on how to evaluate different factors which affect the risk of extinction. Moreover, they provide a system which facilitates comparisons across widely different IUCN taxa. (2012). Figure 3.8 shows the Red List system declined according to the IUCN Red List Criteria developed at Regional and National Levels; in this context, the word regional is used to indicate "*any sub-global geographically defined area, such as a continent, country, state, or province*" (IUCN, 2010).

When applied at national or regional levels it must be recognized that a global category may not be the same as a national or regional category for a particular taxon. Within any region there will be taxa with different distribution histories, ranging from those that are indigenous (native to the area), and have been there since pre-human settlement, to those introduced more recently (IUCN, 2010).

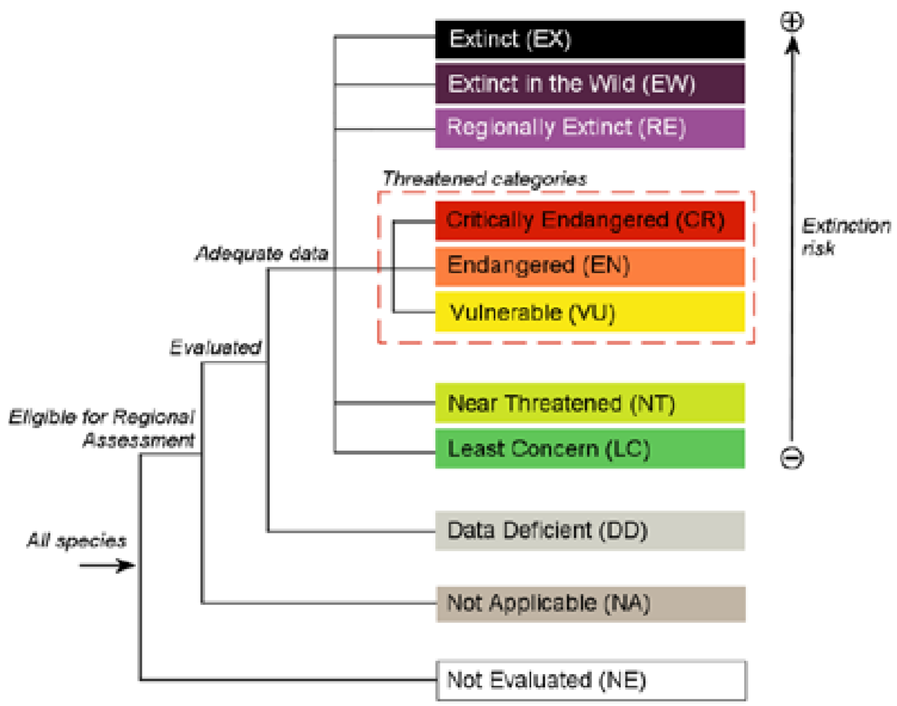


Figure 3.8. the Red List categories regional structure (source: Figure 2 p.14. IUCN. (2010).

Table 3.13. Species listed in the IUCN red list species identified inside FUAs.

IUCN category	IUCN species observed	Observations inside FUA	Share over the IUCN species observed inside FUA	Share over the total IUCN listed species
Regionally Extinct (RE)	1	46	0.02	0.01
Critically Endangered (CE)	27	141	0.66	0.18
Endangered (EN)	95	689	2.32	0.63
Vulnerable (VU)	149	10752	3.63	0.98
Near Threatened (NT)	245	24890	5.98	1.62
Least Concern (LC)	3346	854923	81.61	22.06
Data Deficient	200	13290	4.88	1.32
Not Applicable	37	1774	0.90	0.24

Table 3.13 shows the share, per IUCN category, of species listed under the IUCN red list identified inside European FUAs. Here, 3863 species classified as under different extinction risk levels were observed (906505 observations) inside FUAs (all species listed under the IUCN red list category recognised inside FUAs are reported in Annex 1, Table 1). The species classified as least concerned were 3346 and 517, respectively 81,61% and 12.6% of the IUCN species observed inside FUA, were classified as exposed to different and more serious levels of vulnerability.

One Regionally Extinct species, the northern bald ibis (*Geronticus eremita*) was also observed in Europe with a total of 163 observations, 46 (28%) of which inside FUAs. A taxon is labelled as Regionally Extinct when there is no reasonable doubt that the last individual potentially capable of reproduction within the region has died or has disappeared from the wild in the region, or when, if it is a former visiting taxon, the last individual has died or disappeared in the wild from the region." (see IUCN, 2010).

The northern bald ibis was observed in Austria, Italy and Germany thanks to the “Reason for Hope” EU project (LIFE + Biodiversity) which aims to reintroduce the species in Europe.

4 Analysis of urban ecosystem services

4.1 The role of urban green infrastructure in mitigating urban heat island effect

4.1.1 Key findings

Urban heat islands have a detrimental impact on human health and quality of life in cities. Vegetation in cities can mitigate the impacts of urban heat island by cooing down cities. A model was applied to estimate the effect of urban and peri-urban vegetation in temperature reduction. Green infrastructure in European cities can cool urban microclimate by 1.6°C on average and up to 4°C.

4.1.2 Introduction

The Urban Heat Island (UHI) effect can be described as a distinct urban climate, characterized by higher temperatures in densely built-up areas than in the surrounding areas (Oke, 1982). It is caused by the anthropic alteration of the natural environment: impervious surfaces, due to their higher heat capacity and conductivity, trap more solar radiation with consequent increase in temperature. In addition to this, anthropogenic activities such as heating and transportation, further increase the heat released in urban areas, if compared to the natural landscape (Zhou et al., 2017). It is known that UHI exerts a detrimental impact on human health and quality of life in cities (Koppe et al., 2004), particularly during heat waves. Furthermore, it has been observed an increase in the frequency and severity of heat waves in the last decade (Mishra et al., 2015). It is expected that this phenomenon will increase further in the future due to climate change, and it is thought that these changes are mainly driven by higher mean temperature rather than by temperature variability (Ballester et al. 2010; Lhotka et al., 2018). Heat waves are estimated to increase considerably in Europe by the end of the century, with a 5°C projected increase in peak temperatures (Fischer and Schar, 2010).

The extent and distribution of UHI can be estimated both through air temperature and through Land Surface Temperature (LST) data. The first approach measures the temperature from the ground up to tree height, the so-called "canopy layer" (Schwarz et al., 2012), usually with meteorological monitoring stations. The second approach measures the temperature of the land surface, retrieved through satellite measurements. Air temperature measurements can provide representative and temporally continuous UHI information, but the presence of weather stations on the territory is often limited. On the other hand, estimating LST allows a spatially explicit analysis of UHI (Clinton and Gong, 2013). LST-based studies are increasingly common in urban temperature and UHI research, due to the practical applications, immediacy and increasing availability of sensors at no cost, particular when there is the necessity to analyse temperature variations at regional or even global scale (Ottlè et al., 1992).

In this context, the deployment of urban Green Infrastructure (GI), is recognized as one of the most important strategies to counteract UHI (Saaroni et al., 2018), thanks to the microclimate regulation effect of vegetation. Microclimate regulation is based on two main processes: shading effect, which consists in the interception of the solar radiation by leaves, and evapotranspiration, which converts it into latent heat. The cooling capacity can vary largely, being different between vegetation types such as grass, shrubs and trees, reaching the maximum effectiveness with urban forests (Yoshida et al., 2015).

Several studies have highlighted the benefits of patches of vegetation inside urban areas to cool summer temperatures. Bartesaghi-Koc et al., (2020) showed that in Sidney, Australia, different types of urban GI can cool summer temperatures up to 12 °C, considering a combination of water and vegetated surfaces, whereas large temperature reductions (up to 8°C) were achieved by a mixture of irrigated grasses and shrubs and a dense tree aggregation. Furthermore, Venter et al. (2020), estimated that each city tree in Oslo, Norway, has the potential to mitigate heat exposure for one citizen by one day. Since the enhancement of GI represents an effective nature-based solution to reduce UHI, this study aims to estimate the role of urban and peri-urban vegetation in mitigating air temperature. For this purpose, a spatially explicit model which couples both air temperature and LST measurements has been developed.

4.1.3 Data and methods

The model has been run entirely in a Python environment. It has been applied and run separately for 603 European Functional Urban Areas (FUA) in EU 27 (Eurostat, 2020), using a basic spatial unit of 100 m^2, between July and August (year 2018). Some FUA have been excluded from the analysis due to inadequate or lacking data. It has been noticed that in some agricultural and bare soil areas, LST values were extremely high. This can be due to the fact that at the time of the satellite passage (around 10 a.m.), these land cover types heat up faster and more intensely due to their higher thermal conductivity. Since these values could introduce a bias in the temperature estimation, it has been decided to exclude those areas from the analysis. Also, since the focus of the study is the temperature reduction on land from vegetation, also water bodies have been excluded.

The biophysical model is based on the methodology reported in Heris et al. (in press) and comprises 5 steps:

1. First, Landsat 8 OLI/TIRS images (median July-August 2018) have been used to compute Land Surface Temperature (LST) through a single channel algorithm developed by Parastatidis et al. (2017).
2. Then, for every city, a linear regression model, trained on LST data, has been developed to estimate the impact of trees on LST reduction at pixel level. The model uses tree cover density from Copernicus High Resolution Layer, and the Normalized Difference Vegetation Index (NDVI) retrieved from Landsat 7 images as independent variables. Before deciding to use tree cover and NDVI as predictor variables, other additional covariates have been tested, such as elevation, imperviousness, distance from water bodies, soil and land cover types, moisture index, leaf area index. Furthermore, also other machine-learning algorithms, in particular random forests and decision trees have been explored. Nevertheless, a simple linear regression with two explanatory variables has been identified as the most suitable approach in a cost-benefit perspective. To increase the algorithm's efficiency, the raster data (pixels) have been converted to Numpy arrays. Then, a value of zero was assigned to tree cover and NDVI to estimate LST in a no-vegetation scenario.
3. In analysing the relationship between vegetation and air temperature, LST has proven to be a suitable mediator variable between the two. Therefore, after that, a second regression model, trained with an air temperature dataset, allowed to estimate maximum air temperature on the basis of LST.
4. The two models have been coupled to estimate the impact of trees on air temperature reduction: the second regression model has been then used to estimate air temperature for the no-vegetation scenario.
5. It was then possible to estimate, for each FUA, the average cooling capacity of vegetation (°C), defined as the difference between the temperature of vegetated areas and the temperature of the same area in a no-vegetation scenario.

4.1.3.1 LST retrieval

The process to estimate LST from satellite data relies on the availability of thermal infrared sensors. Satellites such as Landsat 5 TM, 7 ETM+ and 8 OLI/TIRS are suitable for this purpose. LST data have been acquired through the Google Earth Engine (GEE) platform, using a single channel algorithm developed by Parastatidis et al., (2017). The algorithm analyses Landsat thermal bands and relies on different emissivity sources: i) a global emissivity map derived from ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) data at a 100 m spatial resolution; ii) the MODIS (Moderate Resolution Imaging Spectroradiometer) daily LST/emissivity product (1 km spatial resolution); and iii) vegetation fraction-based emissivity, estimated from NDVI (Normalized Difference Vegetation Index). In the GEE environment, the median summertime LST (1st July - 31st August 2018) has been calculated, extracted in correspondence of the FUA boundaries and downloaded.

4.1.3.2 Air temperature dataset

Because of the lack of high-resolution air temperature datasets at European scale (global scale models such as CHELSA were highly correlated with elevation), and due to the insufficient coverage of the existing weather stations network, a dataset elaborated by the University of Colorado, derived from NOAA (National Oceanic and Atmospheric Administration) weather stations network daily measurements in the U.S. has been used to build a predictive model of the relationship between surface temperature and air temperature. The dataset consists in more than 6,500 records of maximum summertime air temperature (June 15th to August 15th) from weather stations, comprises their latitude and longitude, and the average surface temperature of each station's neighbourhood (using a buffer of 1 km). Assuming that the relationship between air temperature and surface temperature is constant, this model has then been used to predict air temperature from surface temperature of the EU FUAs.

4.1.3.3 Population data

The GHS population grid, derived from EUROSTAT census data (2011) and ESM R2016 population density dataset, depicts the distribution and density of residential population, expressed as the number of people per cell. It has been selected to compute the benefit received from urban dwellers of the temperature mitigation service. The benefit, currently under investigation, is being computed as the share of population residing in areas with different degrees of cooling, which can be expressed with different levels (low, medium, high).

4.1.4 Results

In Figure 4.1, the average cooling (°C) for each FUA can be observed. Proportional circles express population size in core cities. The average cooling for all EU is 1.6°C, which is in line with what reported in other studies (Oke, 1987; Tsiros, 2010). The highest average cooling (above 2°C and up to 4°C) can be observed mainly in continental cities and in some coastal areas, for 31% of the examined cities (Figure 4.2). Around 65% of the cities display an average cooling below 2°C. On the other hand, a cooling below zero has been estimated in 5% of the cities, which are mainly located in coastal areas of southern areas of Spain and Italy. It is known in fact that a negative UHI, i.e. when the temperature difference between urbanized and vegetated areas is negative, can be present especially in arid regions in conditions of atmospheric stability (Alonso et al., 2003; Sobrino et al., 2013) This phenomenon could be the results of a combination of factors: vegetation structure (grassy GI can potentially have a higher temperature than the surrounding, in particular if they are not irrigated, (Potcher et al., 2006; Saaroni et al. (2015)), environmental constraints of the Mediterranean area which can limit evapotranspiration through drought (Fusaro et al., 2015) and the share of shaded surfaces in urbanized cores, where the density and height of buildings is higher (Memon et al., 2009). In fact, it has been observed that in those cities, surface temperature was inversely related with both tree cover and NDVI. Furthermore, the R^2 of the regression model is also low. Figure 4.3 shows the share of FUA area (%) characterized by different cooling intervals (°C) in EU capital cities. Average cooling is largely influenced by the amount of land falling in a certain cooling interval (i.e.: in cities such as Valletta, Stockholm, Nicosia, Lisbon, where average cooling is near zero, a negative UHI characterizes 50% of the land, whereas in cities such as Sofia, Rome, Zagreb and Luxembourg, where the average cooling is higher than 2.5°C, more than 70% of the area shows cooling values over 2°C). This difference is in part due to the amount of green areas surface inside the FUA. It is known in fact, that the extent of GI in an urban area exerts an influence on UHI magnitude (Yu et al., 2017). Figure 4.4. shows the share of tree cover within a sample of cities falling in the five cooling intervals. The difference between cities falling in different cooling intervals is statistically significant for tree cover ($p < 0.05$). This result underlines the importance of the amount of GI in terms of surface extension inside urban areas in the regulation of extreme temperatures.

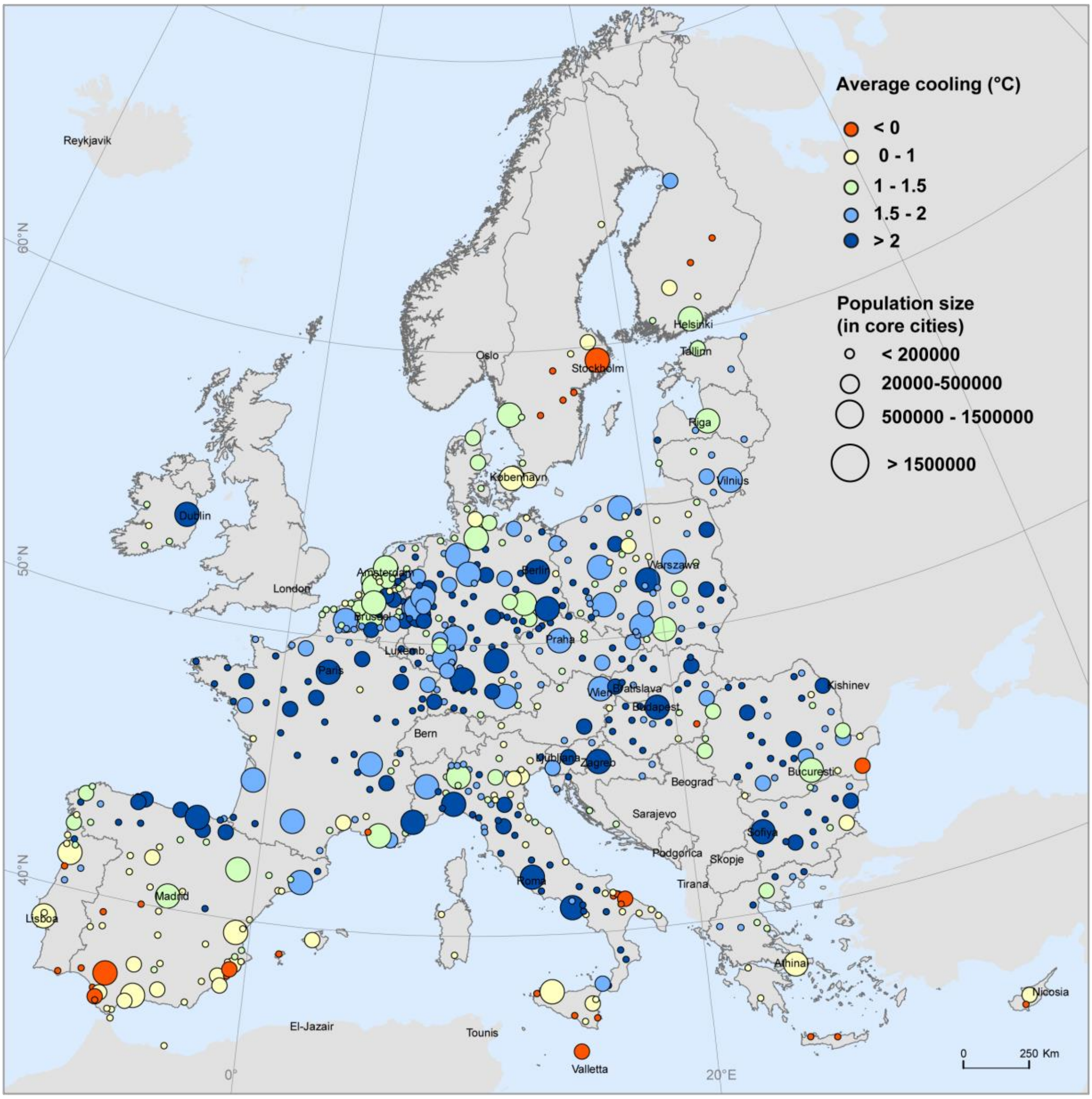


Figure 4.1 Map of average cooling (°C) in EU 27, 2018.

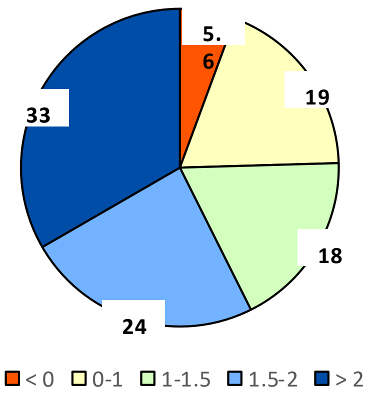


Figure 4.2. Proportion of cities with a different degree of cooling (%).

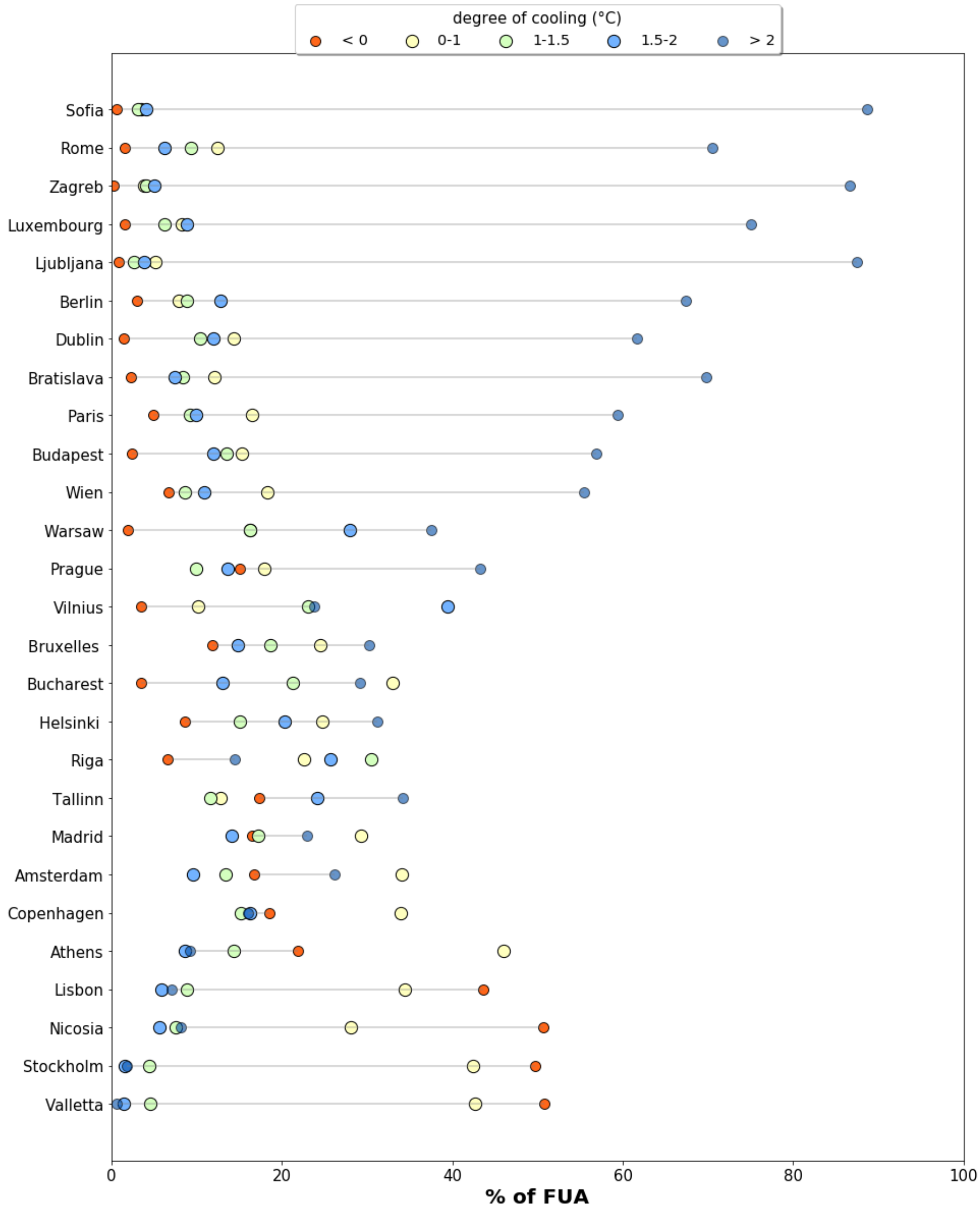


Figure 4.3. Percentage of FUA for different cooling intervals (°C) in EU capital cities. The dots represent the share of FUA (%) for which a certain degree of cooling has been estimated.

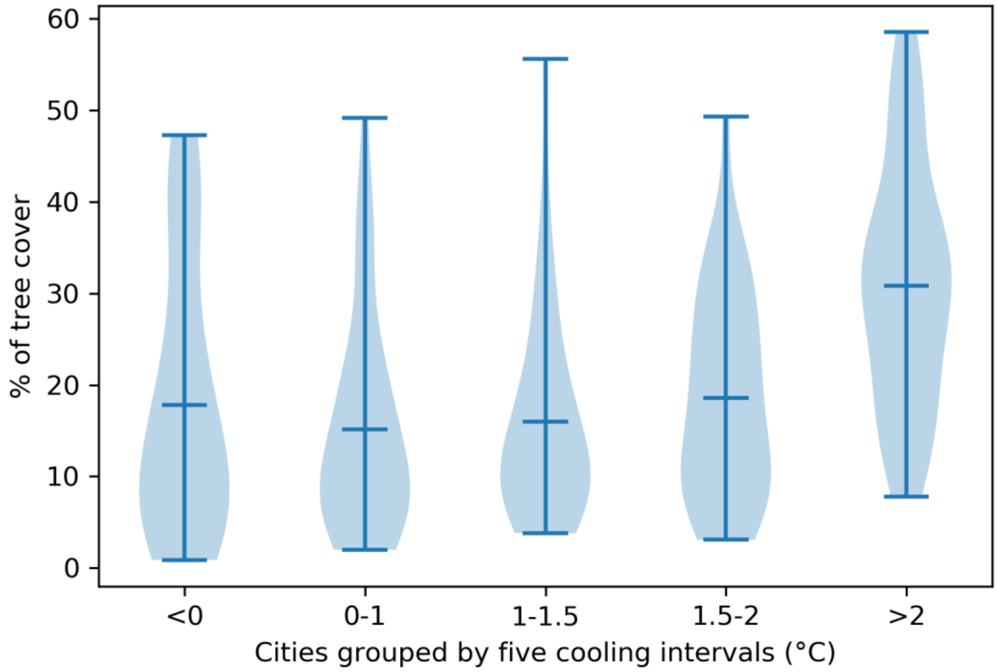


Figure 4.4. Percentage of tree cover in cities grouped by different cooling intervals (°C)

4.2 Urban recreation

4.2.1 Key findings

Contact with nature improves physical and mental health and wellbeing. Urban ecosystems provide several opportunities to improve contact with nature through nature-based recreation activities

Urban ecosystems deliver more than 20 million of hectares of land suitable for recreation. The value represents, in average, 20.5% of the FUAs surface, ranging from a minimum of 0.3% to a maximum of 76.5%.

Opportunities for nature-based recreation increased by 4.4% per decade between 2000 and 2018.

The demand of nature-based recreation increased by 2.6% per decade.

In average citizens have 1.3 possible choices per person for nature-based recreational opportunities available per day. This estimate increased by 1.62% per decade between 2000 and 2018. Nevertheless, in 46% of the FUAs less than 1 possible destination per inhabitant was assigned to citizens in 2018.

In 2018, 43.95% of citizens did not have enough nature-based daily recreation opportunities. Between 2000 and 2018 the unmet demand decreased by 4.5% per decade. However the pattern is not homogeneous at the FUA level with unmet demand having increased in 28.7% of the cities over the same time period.

4.2.2 Introduction

Nature based recreation or "Physical and experiential interactions with natural environment" (CICES, https://cices.eu/) includes a wide list of possible experiences and activities such as biking, boating, climbing, hiking, horseback riding, walking the dog in a nice area, enjoying a local play ground or enjoying an urban park nearby.

ESTIMAP nature-based recreation was developed to map the recreation opportunities available in a given location. The original (Liquete et al., 2016; Paracchini et al., 2014; Vallecillo et al., 2019; Zulian et al., 2013), up to now applied at European level, was adapted to fit the urban setting. In previous applications the approach was used in urban context (Zulian et al., 2017), focusing on specific local applications and cities, such as in Barcelona (Baró et al. 2016) or Trento (Cortinovis et al., 2018).

4.2.3 Methods

This urban version of ESTIMAP – recreation has been improved to include facilities to enjoy and reach the locations and to account for accessibility. The approach consists of five basic sections, divided in two parts. The first part of the approach is based on 'Advanced multiple layer Look-up Tables" (LUT) and "proximity" concepts; while the second part is based on potential accessibility models, implemented from a location of origin perspective.

Advanced LUT consist of a combination of elements, scored according to their suitability to provide recreation opportunities. In this application the scores for each input were generated from either the literature or expert input (Schröter et al. 2015). The final outcomes are based on cross tabulation and spatial composition derived from the overlay of different thematic maps (Zulian et al. 2017). Figure 4.5 shows an example of ROS map, applied to the FUA of Padova (Italy).

The Recreation Potential map (RP) estimates the potential capacity of ecosystems to support nature-based recreational activities. It is based on land suitability for recreation and a combination of the natural features that influence recreational opportunity provision (e.g. proximity to lakes; viewpoints of geological or geomorphological interest …)

The Opportunity map (OS) expresses the presence of facilities to enjoy and reach areas with potential opportunities.

The Recreation Opportunity Spectrum map (ROS) combines the Opportunity map (OS) and the Recreation Potential (RP).

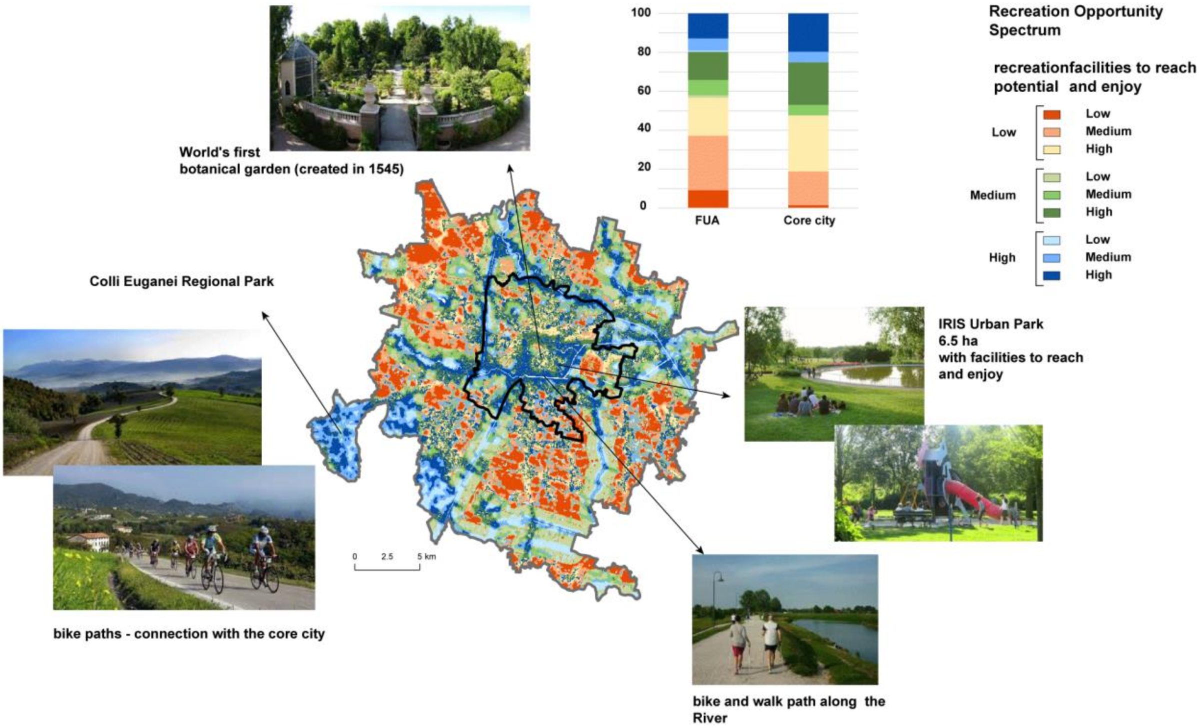


Figure 4.5. The approach for mapping recreation opportunities in cities explained for the functional urban area of Padua (Italy). Source: Maes et. al 2019 (Box 2.).

The second part of the approach measures accessibility. Accessibility of a particular location is a function of its relative proximity to all alternative destinations in a given area. From this perspective, the more accessible a location is, the higher is the potential spatial interaction with surrounding locations. The accessibility map is derived from the cumulative availability of opportunities map.

The cumulative availability of opportunities map

The cumulative availability of opportunities map measures the total amount of possible opportunities available within a defined distance. It expresses the co-occurrence of different characteristics that contribute to define an opportunity (e.g. a nice beach on the lake very close to a playground and a forest patch, is an example of area that is attractive for a specific type of users). It is based on the ROS map, specifically:

- The ROS map, only categories with high RP are considered: they represent the pixels with a possible destination.
- The RP map, used to weight the destinations
- A function of the distance that simulates their area of influence

The cumulative map is based on a focal operation.

- Each clustered group of pixels with high RP are treated separately with a focal operation (moving window with kernel)

1. They are clumped together

2. They are multiplied by a function of the distance by their RP value. In this way we simulate their area of influence and their value (not all important location have the same weight, the weight depends on all the characteristics measured with RP)

3. The focal maps of all locations are summed together

4. For mapping purposes values are normalised per reporting unit (e.g. at FUA level) on the maximum value. In this way each reporting unit is evaluated considering its specific context.

The potential accessibility map

Assuming that the individual makes one trip a day and that the destination depends on the distance and on the availability of opportunities for nature-based recreation, this map expresses the amount of possible destinations (choices) available per capita per day.

It is based on the cumulative availability of opportunities map, the population, and the distance people may travel to reach a destinations related to nature-based recreation on a daily base. Several combined factors affect the capacity of parks and recreational sites to attract users. Determinants of attractiveness include the characteristics of the site and of the spatial context; the socio-cultural environment; the characteristics and behaviours of individuals. Examples are the presence of a pedestrian friendly road network to reach the site, the availability of facilities to enjoy the site, the presence of amenities and elements preferred for nature-based recreation (Weyland and Laterra 2014), and the size of the site (More 1990; Iacono et al. 2008; Kaczynski et al. 2008).

All these elements are, as much as possible, part of the ESTIMAP-nature-based recreation model. They were combined to measure the potential accessibility to recreational sites using the walking distance as the distance people accept to travel to reach a destination related to recreation on a daily base. Walking distance was chosen because several studies demonstrated that proximity and walkability to recreational sites are determinant for a daily use (Wolch et al. 2014; Vale et al. 2015; Burrows et al. 2018). Moreover, although network distance would be preferable (Apparicio et al. 2017), we decided to use the Euclidean distance due the size of the sample (700 functional urban areas). A short walking distance reduces the margin of error introduced from a generic measure of distance.

Accessibility is a determining concept behind the availability of opportunities (jobs, services, etc.) and if they can be realized or not. In a high accessibility setting, an individual will have access to a wider array of goods and services (Rodrigue, J-P et al. 2020). Several spatial approaches are available to measure accessibility (Handy and Niemeier 1997), in this application we implement a “contiguous accessibility approach, which involves measuring accessibility over a surface. Under such conditions, accessibility is a cumulative measure of the attributes of every location over a predefined distance, as space is considered in a contiguous manner.

We implemented a gravity-based model, from a location of origin perspective. Gravity-based accessibility models weight opportunities according to a travel impedance function (Páez et al. 2012; Reyes et al. 2014; Vale et al. 2015).

The model accounts for all destinations an individual can potentially reach within a defined area. This measure of accessibility is a function of the number of opportunities (W) of type k at location j, and the cost of moving between i and j, as perceived/experienced by person p. The function fd defines a kernel around location i (Vale et al. 2015). Figure 4.6 shows the decay function used in this study to represent the cost of walking from location i to location j.

Eq. (1) gives the accessibility from the standpoint of location i (origin), to opportunities of type k, from the perspective of individual p:

$$A_{ik} = \sum_{j} (Wjk) * fd * Pi \qquad \text{Eq. (1)}$$

Where:

Aik = represents the accessibility at zone ***i*** to opportunities of type **k**

Wjk = Areas providing nature based recreation opportunities. Each site is weighted according to its RP score and its size.

Pi = population at pixel i

Fd was derived from a Distance Decay Curves for Walking Trips proposed by (Iacono et al. 2008 ; Appendix A1: Figure A-4)

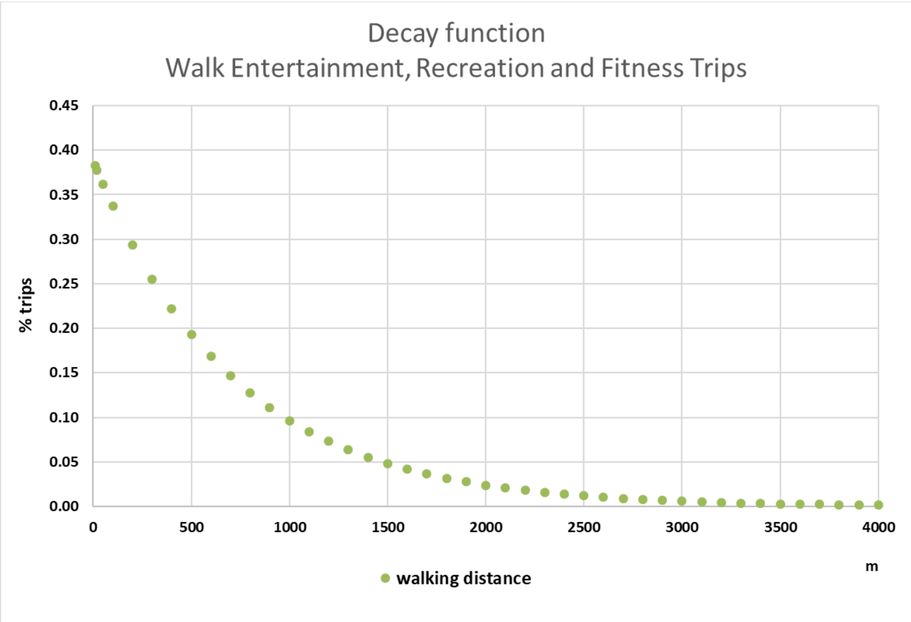


Figure 4.6. Decay function representing the probability to reach the closest recreation site (Iacono et al. 2008 ; Appendix A1: Figure A-4)

The framework for the assessment of nature-based recreation was implemented following the structure proposed in Vallecillo et al (2019). Table 4.1 presents the different components of the framework, metric and years assessed:

- The **service potential** is evaluated using the cumulative opportunities map. The idea is that a person can have several opportunities within a defined area of interest (in this case represented by the decay function, figure 4.6). The cumulative opportunities map reports the sum of potential opportunities weighted according to their quality for recreation. This value is normalised between 0 and 1 on the maximum value of the FUA and defined as cumulative opportunities score per reporting unit. The service potential is also reported in terms of areas that provide high value opportunities for nature-based recreation, and it is expressed in ha and % of the FUA.
- The **actual flow** is measured in terms of share of recreation opportunities per inhabitant per day. The accessibility map is divided by the total population (at the pixel level).
- The **demand** for the service is expressed by the population density.
- The **unmet demand** is expressed as percentage of population inside the FUA with less than 1 possible opportunity per capita.

Table 4.1. Components of nature-based recreation service, metric and overview of temporal availability.

Component	Indicator	Metric	Years assessed
Service potential	ROS - 789	Ha %	2000-2012-2018
	cumulative opportunities score per reporting unit	dimensionless	2000-2012-2018
Demand	Population	population (number inhabitants)	2000-2015
Actual flow	opportunities per inhabitant per day	share of recreation opportunities per inhabitant per day	2000-2012-2018
Unmet demand	percentage of population with less than 1 potential opportunity per capita	%	2000-2012-2018

The model was implemented at the pixel level and detailed maps are available for 700 Functional Urban Areas (FUA), see Annex 2 for the description. Table 4.2 presents the input data used.

Table 4.2. Input data.

Data	Source
CLC	Corine Land Cover map https://land.copernicus.eu/pan-european/corine-land-cover
Geomorphology of coast	Eurosion, 2005. Geomorphology, geology, erosion trends and coastal defence works, Version 2, 1:100 000. Dataset available at http://www.eea.europa.eu/ data-and-maps. More information at http://www.eurosion.org/
Stream riparian areas	http://land.copernicus.eu/local/riparian-zones/ (rpz_drza)
Bathing water quality	Bathing water quality https://www.eea.europa.eu/data-and-maps/data/bathing-water-directive-status-of-bathing-water-11
Open Street Map	"OpenStreetMap contributors. (2015) Planet dump [Data file from 2018]. Retrieved from https://planet.openstreetmap.org.".
Natural Protected areas	Natura 2000 https://www.eea.europa.eu/data-and-maps/data/natura-11
	CDDA https://www.eea.europa.eu/data-and-maps/data/nationally-designated-areas-national-cdda-12/gis-data/cdda-shape-file
GHS-POP	https://data.jrc.ec.europa.eu/dataset/jrc-ghsl-10007
Multinet teleatlas	Tele Atlas MultiNet Shapefile 4.3.2.1

4.2.4 Results

Results are reported at European level (EU-28). Indicators are reported at the FUA level. Status values (using 2018 as reference) and a long term trend analysis (2000 -2018) is presented here for all the indicators. The indicators have been mapped at the FUA level and presented in figure 4.7, 4.8, 4.9.

Table 4.3. Summary results nature based recreation at European and FUA level (*population data are modelled at pixel level in 2000 and 2015).

		Status 2018			2000-2018 change (% per decade)		
		FUA level			FUA level		
		Average	Minimum	Maximum	Average	Minimum	Maximum
Service potential	Land providing recreation opportunities (ha)	28 833	47	671 472	2.95	-22.8	143.8
		20.5%	0.3%	76.5%	4.4	-22.2	155.5
	cumulative opportunities score	0.22	0.02	0.75	1.8	-22.03	71.9
Demand (number of inhabitants*)		456 301	52 085	12 813 686	2.6	-22.0	133
Flow of service share of recreation opportunities per inhabitant per day		1.3	0.01	5.14	1.62	-36.4	75.4
Unmet demand (% population < 1 trip per inhabitants)		56.0	0.32	100	-1.33	-24.1	13.67

Table 4.3 shows a summary of the results. In Europe, urban ecosystems deliver more than 20 million of hectares of land providing opportunities for recreation. Cities performance is very diverse and goes from a minimum of few hectares to a maximum of 671472 hectares. Between 2000 and 2018 the area almost didn't change either at EU level neither at FUA level.

When expressed in terms of **cumulative opportunities** within a maximum distance of 3 km, the indicator presents a wide rages of values which differ greatly among cities. Between 2000 and 2018 there has been a long term overall upward trend at EU level, with an increase of 1.8 % per decade. Compared to the simple ROS this indicators increases when in a certain area several opportunities (with different qualitative characteristics) are present at the same time, this explains the difference between the ROS and the cumulative map. Figure 3.3.3 shows the cumulative opportunities available at FUA level in 2018 (map A) and the change per decade (map B). The trend is not homogenous among cities, going from a clear downward trend (minimum -22.2%) to a sharp upward trend (maximum +155.1%). 77% of FUAs improved their service potential.

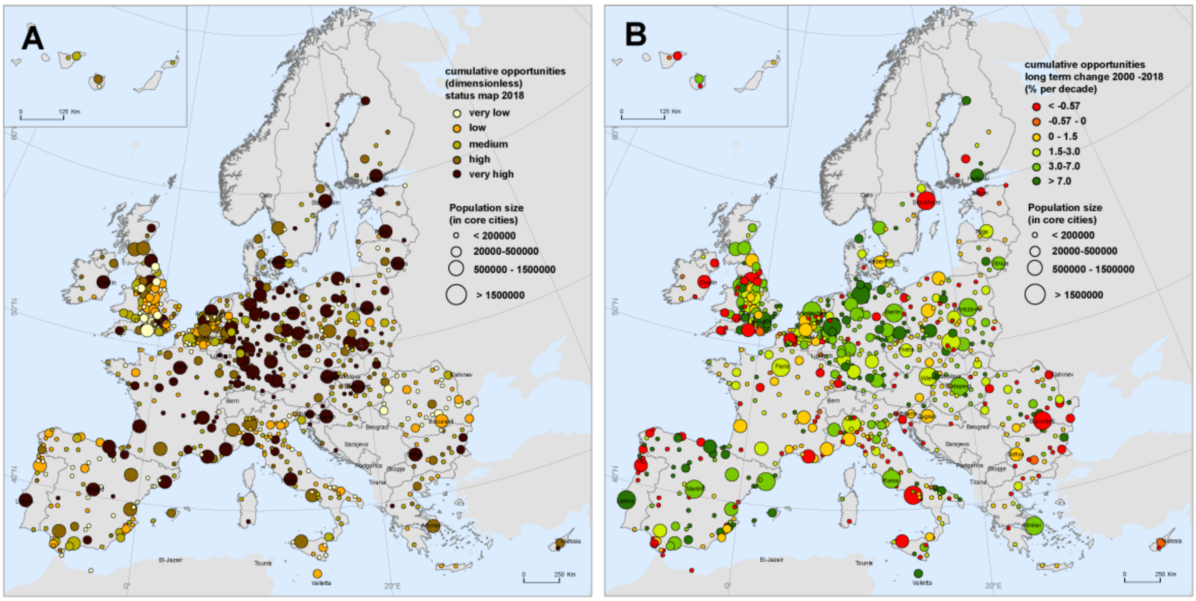


Figure 4.7: Cumulative opportunities (A. 2018, B. change map 2000-2018).

The **demand** for nature-based recreation opportunities inside FUA, expressed in terms of population density is increasing by 3.7 % per decade at the EU level.

The **actual flow of the service**, measured in relative share of recreation opportunities per inhabitant per day, expresses the amount of service that is actually available for the population. At FUA level citizens have an average of 1.3 potential opportunities per capita. Interestingly the actual flow shows a slight upward trend with an increase by 1.62% per decade. This value is driven by population growth (population within FUAs increased by 2.6% in average) in the proximity of the nature-based recreation opportunities. However the pattern among cities is very diverse, going from less than 0 opportunities per capita to more than 5.14. Figure 3.3.4 shows the spatially explicit distribution of the indicator aggregated at FUA level. In 48% of the FUAs less than 1 trip per inhabitant was estimated in 2018.

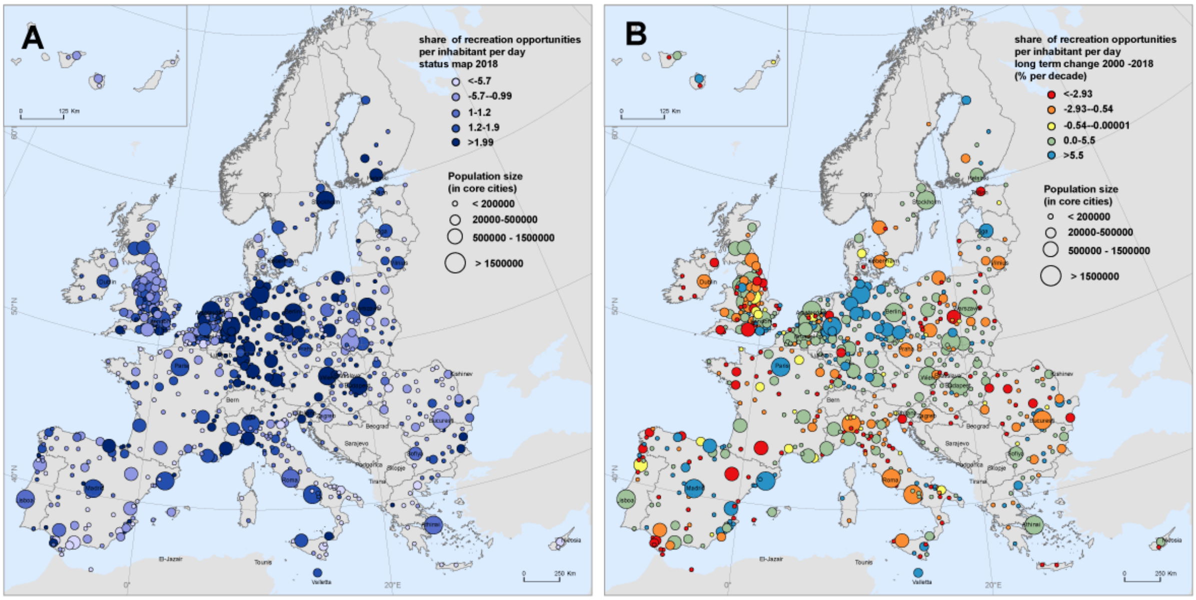


Figure 4.8: Relative share of recreation opportunities per inhabitant per day (A. 2018, B. change map 2000-2018).

In average, at the FUA level, the **unmet demand** was estimated as 56% in 2018. In 60% of the FUAs, more than 50% of the local population do not have at least one possible destination with opportunities for nature-based recreation in the close proximity (Figure 4.9 A).

Between 2000 and 2018 the overall situation slightly improved with a decrease in the unmet demand (-1.33%, average at the FUA level). However, also in this case, the pattern is not homogeneous (see Figure 3.3.5 B and Table 3.3.3) with unmet demand having increased in 30.28% of the cities.

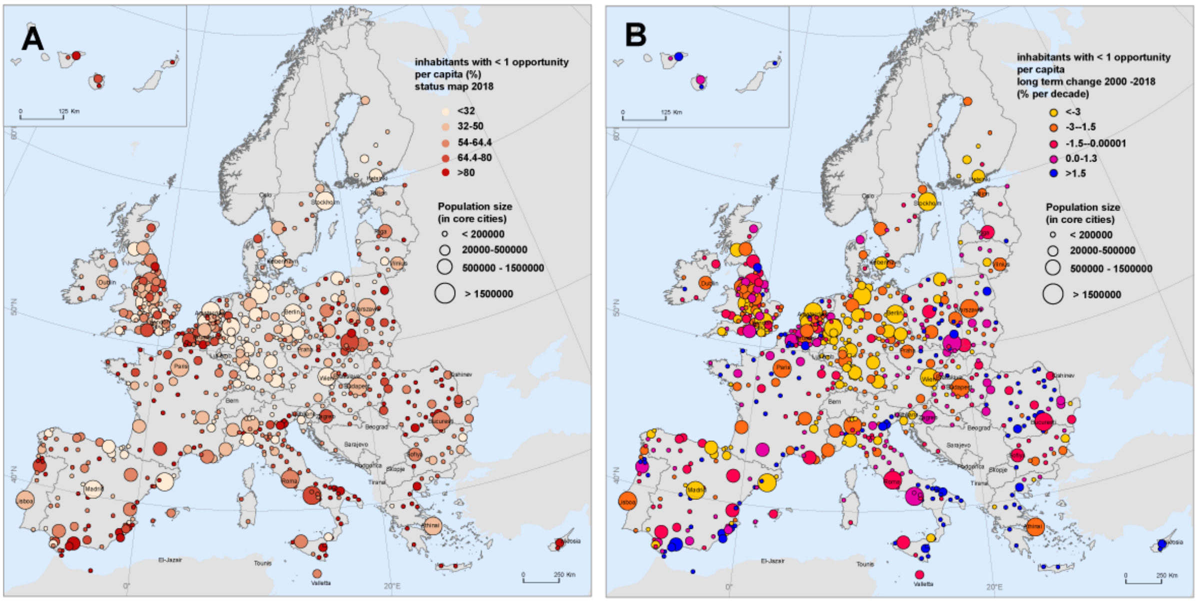


Figure 4.9: Unmet demand (A. 2018, B. change map 2000-2018).

Urban ecosystems are not only public urban parks. Nature-based recreation opportunities within and in the proximity of cities are in fact provided by a wide range of ecosystems. Moreover, the configuration of urban ecosystems, their condition and the availability of facilities to reach and enjoy specific locations all together contribute to the provision of this ecosystem service that appears to be extremely important especially considering the current health emergency.

European citizens have recreation opportunities and at a European level the situation is improving (opportunities to be enjoyed on a daily based increased by 1.8% per decade and the share of citizens that cannot enjoy the service decreased by 1.33 %). Nevertheless, the situation is very diverse among cities and within cities. The share of available opportunities per inhabitant varies from a minimum of 0.01 to a maximum of 5.14 with an average value of 1.3 per FUA. The ecosystem potential (assessed through the biophysical model) essentially depends on the presence of natural and semi-natural features, parks, freshwater and seacoast together with the presence of facilities to enjoy and reach these locations. The ecosystem demand on the other side depends on the population density. In order to increase the share of potential destinations per inhabitant, several types of actions can be implemented when the gap between the demand and the availability of service is estimated. For example, nature-based solutions could be an intrinsic part of the land take in order to have an embedded compensation process. Besides that, even mobility could be part of the solution by increasing walking and bike paths within the city and its surrounding.

5 Contribution to the indicator framework for the green city accord

The Green City Accord is a movement of European mayors committed to making cities cleaner and healthier. It aims to improve the quality of life and accelerate the implementation of relevant EU environmental laws. By signing the Accord, cities commit to addressing five areas of environmental management: air, water, nature and biodiversity, circular economy and waste, and noise. In each of these areas, signatories commit to:

- establishing baseline levels and setting ambitious targets that go beyond minimum requirements set by EU laws within two years of signing
- implementing policies and programmes in an integrated manner, to achieve their targets by 2030
- reporting on implementation and progress every three years

(https://ec.europa.eu/environment/topics/urban-environment/green-city-accord_en)

Within the Biodivercities project we contributed to the selection of indicators for the nature and biodiversity area.

Indicators cover 3 main sections: the first refers to the presence of natural or semi-natural areas inside the municipal boundary; the second considers the presence and variation of vegetation cover and the third focuses on presence of species of specific interest. Five indicators are defined as basic and one is considered additional. Basic indicators are relatively easy to be computed and monitored along the years. Additional indicators are more complex but provide a more precise and explicative overview of the process.

The first indicator is the "**Share of natural, restored and naturalised areas in the city**". This is an area based metric which measures the proportion of natural, restored and naturalised areas in the city. The definition also takes into consideration "restored ecosystems" and "naturalised areas" in order to recognize efforts made by cities to increase the natural areas of their city. Restoration helps increase natural areas in the city and cities are encouraged to restore their impacted ecosystems.

Second indicator is related to the **availability of urban green spaces for the population**. It will be expressed as percentage of citizens that live within 300 m of green spaces. We suggest to distinguish between public and green spaces. Proximity to public green areas provide opportunities for active daily-based recreation activities while proximity to any kind of green provide regulating services very important for human health such has microclimate or air quality regulation.

Third indicator is the **Share of urban tree/ canopy cover**. Canopy Cover is the layer of leaves, branches, and stems of trees that cover the ground when viewed from above. This is a status indicator, no trends are possible for the moment.

The fourth indicator is an additional one: **Change in vegetation cover inside the urban green infrastructure**. It is a trend detection indicator that refers to structural ecosystem attributes. It examines how and in which direction vegetation cover changes within the UGI with no differentiation between different types of green. It is accurate and captures the abrupt changes that characterize highly modified ecosystems (induced by land cover change or intensive green space management) as opposed to other ecosystems where vegetation trends tend to be stable and changes are only gradual (no changes to be recognized during 1-3 year period)

The fifth indicator concerns the **species diversity within the city**. It provides an overview of the species diversity within 2 taxonomic groups: birds and butterflies (optional) as proxy for habitat quality. It is expressed as total number of different bird / butterfly species in municipality / or in areas of the municipality with a certain proportion of built-up (excluding natural and semi-natural areas). Citizens-science campaigns (bioblitz) can be useful for data collection. This is a status indicator, no trends are possible for the moment.

The sixth indicator concerns the presence of **Invasive Alien Species of Union Concern**.

Provides an overview of the prevalence of potentially harmful species. It is expressed as Total number of IAS of Union concern present in the city. This is a status indicator, no trends are possible for the moment.

6 Next steps for the BiodiverCities project and conclusions

6.1 Next steps on citizens engagement

During 2021, Engage Corners will be happening once every two months, unless cities express a desire for meeting more often or specific circumstances will necessitate additional discussions. The first topic during the upcoming Engage Corners will be a reflection on Guidance reports (Deliverable no 1).

Since several experts expressed a desire to work closer with other cities (due to overlapping focuses and a desire to exchange experiences), we hope that bilateral meetings between cities will be taking place during the upcoming months. The cities are encouraged to arrange these meetings on their own, which might contribute to the formation of a network/community; however, we are also considering arranging more formal structure for exchange in the shape of, e.g., a workshop.

A series of capacity building activities has been planned to take place during the next months:

12.02.2021 – Workshop on mapping recreation in urban green spaces

26.02.2021 – Workshop on online citizen engagement and digital tools

26.03.2021 – Workshop on mapping urban biodiversity

We plan to continue the series with more learning activities at a later date and depending on the needs of the cities as the project develops.

6.2 Nest steps on the assessment of urban biodiversity

During 2021 the work on urban biodiversity will be extended to better understand if urban biodiversity is similar to what we find beyond the urban fringe or it is something special. Specifically we are interested in exploring if urban biodiversity has something special per se or it is a spill over of what is outside. This aspect will be tackled with an analysis of spatial patterns of species inside FUAs and at a regional level, with a specific interest on how urbanisation affects biotic homogenisation.

Additionally an analysis of other non-opportunistic datasets will be carried on to explore how informative citizen science data can be considered. This part will be organized in two phases:

The first includes an analysis of urban birds using standardized monitoring schemes, namely the French Breeding Bird Survey (STOC), standardised monitoring scheme (Jiguet et al. 2012). This part will focus on the analysis of the role of spatial configuration of urban ecosystems to support birds, using the French dataset. The second will extend the approach to work at EU level. Many cities need to account for urban richness or biodiversity. This analysis will be useful to explore to what extent opportunistic citizen-science data can support the development of an urban biodiversity profile

6.3 Nest steps on the assessment of urban ecosystem services

The work of the upcoming months will focus on the spatial configuration of GI, through the analysis of the role of size and shape of urban green areas on the extent of the temperature mitigation. Different studies underlined the importance of these attributes in defining the contribution of GI in microclimate regulation. As an example, the cooling effect of a large park is higher than that of a small park, as it has been demonstrated by a study in 61 green areas in Taipei (Chang et al., 2007). In a study on 21 parks in Addis Ababa, Feyisa et al. (2014) showed how air temperature was mainly dependent on canopy cover, size and shape of parks, as well as their species composition. In order to explore these aspects, different methodologies, available in Guidos Tool Box (GTB) will be applied. GTB is an open-source image analysis software developed at the Joint Research Centre (http://forest.jrc.ec.europa.eu/download/software/guidos/). In particular, the structural configuration of urban green areas can be assessed by looking at i) patch size distribution (distribution of green patches over a series of moving windows; this approach provides an overview of the distribution of the GI cover by detailing up to 6 different patch sizes) and ii) their spatial integrity (the proportion of pixels in a surrounding fixed-area neighbourhood that are defined as GI). Furthermore, in order to better characterize the cooling effect of GI, the maximum distance at which the cooling occurs will be evaluated. In fact, the cooling effect of GI decreases with distance from the boundary of the green area and is no longer effective at a certain distance (Lin et al., 2015; Yu et al., 2017). The cooling distance can be calculated, as described by Yu et al., (2017), as the distance between the edge of the greenspace and the first turning point of temperature drop compared with the greenspace's temperature.

Furthermore, besides the analysis of the structural features of urban green spaces, the forthcoming analyses will include the continuation of the analysis of the beneficiaries, through the calculation of the share of population residing in different cooling intervals, in each FUA.

Finally, an economic assessment of the ecosystem service of microclimate regulation will be carried out. This aspect can be explored by analysing the energy savings resulting from the temperature reduction realized by the GI.

As for urban recreation, the following research is planned:

- the valuation in monetary terms, by using a benefit transfer meta-regression analysis based on 91 case studies
- the accounting in physical and monetary terms, developed from current frameworks available in ecosystem accounting for urban areas

6.4 Conclusions

Current global challenges, such as climate change, environmental degradation and air pollution, and the Covid19 pandemic, have increased the role and importance of urban green spaces. They provide nature-based solutions to reduce air pollution and flood risk; they increase the resilience of cities against extreme temperatures; they provide opportunities for recreation and stress relief and thus contribute to our physical and mental health and well-being. These benefits are delivered by the biodiversity and ecosystems that underpin the ecological functions of urban green spaces.

BiodiverCities increases the awareness of this underpinning role of urban biodiversity. Thirteen European cities contribute to the BiodiverCities project by setting up citizen engagement activities. The results of these local projects will help us understand better how to involve citizens in making cities greener and more biodiverse.

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List of abbreviations and definitions

ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
CBD	Convention of Biological Diversity
CLC	Corine Land Cover
COP15	15th Conference Of the Parties
Covid-19	Corona Virus Disease 2019
EU	European Union
FUA	Functional Urban Area
GEE	Google Earth Engine
IAS	Invasive Alien Species
iNaturalist	A social network of naturalists, citizen scientists, and biologists built on the concept of mapping and sharing observations of biodiversity across the globe
IUCN	International Union for Conservation of Nature
JRC	Joint Research Centre
LST	compute Land Surface Temperature
MODIS	Moderate Resolution Imaging Spectroradiometer
NDVI	Normalized Difference Vegetation Index
OECD	Organisation for Economic Co-operation and Development
ROS	Recreation Opportunity Spectrum
SAD	Species Abundance Distribution
SRA	Simeto River Agreement (case study of Regalbuto)

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Annex 1. Call for an expression of interest – BiodiverCities

The Call was made public on Oppla (https://oppla.eu/call-expression-interest-collaborate-biodivercities-project) on February 11, 2020 and it was open for submission until March 9, 2020. Applicants responded via EU Survey. Due to the outbreak of the Covid-19 pandemic, the deadline for submission was extended for a few days (from March 4 to March 9).

SETTING THE SCENE

In the wake of the European Green Deal for EU and its citizens sets out by the European Commission, "tackling climate and environmental-related challenges" have become one of the top political priorities of current times. The EU's aim to become the first climate-neutral continent by 2050 will require consistent investments, fair transition mechanisms and engagement of all publics involved – from citizens to municipalities.

Coherently with such agenda, the **Joint Research Centre (JRC)** is looking for **10 cities** to be involved in the project **BioDiverCities**, aiming at enhancing the use of green infrastructures in urban contexts, now deemed essential to increase the livability for cities.

By **engaging with citizens**, the project aims to promote innovative approaches to enhance biodiversity and the planning and implementing of green infrastructures in cities across the EU.

LOCAL ENGAGEMENT OF CITIZENS IN URBAN NATURE

We would like to work with cities that are interested and committed to endorse **participatory planning of green infrastructures and urban green.** Local engagement will aim at:

1. Developing **visions** for a greener city where citizens, planners, local institutions do it together
2. Implementing or testing **monitoring** approaches for urban biodiversity based on citizen science
3. Proposing citizen-centered **actions** that can locally enhance the quantity and quality of urban green space

What we offer

- Capacity building on participatory ways to do urban planning. More specifically, we provide expertise on:
    - co-designing and co-creation
    - on citizen science
    - mapping and assessing urban green infrastructure and ecosystem services
- Running a citizen engagement session
- A contract for a local expert which covers working time and participation to meetings.
- Critical friend to local processes of "greening cities"

What we ask from cities

- To provide a list of needs related to urban and peri-urban biodiversity/urban nature/urban green-blue spaces
- to support us in organizing a participatory process with local actors (e.g. city planners, civil society & grassroots organizations, unrepresented citizens, event planning)

Selection process

Cities are invited to express their interest by filling in the form available here until March 09, 2020. Short-listed cities will be contacted for a follow-up interview. Successful candidates will be notified by March 15, 2020. We welcome cities of every size from all 27 Member States. We also welcome expressions of interest of other countries including the UK or Norway.

Annex 2. Synthesis of the BiodiverCities citizen engagement projects.

	General comments	**What**	**Why**	**Where**	**Who**	**How**	**Policy anchor**	**Impact of covid-19 and of government responses to the pandemic**
Leiden, Netherlands *Keywords*: marginalized groups, active citizenship	The project aims to: • learn how to engage not-white and not-middle class social groups into participatory processes; • co-create and co-maintain with local inhabitants biodiverse urban spaces; • explore locals' ideas on nature, biodiversity, and public participation.	• Activation and empowerment of local inhabitants • Re-development of existing green areas into biodiverse hotspots for the benefit of citizens and beyond	• The quality and quantity of green space in the city is under pressure, creating additional risks for a further decline in biodiversity • Securing citizens' awareness and commitment to biodiversity protection as key to a biodiverse and climate change resilient city • Unwillingness or impossibility of citizens to actively participate in public life is understood as a political issue	Green spaces, mostly lawns with very low biodiversity, around post-war housing estates in Gastwijkhuis/Haagweg Zuid neighbourhood	Inhabitants of the social housing estates (mostly elderly, low-income, immigrants, and ethnic minorities), social housing representatives, local organizations	• Walking interviews to collect information on local needs and concerns • Outdoor workshops, idea box, co-design, and co-creation to develop the green spaces • Continuity of co-maintenance ensured by citizens and local organizations (day care, sports clubs)	• Extensive national and city-level in experience and culture of citizen engagement • Close collaboration between the expert and the Municipality; the local working plan has been jointly designed • Development of a written contract between the citizens, Municipality, and housing estates • The pilot case can become 'best practice' to be scaled-up to the city or regional level; many green lawns have the potential to be transformed into	• Lockdown rules currently in place with restrictions on social gatherings. Access to public green spaces is not prevented • Physical meetings postponed at a later stage of the project, adaptation of the format (small groups; walking tours), asynchronous forms of engagement (e.g. suggestion box) • Possible greater interest and affection on the side of citizens toward nature and green spaces

	General comments	**What**	**Why**	**Where**	**Who**	**How**	**Policy anchor**	**Impact of covid-19 and of government responses to the pandemic**
							biodiversity-rich areas	
Maribor, Slovenia *Keywords*: local knowledge	The project aims to: • build *green vision* around urban nature; • map, explore, and learn about local knowledge; • develop solutions to improve urban biodiversity.	• *Mobilization* of local knowledge on biodiversity, urban landscape, green infrastructure, urban green open space, and nature-based solutions • *Multiple* focuses: green infrastructure and mapping of trees, pollinators, urban nature	• Scattered knowledge about biodiversity • Need to mobilize citizens for an ecological transition to happen • Need to integrate citizen engagement processes (of different kinds) into the policy process • Strategic timing: 'greening' is high on the political agenda of Maribor • Need to map onto citizens' needs to design better policies	Drava riverfront	Heterogeneous publics: local inhabitants, civil servants and policy officers, NGOs, online groups, school community, etc.	Green Infrastructure and trees mapping: GIS Pollinators & plants for pollinators: citizen science Urban nature knowledge: walking interviews For each issue addressed, hybrid methodologies, mixing online and physical activities, are envisaged.	• Close collaboration between the expert and the Municipality – the local working plan has been jointly designed • Integration of participatory activities in existing projects and strategic policy processes on the city level	• Lockdown rules currently in place with restriction on social gatherings • Attention to the issue of equal access to public green spaces has likely increased among citizens • Physical meetings will take place, when possible, as individual walking interviews. All other activities will take place online.
Novi Sad, Serbia *Keywords:* bottom-up;	The project aims to: • address the distrust between citizens and the Municipality;	• Building a more inclusive (not top-down) narrative about the city	• Lack of green spaces and unequal access to them • Lack of participatory culture and opportunities for	• Five pre-selected city districts with limited green spaces	Heterogeneous publics: citizens from selected	• Activities to start with two public debates (one in an art gallery the other in a park) on the	• Novi Sad is the European Capital of Culture for 2021: this provides the possibility to connect biodiversity	• Some restrictions are in place but social gatherings are allowed (with the mandatory use of masks)

	General comments	**What**	**Why**	**Where**	**Who**	**How**	**Policy anchor**	**Impact of covid-19 and of government responses to the pandemic**
new green imaginary	• introduce citizens' needs and matters of concern for planning a greener city; • Establish a new culture for biodiversity protection and the environment at large.	• Mapping of citizens' meanings and understandings *vis à vis* urban nature and biodiversity, and access-related issues to green areas; • Co-design of green spaces	citizens to affect the planning process and the development trajectory of their city	• Renewal of a city park with potentials from a biodiversity perspective, selected by the citizens	districts, artists, representatives of formal and informal associations	importance of nature in the city • A series of outdoor workshops with the use of participatory mapping techniques aiming to develop designs for two parks • A "futuring" walking tour to elaborate a green vision for the city	with the making of a *culture of biodiversity* • A set of recommendations for the Municipality to influence the planning process will be generated	• The activities of the project have been designed in order to be adaptive to the situation. They can be implemented both indoor and outdoor.
Palermo, Italy *Keywords*: outdoor education, future of schools	The project aims to: • promote dialogue about the future of schools, to reimagine the school system and the fruition of urban green spaces;	• To start a participatory process that prioritizes children's rights to education, involving the extended educational community	• Lack of dialogue about the future of schools • Current lifestyles and some education practices have negative effect on children's development	Whole municipality	School community, including teachers, headmasters, public servants, parents, and children	Series of participatory workshops to be held online or at Parco Villa Tasca, including mapping of issues and needs, co-development of educational	• The expert aims to establish new ways to collaborate with the Municipality amid the pandemic, and the educational community at large by setting up a participatory process	• Lockdown rules currently in place with restriction on social gatherings. Regional rules complement national dispositions. Access to public green spaces is not forbidden but regulated

	General comments	What	Why	Where	Who	How	Policy anchor	Impact of covid-19 and of government responses to the pandemic
	• connect schools with urban green infrastructure; • illustrate the significance of biodiversity and contact with nature for everyday life; • promote environmental and outdoor education for children.	• To problematize the concept of education in relation to access to green spaces • To promote outdoor school education • Development of a green city vision with education at its centre	• Covid-19 has limited the scope of educational options			plan, co-drafting of documents, as well as experimenting with outdoor educational activities (depending on the Covid-19 restrictions)	• A set of recommendations on intertwining educational activities for children with urban green areas will be co-created with participants of the process and shared with the Municipality, headmasters, and teachers to influence the educational policy and practice • A guidance for school directors will be prepared to practically facilitate the integration of school activities with outdoor activities in green areas of the city • Possible follow up on re-development of abandoned urban	• The plan has been re-designed on various occasions due to the evolution and governance of the pandemic; • Today, the process is open-ended with the physical activities to be planned as the process unfolds and held at a later stage. The initial meetings took place online • Emerging significance of accessing green spaces for mental and physical well-being

	General comments	What	Why	Where	Who	How	Policy anchor	Impact of covid-19 and of government responses to the pandemic
							green areas together with the Municipality	
Palma de Mallorca, Spain *Keyword*: institutional innovation	The project aims to: • experiment with co-creation as a planning practice via pilot cases; • use *incremental* approach to change; • anchor the activities to the revision of the City Masterplan.	Endorsement of forms of engagement (invited and uninvited) to address a diversity of issues - from pollinators' decline to the management of quarries and heritage of previous industrial activities	• A political green vision and related planning instruments, underway • Access to nature is segregated by neighbourhoods; pollution and polluted waste; climate change related vulnerabilities • Change is understood as viable via greater citizen participation	Diversity of places, depending on the activity foreseen: from small pollinator gardens located in yet-to-be defined areas of the city, to streets to be made pedestrian; and peripheral neighbourhood lacking (access to) green spaces	Different actors engaged depending on the activity foreseen. They include but are not limited to: children, local inhabitants, existing stakeholders and civic actors (e.g. Children Council, research partners, civil servants, neighborh	*Activity 1* – Pollinator urban gardens to increase biodiversity *Activity 2* – Co-creation for the pedestrianisation of Cotlliure Axis *Activity 3* – Co-design of the periurban border in Es Pil·larí Each activity is presented as open to experimentation with an array of methods and forms of engagement and degrees of	• Institutional commitment by *diverse* municipal departments to work *together* on the project (great institutional innovation potentials) • Close collaboration between the expert and the Municipality; the local working plan has been jointly designed • To make the case for greater co-creation in planning (*institutional 'test-bed'*) • Pilot cases that differently feed into the design of the Green Infrastructure Strategy	• Access to public spaces and outdoor activities is not restricted but encouraged • Restriction to social gatherings exists (max. number of people allowed in the same space, whether indoor or outdoor). • Part of the plan had to technically re-adapt to the evolution of the pandemic, but from a substantial point of view, the project has been proceeding

	General comments	**What**	**Why**	**Where**	**Who**	**How**	**Policy anchor**	**Impact of covid-19 and of government responses to the pandemic**
					ood associations; business owners etc.)	participation (deliberation vs. co-creation)	• Empowerment of citizens and ownership by citizens (*Activity 2*) • Education of youth on the topic (Activity 1) • Creation of *partnerships* with local inhabitants (Activity 3)	
Regalbuto, Italy *Keywords:* deliberation; territorial development	The project aims to: • reinforce the links and interactions between people and nature; • re-conceptualize the relationship between humans and non-humans in a non-utilitarian way; • make out of this an asset for a public debate *about* local development, and *for* local development;	Co-design, co-analysis and co-production of a strategic development plan to design local integrated policies that address multiple challenges affecting Regalbuto: de-population, biodiversity loss, etc.	'More' democracy under the guise of collaborative planning and co-production of public policies to address territorial decline and a widespread sense of resignation of the local population Search/demand for commitment on the side of citizens engaged, conveying the idea that engagement is also about ownership and responsibility	Whole municipality Lake Pozzillo and Sant'Ignazio neighbourhood as potential places of engagement Scale-up opportunities due to the Simeto River Agreement: from the city scale to the territorial one	Distinction between actors they would like to engage with (particularly, youth) and those that, as gatekeepers, will help them reach out to the desired groups	• Out-reach activity: to build relationships and trust with partners and citizens • Co-analysis: of the challenges, framings, narratives, issues, places • Co-design: of a strategic plan oriented towards outputs by the previous activities	• Deliberative approach: what comes out of the citizen engagement process produces political and regulatory effects; • Expert acts as a council member of the Municipality, this warranting great potentials of institutional innovation within the Municipality itself	• Lockdown rules currently in place with restriction on social gatherings. Regional rules complement national dispositions. Access to public green spaces is not forbidden but regulated • The plan has been designed in a way to adapt to the evolving situation, both methodologically (co-creation, co-design, co-production are

	General comments	What	Why	Where	Who	How	Policy anchor	Impact of covid-19 and of government responses to the pandemic
	• experiment and extend existing participatory dispositives (Simeto River Agreement – SRA) in Regalbuto.		Definition of responsibilities between the municipality and other actors involved (specifically, the Simeto River Agreement Presidium)		beyond the usual suspects Possible partners: civil society organizati ons (CSO); parishes, schools, civil servants and policy officers; Targets: youth, farmers, marginaliz ed groups, elders	• Co-production: design and implementation of a pilot case • Mix of social research methods and planning techniques (interviews, mapping, public debates) • Mix of hybrid tools (online and offline; discursive and experimental)		approaches that are, by definition, adaptive to emergent issues) and practically (physical activities have been planned to happen from Spring onwards. • The pandemic is understood to be affecting the perception of public spaces, including green spaces as well as the very possibility to carry out a meaningful participatory process
Stavanger, Norway	The project aims to: • expand the knowledge base on trees, including	• Develop map register of urban trees and a series of	• Conflicts over trees and a general disregard for the important role they play in the city	Whole Municipality with a specific	Citizens, outdoors groups, civil servants,	• Co-creation workshops with citizens and stakeholders organized in	• Long term commitment on the side of the Municipality to make it a flagship	• Restrictions and rules concerning social gatherings and outdoor activities are in place. They are less severe

	General comments	**What**	**Why**	**Where**	**Who**	**How**	**Policy anchor**	**Impact of covid-19 and of government responses to the pandemic**
Keywords: participator y mapping; awareness	both scientific and local knowledge; • increase awareness about urban trees among the general public.	tree-related activities • Explore the stories, meanings, and values associated with trees	• Lack of systematic knowledge of trees present in the city • Pressure from the side of housing developers	focus on urban districts	and policy officers	order to start a conversation about trees • Tree mapping platform Hybrid methodologies: mix of physical and digital tools and activities	initiative that 'survives' the duration of the BiodiverCities project; • Close collaboration between the expert and the municipality; the expert acts as a facilitator and the local working plan has been jointly designed • Potentials of institutional innovation within the Municipality itself	than in other contexts, this allowing to carry out the activities without major changes;
Valongo, Portugal *Keywords*: awareness, community	The project aims to: • generate a common understanding and vision of a city rich in biodiversity with citizens; • expand on the existing	• Development of a shared green vision for the territory • Improvement of communicatio n between citizens and	• Lack of citizens' connection to green urban spaces and lack of interest in matters relating to biodiversity • Difficulty on the side of the municipality to activate citizens	Whole municipality, experimental actions in specific spots of the city	Citizens, municipalit y technician s, educationa l community , local	• A series of online or face-to-face workshops, including joint identification of matters of concerns and the co-creation of "emotional	• Close collaboration between the expert and the Municipality; the local working plan has been designed jointly • Potentials of institutional innovation within	State of Emergency until April 15. Restrictions are in place with rules and limitations (on social gatherings and others) in the process of being loosen; access to green spaces is regulated and

	General comments	**What**	**Why**	**Where**	**Who**	**How**	**Policy anchor**	**Impact of covid-19 and of government responses to the pandemic**
	participatory projects by experimenting with new methods.	the Municipality • Increase citizens' awareness of environmental issues	• Poor access to and connectivity between different kinds of green spaces		clubs/associations, environmental NGOs, cultural institutions, businesses	maps" of the area • Hands-on experimental actions with citizens in specific spots of the city	the Municipality itself	currently limited to a max. number of people The plan has experienced a general slow-down. Some activities were transferred into online formats with due adaptations to reach out to marginalized groups. Experiential, collective and hands-on actions in outdoor locations are planned to happen during summer.
Vilnius, Lithuania *Keywords*: citizen empowerment; experimentation	The project aims to: • experiment with co-creation as a participatory approach to address conflicts over issues and narratives (also among institutions);	• Introducing a co-creation perspective of engagement • Fostering dialogue about needs, uses, issues, visions related to green spaces in the	• Presence of many poorly developed green spaces with low biodiversity and ecosystem services • Institutional conflict over green infrastructure planning and management	Green spaces, mostly lawns with low biodiversity, between blocks of flats in the Pilaite neighbourhood – an area with complex	Heterogeneous publics: local citizens, local leaders, representatives of local	• Guided neighbourhood tours to exchange knowledge (professional and local) and map biodiversity and ecosystem services	• Development of "Green Neighbourhood Blueprint" for design of small urban green spaces • Development of recommendations for the Municipality that could	• Lockdown rules currently in place until April 30. Restrictions to social gatherings exists with access to green public spaces granted; • The plan has been affected with engagement activities postponed to start from

	General comments	**What**	**Why**	**Where**	**Who**	**How**	**Policy anchor**	**Impact of covid-19 and of government responses to the pandemic**
	• empower local citizens and raise awareness about biodiversity; • Experiment with interventions for biodiversity in post-Soviet neighbourhoods.	neighbourhood and beyond • Valorising green spaces that can provide micro-climate regulation and become places of social significance	• Citizens' disillusionment with participatory process due to tokenistic practices; yet presence of a vibrant and engaged community in Pilaite neighbourhood	planning and architectural history	authorities, environmental NGOs, Municipality, researchers and scientific institutions	• Co-design workshops to develop a neighbourhood-level blueprint for green spaces • Co-creation of a small biodiverse space	contribute to revising public involvement in greening projects	Summer 2021 onwards.

Annex 3. Species Abundance Distributions of groups of species observed inside FUAs.

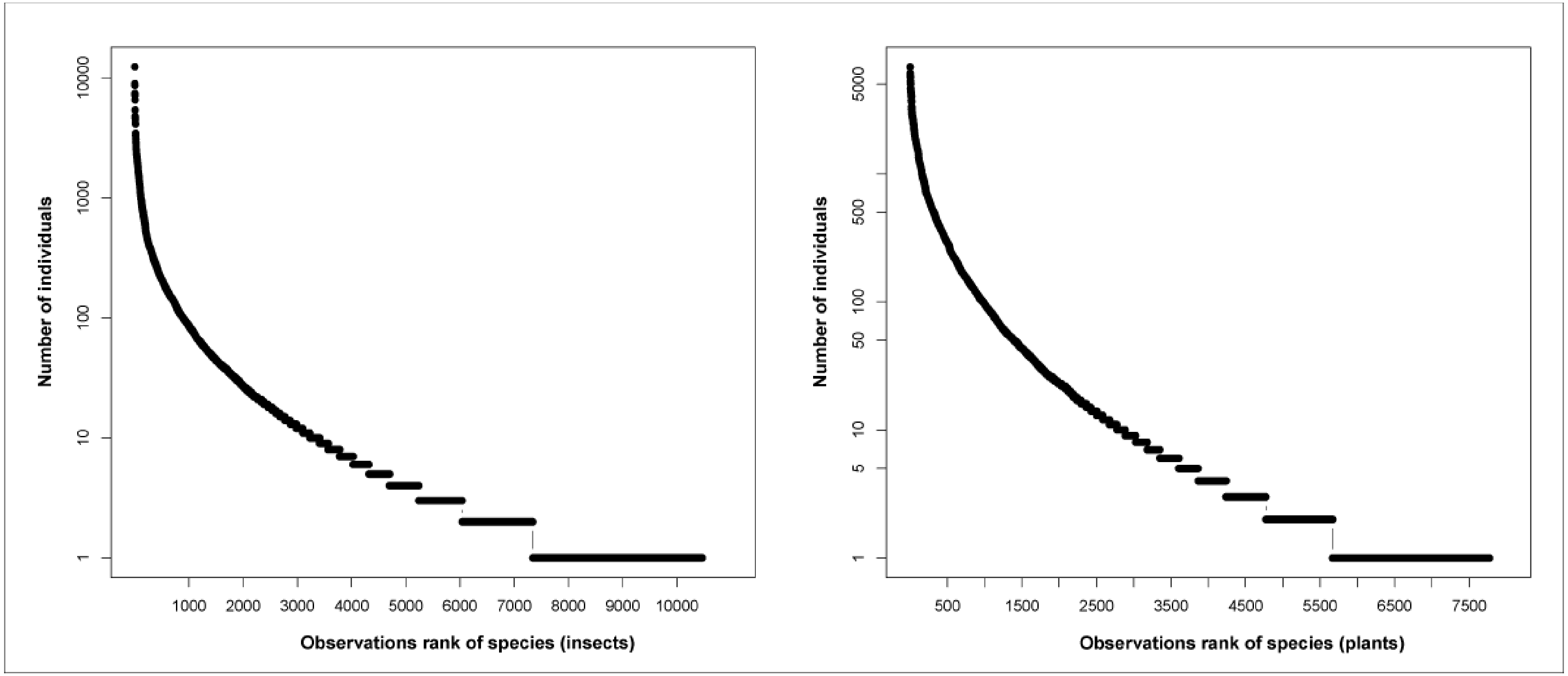

Figure 1. SAD inside FUAs per taxa, represented using RAD (insects, plants).

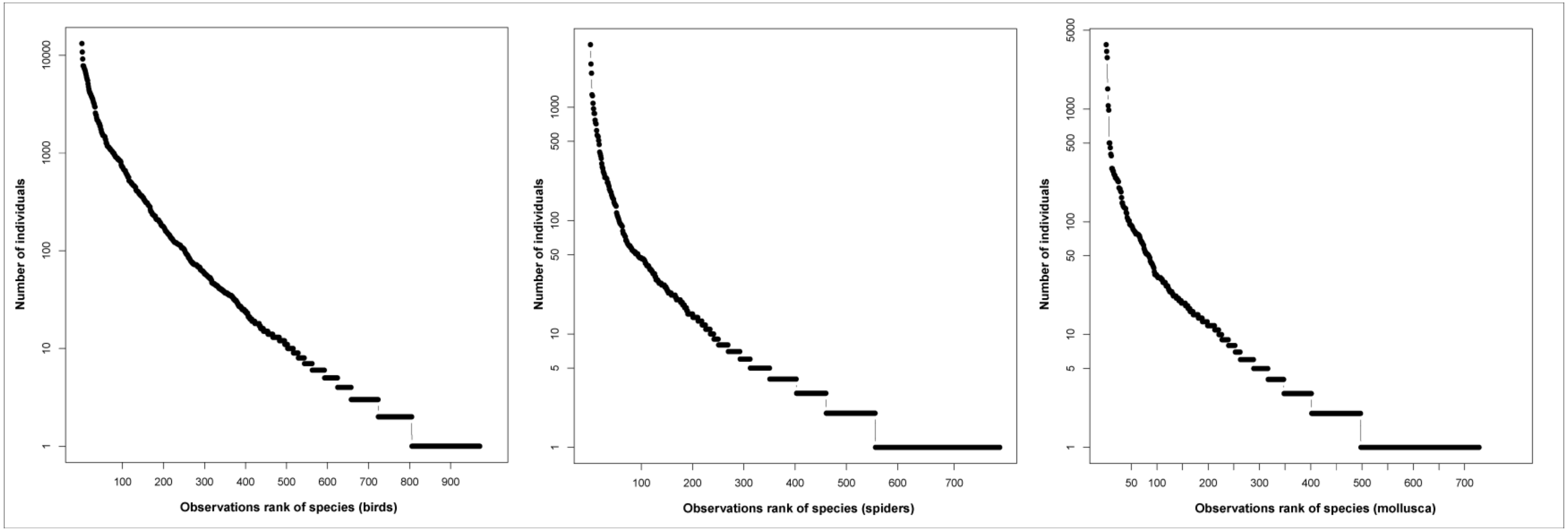

Figure 2. SAD inside FUAs per taxa, represented using RAD (birds, spiders, mollusca).

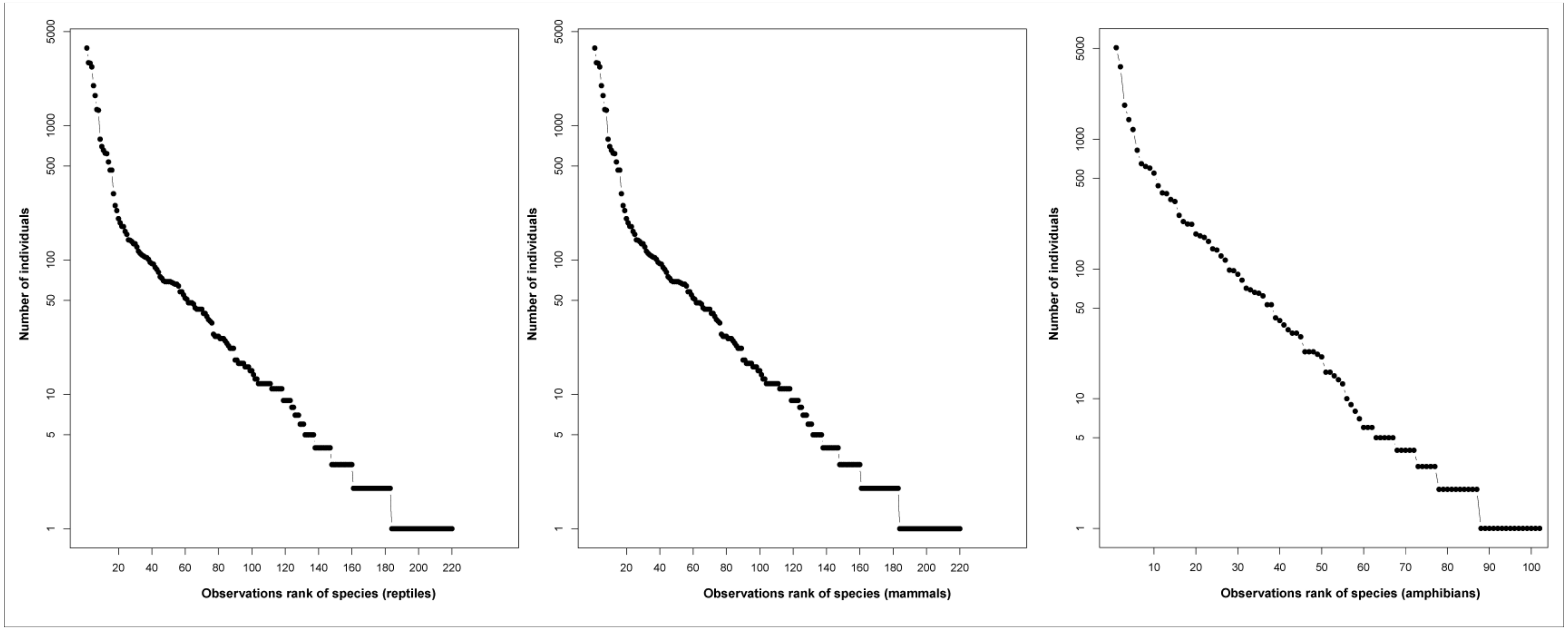

Figure 3. SAD inside FUAs per taxa, represented using RAD (reptiles, mammals, amphibians).

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